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Safety Implication of Respiratory Protection Mask Wear

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12. Abstract

Background: Widespread use of respiratory protection masks has become a critical component of public health interventions. This systematic review explores the acute physiological, cognitive, and psychological impacts associated with different types of masks.

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, utilizing published systematic reviews. De novo systematic reviews were conducted 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 GRADE 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 (3,815 participants). Studies evaluating physiological outcomes demonstrated that various types of masks did not significantly impact heart rate, stroke volume, cardiac output, blood pressure, or respiratory rate during rest or exercise (low certainty for most outcomes). Mask use may be associated with modest but statistically significant changes in minute ventilation, tidal volume, oxygen saturation, maximal oxygen consumption (VO2max), carbon dioxide partial pressure, lactate levels, and exercise performance (low certainty for most outcomes). Studies evaluating cognitive outcomes showed mixed results. Some studies reported reduced mental workload, while 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 an 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 comprehensive overview provides insight into the multifaceted impact of respiratory protection mask use. The limited certainty in evidence warrants further research since mask use is crucial for public health recommendations and policy decisions related to respiratory protection measures.

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1. Introduction

1.1 Background

In recent years, there has been a significant shift in global public health practices, marked by the widespread adoption of face masks across diverse settings, including public transport, workplaces, and recreational activities, as a vital measure to curb the spread of infectious diseases, especially respiratory viruses.(1-3) This shift has garnered substantial attention to the selection of mask type, especially given the reported higher effectiveness of surgical masks and FFP2 (filtering facepiece)/N95 respirators in filtering particle emissions than cloth masks.(4)

While the efficacy of mask use in reducing infection transmission is widely established, (3, 5) concerns have emerged in recent years regarding their potential impact on physiological, psychological, and cognitive aspects, particularly during physical exertion.(6) This is noteworthy, as masks, including FFP2/N95 respirators and surgical masks, may introduce elevated breathing resistance and the potential rebreathing of exhaled air, which could impact gas exchange dynamics.(7) Nevertheless, data reported in the literature remain conflicting (8) (7, 9). A systematic review conducted by Zheng et al. showed a modest effect of mask use on physiological parameters, including gas exchange and pulmonary function. However, the overall impact on exercise performance appeared to be small.(7) In contrast, a systematic review by Shaw et al. reported no considerable influence on exercise performance and only a minimal effect on physiological outcomes. (10)

Moreover, several studies have proposed that the use of masks may have a notable impact on cognitive function due to the perceptual shift caused by obscured facial expressions and communication challenges coupled with the cognitive load associated with mask-wearing.(11) Unfortunately, current data on this topic are limited to a few observational studies demonstrating an increase in the incidence of headaches, attention deficits, and difficulty in concentrating.(12)

Furthermore, the psychological implications of consistent face mask use represent a crucial area requiring in-depth exploration since human connection and emotional communication heavily rely on facial expressions as visible cues. Alterations induced by masks in these cues may contribute to social and emotional challenges, (13) potentially affecting mental well-being. Understanding the psychological consequences of prolonged face mask use is essential for developing strategies to mitigate possible adverse effects and promote overall mental health.

1.2 Purpose and Scope of the Systematic Review

This report aims to synthesize existing literature, offering a comprehensive evaluation of the multifaceted impact of face mask usage on physical, cognitive, and psychological health.

2. Methods

2.1 Review Approach

Due to the availability of multiple systematic reviews that addressed physiological outcomes, an umbrella overview was conducted to systematically identify and synthesize data from published systematic reviews. For the cognitive and psychological outcomes, no systematic reviews were identified, and, therefore, de novo reviews were conducted. **Table 1** details PICOTS questions addressed in this comprehensive systematic review.

2.2 Search Strategy

A comprehensive search of several databases from 2000 to July 28, 2023, of any language was conducted. The 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. Controlled vocabulary supplemented with keywords was used to search various outcomes from wearing medical masks or air-purifying respirators. The complete search strategies are available in Appendix A.

2.3 Study Selection and Data Extraction

Study selection and data extraction were completed in duplicate, and disagreements were resolved by consensus. For the systematic reviews addressing physiological outcomes, we selected reviews that had explicit inclusion and exclusion criteria and searched more than one database. The selection process prioritized titles and methods that unambiguously indicated a systematic review rather than a narrative review. Inclusion was restricted to publications in the English language. In cases where multiple systematic reviews existed for a particular outcome, preference was given to the most recent one, followed by the review with the highest number of studies and superior evidence synthesis based on the design of the included studies. Notably, at least one systematic review was included for each intervention under investigation. Primary studies meeting the inclusion and exclusion criteria highlighted in **Table 1** for cognitive and psychological outcomes were included.

2.4 Risk of Bias Assessment and Grading the Strength of Evidence

The methodological quality assessment was conducted using the modified Cochrane Collaboration´s Tool for Randomized Clinical Trials and the modified Newcastle Ottawa Quality Assessment Tool for observational studies.

We evaluated the quality of evidence using the Grading of Recommendations Assessment, Development, and Evaluation (GRADE) approach. Certainty from randomized controlled trials was considered high but may be rated down for bias, indirectness, imprecision, inconsistency, and publication bias (if applicable, more than 10 studies per analysis). Certainty is rated down due to inconsistency when high heterogeneity (I2>50%) persisted despite subgroup analysis. For imprecision, we rated down if sample size was <500 or the study had <100 events. If confidence intervals cross the null effect with appreciable harm or benefit (<30 fewer outcomes or >30 more outcomes per 1,000), certainty was rated down for imprecision.

Table 1

Key PICOTS (population, interventions, comparisons, outcomes, timing, and setting)

Questions: Three questions addressing acute physiological, cognitive, and psychological outcomes associated with mask use

Population of Interest	Intervention	Comparison	Outcomes	Study Design	Timing	Subgroup Analyses
Adults 18 years and older	▪ Surgical/ medical masks ▪ N95 masks/ filtering facepiece respirators ▪ Military and Fire Service air-purifying respirators (APRs) ▪ Cloth masks	No mask	**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 responses:** ○ Arterial oxygen saturation ○ Oxygen extraction /muscle oxygenation ○ Carbon dioxide/end-tidal CO2 ○ 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**	Systematic review and meta-analysis for Q1, comparative individual studies for Q2 and Q3	From 2000 to 2023	▪ People working in a field with a position description that reasonably expects them to wear a face mask (healthcare workers, pilots, or qualified aircrew, including flight attendants, military, and public safety professionals) ▪ Duration of masking ▪ Activity level: ○ At rest ○ With exercise ▪ Altitude level (when relevant)

Population of Interest	Intervention	Comparison	Outcomes	Study Design	Timing	Subgroup Analyses
			▪ **Functional Activities Questionnaire** ▪ **Abbreviated Mental Test** ▪ **Six-Item Cognitive Impairment Test:** ○ Distraction; Total number of errors, correct responses, and response time; Self-perceived arousal; and Ability to concentrate. **Q3. Psychological outcomes** ▪ **Anxiety** ▪ **Depression** ▪ **Claustrophobia**			

APR, air-purifying respirator; CO_2, carbon dioxide; MOCA, Montreal Cognitive Assessment; Q1,2,3, Question 1,2,3; RPE, rating of perceived exertion; VE/VCO_2, minute ventilation/carbon dioxide production.

3. Results

3.1 Literature Search Results

The electronic search yielded 13,370 potentially relevant citations. Of these, nine systematic reviews (7, 10, 14-20) that included 87 primary individual studies (74 randomized controlled trials (RCTs), 9 non-randomized controlled trials, and 4 observational studies) enrolling 3,404 participants were included to assess the impact **of respiratory protection mask use on acute physiological outcomes.** Additionally, ten primary individual studies (two RCTs (21, 22), one non-randomized control study (23), and seven observational studies (12, 24-29)) involving 411 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**, the key characteristics of the selected studies are summarized in **Table 2-Table 3**, and the methodological quality of the included studies is highlighted in **Table 4-Table 5**: Comparative Observational Studies in **Table 4** and Randomized Clinical Trials in **Table 5**.

Figure 1

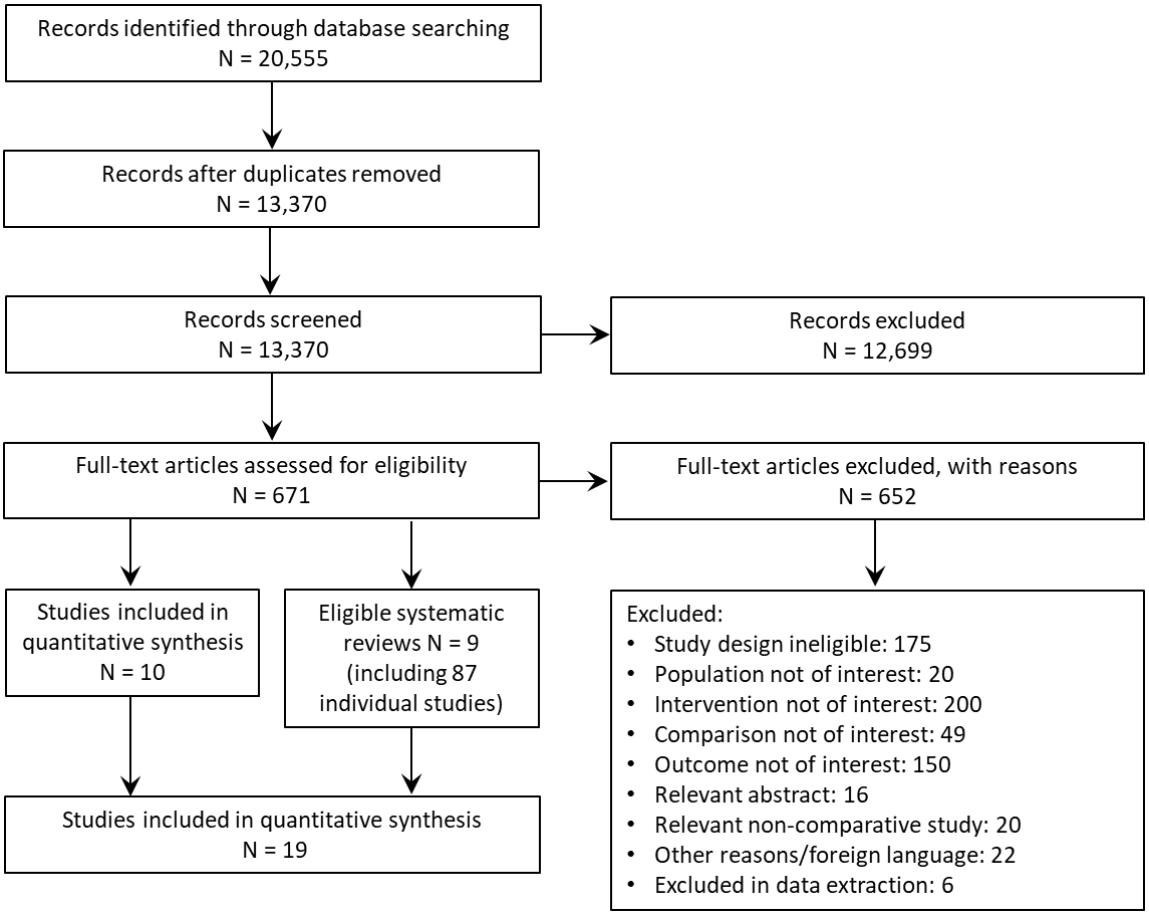

Table 2

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 (18)	6 studies (3 randomized crossover trials/RCT and 3 non-randomized controlled trials)	313 COPD patients	Surgical face masks, N95 respirators, dual-cartridge half-face face masks, and disposable non-filter medical face masks	No mask	Six-minute walk, Steady Exercise state, High-intensity exercise	End-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 (16)	14 studies (14 randomized controlled crossover trials)	246 Healthy individuals	Surgical masks, FFP to/N95 respirators with and without exhalation valve	No face mask	Rest, Steady exercise state, Graded exercise	Oxygen uptake and saturation, Carbon dioxide exhalation and partial pressure, Pulmonary function, Physical performance
Glanzel, 2022 (20)	36 randomized crossover studies	749 Healthy adults	Cloth masks (CMs), surgical masks (SMs), FFP2/N95, and exhalation valved FFP2/N95	No face mask	NR	Discomfort, Subjective stress responses, Dyspnea, Time-to-exhaustion performance, Power output performance, Muscle force, and exercise performance
Lima, 2023 (17)	10 studies (13 randomized crossover trials/randomized controlled trial)	306 (1 study with 106 participants who were children aged 7-14)	N95/FFP2 respirators	No face mask	Aerobic exercise	HR, RR, Blood pressure, Oxygen saturation (SpO2), Perceived exertion

Investigator	Included Studies	Participants	Intervention	Comparison	Exercise Protocol	Outcomes Reported
Litwinowicz, 2022 (15)	26 studies (25 randomized crossover studies and one retrospective observational study)	751 Healthy individuals	Surgical face masks, (FFP1, FFP2, FFP3/ N95, N97, N99 respirators), cloth masks	No face mask, Different type of face mask	Low-intensity activities, Moderate-to-high-intensity activities	Heart rate, Respiratory rate, Pulse oximetry measures -peripheral oxygen saturation (SpO2), Oxygen uptake, Tidal volume, Transcutaneous partial carbon dioxide pressure ($TcPCO_2$), Systolic blood pressure (SPB), Thermoregulation measures and subjective heat perceptions, Perception of exertion
Roeckner, 2020 (19)	4 studies (1 randomized crossover trial/3 prospective trials)	42 Pregnant women	N95 respirators	Non-pregnant women, No face mask	Rest, Progressive exercise state	Heart rate, Respiratory rate, Blood pressure, Fetal heart rate, Oxygen saturation, Transcutaneous CO_2, Perceived exertion
Shaw, 2021(10)	22 studies (13 randomized crossover trials, 7 non-randomized crossover trials, and 2 retrospective studies)	1573 Participants (1 study with 106 participants who were children aged 7-14)	Surgical face masks, FFP2/N95 respirators, cloth masks	No face mask	Low-to-moderate exercise, Progressive exercise state	Exercise performance, Arterial oxygen saturation, Muscle oxygenation, End-tidal and arterial CO_2, RPE, Cardiac output and stroke volume, Blood pressure, Respiratory rate, Ventilation and tidal volume, Lactate
Wangsan, 2022 (14)	13 studies (8 randomized crossover studies, 3 non-randomized studies, and 2 observational studies)	260 Participants	N95/FFP2 respirators	No face mask	Low-moderate physical workload, High physical workload	Oxygen saturation, Partial pressure of carbon dioxide (PCO_2)
Zheng, 2023 (7)	45 studies (42 randomized crossover studies, 2 RCTs, and 1 non-randomized repeated measure study)	1264 Healthy individuals (1 study with 106 participants who were children aged 7-14)	Surgical face mask, FFP2/N95 respirators, Cloth masks	No mask	Steady exercise protocol, Progressive intensity protocol	Heart rate, VO_2, SpO2, $PetCO_2$, RPE, Thermal sensation, Blood lactate, Respiratory rate, Minute ventilation, Tidal volume, VE/VCO_2

CM, cloth mask; CO_2, carbon dioxide; COPD, chronic obstructive pulmonary disease; FFP, filtering facepiece; HR, heart rate; NR, not reported; PCO_2, partial pressure of carbon dioxide; $PetCO_2$, 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; $TcPCO_2$, transcutaneous partial carbon dioxide pressure; VO_2, rate of oxygen consumption; VE/VCO_2, minute ventilation/carbon dioxide production.

Table 3

Characteristics of the included primary studies for cognitive and psychological impact of respiratory protection mask use

Author, Year	Study Design	Population / Country	Total Number of Participants	Mean Age (SD)	Female (%)	Interventions	Control	Outcomes
Braun-Trocchio, 2022 (23)	Non-randomized control study	Healthy university students and staff/USA	54	21.2 (5.5)	70%	Face mask	No mask	Task-specific motivations, Task duration, Commitment check, Attention allocation, Rating of perceived exertion (RPE)
Chong, 2022 (24)	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 (21)	RCT	Healthy university students and staff/USA	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 (22)	RCT	Healthy adults/ Germany	23	23.5 (2.1)	56.5%	Surgical mask, Filtering facepiece type 2 (FFP2)	No mask	Hemodynamic parameters, Metabolic response to mask-wearing, Self-reported data including cognitive performance
Ipek, 2021 (12)	Cross-sectional study	Healthcare workers /Turkey	34	31.3 (6.4)	56%	Surgical mask	N95 masks	Attention deficit and difficulty in concentrating

Author, Year	Study Design	Population / Country	Total Number of Participants	Mean Age (SD)	Female (%)	Interventions	Control	Outcomes
Jahangiri, 2022 (25)	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 (26)	Cross-sectional study	Gastroenterologists /USA	12	NR	NR	Surgical mask	SM and N95 FFR, Powered air-purifying respirator	Claustrophobia
Slimani, 2021 (27)	Cross-sectional study	Healthy students/ Tunisia	17	17.6	47%	Cloth mask	No mask	Concentration performance, Total number of errors, RPE
Su, 2021 (28)	Cross-sectional study	Healthcare workers /Taiwan	68	41	23.5%	Surgical mask	N95 respirator	Anxiety, Fatigue, Depression, Difficulty talking (determined via questionnaire)
Tornero-Aguilera, 2021 (29)	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 facepiece; NR, not reported; PAPR, powered air-purifying respirator; RCT, randomized controlled trial; RPE, rating of perceived exertion; SM, surgical mask; USA, United States of America.

Table 4

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 (23)	Moderate risk	Low risk	High risk	High risk
Chong, 2022 (24)	High risk	High risk	High risk	High risk
Ipek, 2021 (12)	Moderate risk	Low risk	High risk	High risk
Jahangiri, 2022 (25)	High risk	Low risk	High risk	High risk
Khalid, 2021 (26)	High risk	Low risk	High risk	High risk
Slimani, 2021 (27)	High risk	Low risk	High risk	High risk
Su, 2021 (28)	Moderate risk	Low risk	High risk	High risk
Tornero-Aguilera, 2021 (29)	High risk	Low risk	High risk	High risk

Table 5

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 (21)	Low risk	Low risk	Low risk	Moderate risk	Low risk	Moderate risk	Moderate risk
Grimm, 2022 (22)	Low risk	Low risk	Low risk	Low risk	Low risk	Moderate risk	Moderate risk

3.2 Q1. Acute Physiological Impact of Respiratory Protection Mask Use

3.2.1 Key points

- No significant difference in heart rate was observed with various types of face masks in healthy individuals during rest or progressive exercise.
- Surgical masks and N95 masks showed no impact on stroke volume or cardiac output during exercise.
- No significant difference in blood pressure was observed with surgical masks or N95 respirators during rest or exercise.
- No significant difference in respiratory rate was noted with various mask types during rest or exercise. A slight statistically significant increase in respiratory rate was noted in COPD (chronic obstructive pulmonary disease) patients during exercise with masks.
- Statistically significant moderate reduction in minute ventilation with mask usage during exercise, especially in a progressive exercise state.
- Statistically significant modest reduction in tidal volume during exercise with face masks; more pronounced with surgical masks than N95 masks.
- Statistically significant modest reduction in oxygen saturation and VO_2 (rate of oxygen consumption) with mask use; more pronounced during exercise.
- Statistically significant modest increase in carbon dioxide partial pressure with N95 respirator masks during high-intensity exercise.
- Statistically significant modest reduction in VCO_2 (carbon dioxide production) with surgical masks and N95 respirators compared to no masks.
- No significant difference in lactate levels with various mask types.
- Statistically significant modest reduction in exercise performance and time to exhaustion observed with face masks.
- Statistically significant modest increase in thermal sensation and facial skin temperature with mask usage during exercise.
- Statistically significant modest increase in perceived exertion with face mask use, especially during progressive exercise.

3.2.2 Cardiovascular responses

3.2.2.1 Heart rate

Seven independent systematic reviews (7, 10, 15-19) (encompassing 53 individual studies: 46 randomized control trials/crossover trials, 5 non-randomized control trials, and 2 retrospective observational studies), including 2394 participants, assessed the impact of mask-wearing on heart rate via electrocardiogram (ECG) or transcutaneous monitoring. In a meta-analysis of the randomized controlled studies in comparison to no mask use in healthy individuals, no significant difference was seen in those wearing surgical masks (mean difference (MD): 0.96; 95% CI: -1.01 to 2.93), FFP2/N95 respirators (MD: 1.63 (-2.79 to 6.05)), or cloth masks (MD: -0.94 (-6.39 to 4.52)) **(Table 6).** During a steady exercise state, using a mask increases heart rate compared to not wearing a mask (25 studies) (MD: 2.69 (1.10 to 4.28). Notably, when studies with a high risk of bias were excluded, this increase in heart rate was no longer statistically significant. Additionally, no significant difference was noted among the different mask groups during a progressive exercise state (31 studies) (MD: -0.74 (-4.48 to 2.99)).

A systematic review by Chen et al. (18) that included two individual studies (one non-RCT and one RCT) with 124 participants assessed the impact of mask use on heart rate in patients with COPD and noted no significant difference in heart rate between COPD patients with and without face masks (MD: 4.70 (-0.30 to 9.70)) following a six-minute walk test (6 MWT). Additionally, no significant difference in maximum heart rate was noted between the groups (MD: -1.90 (-10.84 to 7.04)) **(Table 6)**.

The effect of N95 respirator use on heart rate during pregnancy was assessed in one systematic review by Roeckner et al. (19) that included three observational studies and one randomized crossover study involving 42 pregnant women. It showed no significant increase in heart rate with the use of N95 respirators among pregnant women compared to the no-mask group **(Table 6)**.

3.2.2.2 Cardiac output

One systematic review (10) that included two randomized crossover studies involving 26 participants assessed stroke volume and cardiac output during exercise. The use of surgical masks during exercise had no impact on stroke volume (MD: 12.33 (-4.09 to 28.75)) or cardiac output (MD: 2.26 (-0.15 to 4.67)). A single crossover trial including 12 participants assessing N95 masks found no significant effects on stroke volume (MD: 13.0 (-6.97 to 32.97)) or cardiac output (MD: 1.20 (-2.19 to 4.59)) **(Table 6)**.

3.2.2.3 Blood pressure

Four independent systematic reviews (10, 15, 17, 18) including 12 individual studies (9 crossover trials,1 nonrandomized control trial and 2 retrospective observational studies) and 1359 participants assessed the impact of mask-wearing on blood pressure. In a comparison to the no-mask group, no significant difference was noted in systolic blood pressure in those wearing surgical masks (MD: -2.23 (-5.28 to 0.82)) or N95 respirators (MD: -0.12 (-4.22 to 3.97)). Similar results were noted for diastolic blood pressure in those wearing surgical masks (MD: -0.96 (-5.32 to 3.40)) or N95 respirators (MD: -0.23 (-3.06 to 2.60)) **(Table 6)**.

Comparable results were observed during different exercise states. Removal of studies with high risk of bias did not change these results. Additionally, no significant difference was noted in mean arterial pressure between the mask and no-mask groups (MD: -0.07 (-0.32 to 0.17)).

A systematic review by Chen et al. (18) that included two individual studies (one non-RCT and one RCT) involving 124 participants assessed the impact of mask use on blood pressure in patients with COPD and noted no significant difference in systolic blood pressure between COPD patients with and without face masks following 6 MWT (MD: 0.40 (-4.36 to 5.16)) or maximum exercise test (MD: -6.80 (-24.37 to 10.77)). Additionally, there was no significant difference in diastolic blood pressure between COPD patients with and without face masks at rest (MD: 2.70 (-0.34 to 5.74)) nor after 6 MWT (MD: -0.80 (-4.13 to 2.53)) **(Table 6)**.

Table 6

Effect of respiratory protection mask use on cardiovascular responses and quality of evidence for reported outcomes

Outcome (measurement unit)	Systematic Review	Population	Comparison	Participants (included studies)	Effect Size (95% CI)	Risk of Bias	Certainty of Evidence
Heart rate (beats per minute (bpm))	Zheng, 2023 (7)	Healthy adults	Surgical mask vs. No mask	692 (28 RCTs /randomized crossover trials)	MD: 0.96 (-1.01 to 2.93)	Moderate	Low (due to inconsistency and imprecision)
			N95 respirator vs. No mask	391 (18 RCTs /randomized crossover trials)	MD: 1.63 (-2.79 to 6.05)	Moderate	Low (due to inconsistency and imprecision)
			Cloth mask vs. No mask	115 (5 crossover trials)	MD: -0.94 (-6.39 to 4.52)	Moderate	Low (due to inconsistency and imprecision)
	Chen, 2022 (18)	COPD patients	Face mask vs. No mask	97 (1 non-RCT)	MD: 4.70 (-0.30 to 9.70)	Moderate	Low (due to imprecision)
Maximum heart rate	Chen, 2022 (18)	COPD patients	Face mask vs. No mask	27 (1 randomized crossover trial)	MD: -1.90 (-10.84 to 7.04)	Moderate	Very Low (due to imprecision)
Stroke volume (millimeters (mL) per beat)	Shaw, 2021 (10)	Healthy adults	Face mask vs. No mask	26 (2 crossover trials)	MD: 12.33 (-4.09 to 28.75)	Moderate	Low (due to imprecision)
			N95 respirator vs. No mask	14 (1 crossover trial)	MD: 13.0 (-6.97 to 32.97)	Moderate	Very Low (due to imprecision)
Cardiac output (mL per minute)	Shaw, 2021 (10)	Healthy adults	Face mask vs. No mask	26 (2 crossover trials)	MD: 2.26 (-0.15 to 4.67)	Moderate	Low (due to imprecision)
			N95 respirator vs. No mask	14 (1 crossover trial)	MD: 1.20 (-2.19 to 4.59)	Moderate	Very Low (due to imprecision)

Outcome (measurement unit)	Systematic Review	Population	Comparison	Participants (included studies)	Effect Size (95% CI)	Risk of Bias	Certainty of Evidence
Systolic blood pressure (millimeters of mercury (mmHg))	Shaw, 2021 (10)	Healthy adults	Face mask vs. No mask	1088 (4 crossover trials and 2 retrospective observational studies)	MD: -2.23 (-5.28 to 0.82)	High	Very Low (due to risk of bias, inconsistency, and imprecision)
			N95 respirator vs. No mask	130 (3 randomized crossover trials and 1 RCT)	MD: -0.12 (-4.22 to 3.97)	Moderate	Low (due to imprecision)
	Chen, 2022 (18)	COPD patients	Face mask vs. No mask following 6 MWT	97 (1 non-RCT)	MD: 0.40 (-4.36 to 5.16)	Moderate	Low (due to imprecision)
			Face mask vs. No mask following maximum exercise test	27 (1 crossover trial)	MD: -6.80 (-24.37 to 10.77)	Moderate	Low (due to imprecision)
Diastolic blood pressure (mmHg)	Shaw, 2021 (10)	Healthy adults	Face mask vs. No mask	38 (3 crossover trials)	MD: -0.96 (-5.32 to 3.40)	Moderate	Low (due to imprecision)
			N95 respirator vs. No mask	114 (2 crossover trials and 1 non-RCT)	MD: -0.23 (-3.06 to 2.60)	Moderate	Low (due to imprecision)
	Chen, 2022 (18)	COPD patients	Face mask vs. no mask at rest	97 (1 non-RCT)	MD: 2.70 (-0.34 to 5.74)	Moderate	Low (due to imprecision)
			Face mask vs. no mask following 6 MWT	97 (1 non-RCT)	MD: -0.80 (-4.13 to 2.53)	Moderate	Low (due to imprecision)
Mean arterial blood pressure (mmHg)	Lima, 2023 (17)	Adult patients	Face mask vs. no mask	116 (6 crossover trials)	MD: -0.07 (-0.32 to 0.17)	High	Very Low (due to risk of bias, inconsistency, and imprecision)

COPD, chronic obstructive pulmonary disease; MD, mean difference; 6 MWT, six-minute walking test; RCT, randomized controlled trial.

3.2.3 Ventilatory responses

3.2.3.1 Respiratory rate

Seven systematic reviews (7, 10, 15-19) that included 29 individual studies (25 randomized crossover trials and 4 non-RCTs) involving 806 participants assessed the impact of mask use on respiratory rate (RR). No significant difference was noted in RR in those wearing surgical masks (MD: -1.35 (-3.00 to 0.29)), FFP2/N95 respirators (MD: 0.10 (-3.10 to 3.29)), or cloth masks (MD: -2.57 (-6.44 to 1.29)) compared to the no-mask group **(Table 7)**. Similar results were noted in the subgroup analysis by exercise type, with no significant difference noted during steady exercise state (MD: -0.26 (-1.83 to 1.30)) or progressive exercise state (MD: -1.40 (-4.02 to 1.23)). Removal of studies with high risk of bias did not change these results. Additionally, one systematic review (18) that included two studies and 112 participants reported a slight increase in RR with use of face mask during exercise in COPD patients (MD: 1.00 (0.47 to 1.53)) **(Table 7)**.

The effect of N95 respirator on respiratory rate during pregnancy was assessed in one systematic review by Roeckner et al. (19) that included one observational study and one randomized crossover study involving 42 pregnant women. It showed no significant difference in respiratory rate with the use of N95 respirators among pregnant women compared to the no-mask group **(Table 7)**.

3.2.3.2 Minute ventilation

Six systematic reviews (7, 10, 15, 16, 18, 19) that included 14 studies (13 randomized crossover trials/RCTs and 1 non-RCT) involving 256 participants assessed the impact of mask-wearing on minute ventilation and showed a significant reduction in VE (minute ventilation) (MD: -14.46 L/min (-20.12 to -8.79) in those with masks compared with those with no masks during exercise **(Table 7)**. Similar results were noted in the subgroup analysis by mask type, surgical mask (MD: -13.91 (-20.30 to -7.530)), and N95 mask (MD: -16.30 (-28.73 to -3.87)). Additionally, analysis by exercise type showed a significant reduction in VE during a progressive exercise state (MD:-18.11 (-24.63 to -11.58)); however, no significant difference was noted during a steady exercise state (MD: -0.07 (-4.47 to 4.33)). The result remained consistent even after the removal of studies with high risk of bias.

A systematic review by Chen et al. (18) that included one RCT with 14 participants assessed the impact of mask use on minute ventilation in patients with COPD and noted no significant difference in minute ventilation between COPD patients with and without face masks (MD: -0.33 (-5.08 to 4.42)) **(Table 7)**.

The effect of N95 respirators on respiratory rate during pregnancy was assessed in one systematic review by Roeckner et al. (19) that included one randomized crossover study involving 20 pregnant women. It showed a significant reduction in minute ventilation by 25.8% (15.8% to 34.2%) with the use of N95 respirators among pregnant women compared to the no-mask group **(Table 7)**.

3.2.3.3 Tidal volume

Four systematic reviews (7, 10, 15, 19) that included 10 crossover trials involving 209 participants assessed the impact of mask-wearing on tidal volume (VT), and significant reductions occurred in VT (MD: -0.11 (-0.20 to -0.02) in those with face masks compared to those with no masks during exercise. Similar results were noted in the subgroup analysis among the surgical mask group (MD: -0.14 (-0.23 to -0.05); however, no significant difference was found among the N95 mask group (MD: -0.10 (-0.33 to 0.13) **(Table 7)**. Additionally, analysis by exercise type showed a significant reduction in VT (MD: -0.21 (-0.31 to-0.10)) during a progressive exercise state; however, no significant difference was noted during a steady exercise state (MD: 0.00 (-0.12 to 0.12)), and the result remained consistent even after the removal of studies with high risk of bias.

A systematic review by Roeckner et al. (19) that included one RCT with 20 participants assessed the impact of N95 respirator mask use among pregnant women and showed a significant reduction in tidal volume by 23% (10.5% to 33.5%) compared to the no-mask group **(Table 7)**.

3.2.3.4 Carbon dioxide ventilation equivalent

One systematic review (7) that included six randomized crossover trials involving 139 participants assessed the impact of mask use on carbon dioxide ventilation equivalent (VE/VCO_2). The use of surgical masks during exercise was associated with significant reductions in VE/VCO_2 (MD: -1.69 (-3.10 to -0.27)) **(Table 7)**. No significant difference was noted between the mask and no-mask groups in the subgroup analysis by exercise type: progressive exercise state (MD: -1.18 (-2.42 to 0.06)) or steady exercise state (MD: -2.39 (-4.97 to 0.19)). After removing the studies with high risk of bias, results remained consistent.

Table 7

Effect of respiratory protection mask use on ventilatory responses and quality of evidence for reported outcomes

Outcome (measurement unit)	Systematic Review	Population	Comparison	Participants (included studies)	Effect Size (95% CI)	Risk of Bias	Certainty of Evidence
Respiratory rate (breaths per minute)	Zheng, 2023 (7)	Healthy adults	Surgical mask vs. No mask	358 (13 crossover trials)	MD: -1.35 (-3.00 to 0.29)	Moderate	Low (due to inconsistency and imprecision)
			N95 respirator vs. No mask	248 (11 crossover trials)	MD: 0.10 (-3.10 to 3.29)	Moderate	Low (due to inconsistency and imprecision)
			Cloth mask vs. No mask	81 (3 crossover trials)	MD: -2.57 (-6.44 to 1.29)	High	Very Low (due to high risk of bias, inconsistency, and imprecision)
	Chen, 2022 (18)	COPD patients	Face mask vs. No mask	112 (2 non-RCTs)	MD: 1.0 (0.47 to 1.53)	High	Very Low (due to risk of bias and imprecision)
Minute ventilation (mL/min)	Zheng, 2023 (7)	Healthy adults	Surgical mask vs. No mask	212 (11 crossover trials)	MD: -13.9 (-20.30 to -7.53)	High	Very Low (due to high risk of bias, inconsistency and imprecision)
			N95 respirator vs. No mask	62 (5 crossover trials)	MD: -16.3 (-28.7 to -3.9)	Moderate	Very Low (due to inconsistency and imprecision)
	Chen, 2022 (18)	COPD patients	Face mask vs. No mask	14 (1 RCT)	MD: -0.33 (-5.08 to 4.42)	Moderate	Very Low (due to imprecision)
Tidal volume (mL)	Zheng, 2023 (7)	Healthy adults	Surgical mask vs. No Mask	151 (6 crossover trials)	MD: -0.14 (-0.23 to -0.05)	Moderate	Low (due to imprecision)
			N95 respirator vs. No mask	46 (4 crossover trials)	MD: -0.10 (-0.33 to 0.13)	Moderate	Low (due to imprecision)

Outcome (measurement unit)	Systematic Review	Population	Comparison	Participants (included studies)	Effect Size (95% CI)	Risk of Bias	Certainty of Evidence
Carbon dioxide ventilation equivalent	Zheng, 2023 (7)	Healthy adults	Surgical mask vs. No Mask	139 (5 crossover trials)	MD: -1.69 (-3.10 to -0.27)	Moderate	Very Low (due to risk of bias and imprecision)

COPD, chronic obstructive pulmonary disease; MD, mean difference; RCT, randomized controlled trial.

3.2.4 Metabolic response: Oxygen saturation, end-tidal partial pressure, and oxygen uptake

3.2.4.1 Oxygen saturation

Outcomes regarding oxygen saturation assessed by use of transcutaneous oxygen saturation or a pulse oximeter were reported in eight systematic reviews (7, 10, 14-19) including 42 studies (37 randomized crossover trials/RCTs, 3 non-RCTs, 1 prospective cohort, and 1 retrospective study) involving 1302 participants. A small reduction in oxygen saturation was noted in those wearing any type of mask in comparison to the no-mask group (MD: -0.48% (-0.71 to -0.26)); similar results were noted in the subgroup analysis for the surgical mask group (MD: -0.59% (-0.87 to -0.30)). While no change was observed in those wearing N95 respirators ((MD: -0.35 (-0.75 to 0.05)) or cloth masks (MD: -0.50 (-1.23 to 0.24)), the result remained consistent after removing studies with high risk of bias **(Table 8)**. Moreover, a significant reduction in SpO2 was noted in both a progressive (MD: -0.60 (-1.02 to -0.18)) and steady exercise state (MD: -0.41 (-0.73 to -0.10)).

A systematic review by Chen et al. (18) that included one RCT with 97 participants assessed the impact of mask use on oxygen saturation in patients with COPD and showed a slight reduction in oxygen saturation between COPD patients with and without face masks (MD: -0.80 (-1.56 to -0.04)) **(Table 8)**.

The effect of N95 respirators on respiratory rate during pregnancy was assessed in one systematic review by Roeckner et al. (19) that included one observational study and one randomized crossover study involving 42 pregnant women and showed no significant difference in oxygen saturation with the use of N95 respirators among pregnant women compared to the no-mask group **(Table 8)**.

3.2.4.2 End-tidal oxygen partial pressure

One systematic review (7) including six studies involving 132 participants reported information on end-tidal oxygen partial pressure (PetO2) and showed a significant reduction in PetO2 in those wearing masks versus the no-mask group (MD: -3.79 (-5.46 to -2.12)); similar results were noted in the subgroup analysis for surgical masks (MD: -3.17 (-4.87 to -1.47)) and N95 respirators (MD: -5.10 mmHg (-9.27 to -0.94)) **(Table 8)**.

3.2.4.3 Oxygen uptake

Three systematic reviews (7, 15, 16) that included 14 studies (13 randomized crossover trials and 1 non-RCT) involving 273 participants reported information on oxygen uptake, with a significant decrease in VO_2 (SMD: -0.66 (-0.87 to -0.45)) with exercise with face mask use in

comparison to the no-mask group. In the subgroup analysis, a significant decrease was noted in VO_2 in those with surgical masks (SMD: -0.64 (-0.86 to -0.42)) and N95 respirators (SMD: -0.66 (-1.16 to -0.16)), though no change was noted in those with cloth masks (SMD: -0.73 (-1.96 to 0.51)) **(Table 8)**. Similar results were noted in the subgroup analysis by exercise type, with a significant reduction in the VO_2 in both a progressive (SMD: -0.68 (-0.93 to -0.43)) and steady exercise state (SMD: -0.57 (-0.94 to - 0.21)).

3.2.4.4 Muscle oxygenation

One systematic review (10) that included three studies involving 40 participants reported no significant impact on muscle oxygenation during exercise while wearing face masks (MD: -0.41 (-0.86 to 0.05)) when compared to the no-mask group **(Table 8)**.

3.2.4.5 Carbon dioxide

Three systematic reviews (14-16) that included 10 studies (eight randomized crossover trials and two non-RCTs) involving 143 participants reported information on carbon dioxide levels and showed a slight increase in carbon dioxide partial pressure between the N95 respirator mask and no-mask groups during high-intensity exercise (SMD: 1.17 (0.70 to 1.64)) and low- to moderate-intensity exercise (SMD: 0.43 (0.08 to 0.79)) **(Table 8)**.

Additionally, data regarding VCO_2 were assessed in two systematic reviews (7, 16) that included six individual studies (five randomized crossover trials and one non-RCT) involving 137 participants and showed a reduction in VCO_2 among those wearing surgical masks (SMD: -0.74 (-1.19;-0.28). No significant change was noted among the N95 respirator group (SMD: -0.87 (-1.82 to 0.07)) when compared to the no-mask group. One systematic review (10) that included three crossover trials and two non-RCTs involving 104 participants assessed the impact of face masks on arterial CO_2 and showed a significant increase in arterial CO_2 (MD: 1.33 (0.02 to 2.64)) in the N95 respirator group; however, when studies with high risk of bias or maximal exercise testing were removed, no statistically significant difference was noted (p = 0.051). Additionally, no significant difference was noted when surgical face masks were compared to the no-mask group (-0.41 (-2.15 to 1.33) **(Table 8)**.

3.2.4.6 End-tidal CO_2

Three systematic reviews (7, 10, 18) that included 15 studies involving 469 participants reported information on end-tidal carbon dioxide and showed a significant increase in end-tidal CO_2 in those wearing surgical masks (MD: 2.32 (1.38;3.26) and N95 respirators (MD: 2.93 (2.01 to 3.86) **(Table 8)**. A similar result was noted in the subgroup analysis by exercise type: progressive exercise (MD: 4.15 (2.77 to 5.53) or steady exercise state (MD: 2.09 (0.93 to 3.25). The subgroup analysis of the two studies including 112 patients with COPD (18) showed no significant difference in end-tidal carbon dioxide (MD: 0.10 (-1.57 to 1.78)) among the mask and no-mask groups **(Table 8)**.

3.2.4.7 Lactate

The results regarding lactate level were reported in three systematic reviews (7, 10, 18) that included nine studies and 201 participants; no significant difference was observed for those wearing surgical masks (MD: -0.10 (-1.11 to 1.31)) or N95 respirators (MD: -1.02 (-2.09 to 0.05)) **(Table 8)**. However, the sensitivity analysis by exercise level showed a significant reduction in lactate level during progressive exercise tests (MD: -1.06 (-1.69 to -0.44)), though no significant difference was noted during a steady exercise state (MD: -1.23 (-0.40 to 2.86).

A systematic review by Chen et al. (18) that included one RCT with 27 participants assessed the impact of mask use on blood lactate levels in patients with COPD and showed blood lactate levels from COPD patients without face masks were significantly higher than COPD patients with face masks at exhaustion (MD: -0.90 (-1.73 to -0.07) **(Table 8)**.

Table 8

Effect of respiratory protection mask use on metabolic responses and quality of evidence for reported outcomes

Outcome (measurement unit)	Systematic Review	Population	Comparison	Participants (included studies)	Effect Size (95% CI)	Risk of Bias	Certainty of Evidence
Oxygen saturation (%)	Zheng, 2023 (7)	Healthy adults	Surgical mask vs. No mask	589 (20 RCT/crossover trials, 1 non-RCT)	MD: -0.59% (-0.87 to -0.30)	Moderate	Low (due to inconsistency and imprecision)
			N95 respirator vs. No mask	232 (10 RCT/crossover trials, 1 non-RCT)	MD: -0.35% (-0.75 to 0.05)	Moderate	Low (due to inconsistency and imprecision)
			Cloth mask vs. No mask	164 (6 RCT/crossover trials, 1 non-RCT)	MD: -0.50% (-1.23;0.24)	Moderate	Low (due to inconsistency and imprecision)
	Chen, 2022 (18)	COPD patients	Face mask vs. No mask	97 (1 non-RCT)	MD: -0.80 (-1.56 to -0.04)	High	Very Low (due to high risk of bias and imprecision)
End-tidal oxygen partial pressure (mmHg)	Zheng, 2023 (7)	Healthy adults	Surgical mask vs. No mask	132 (6 RCT/crossover trials)	MD: -3.17 mmHg (-4.87 to -1.47)	Moderate	Low (due to imprecision)
			N95 respirator vs. No mask	42 (4 RCT/crossover trials)	MD: -5.10 mmHg (-9.27 to -0.94)	Moderate	Low (due to imprecision)
Oxygen uptake (mL/kg/min)	Zheng, 2023 (7)	Healthy adults	Surgical mask vs. No mask	202(9 RCT/crossover trials, 1 non-RCT)	(MD: -0.64 (-0.86 to -0.42)	High	Very Low (due to high risk of bias and imprecision)
			N95 respirator vs. No mask	72 (5 RCT/crossover trials)	MD: -0.66 (-1.16 to -0.16)	Moderate	Low (due to imprecision)
			Cloth mask vs. No mask	51 (2 RCT/crossover trials)	MD: -0.73 (-1.96 to 0.51)	Moderate	Low (due to inconsistency and imprecision)

Outcome (measurement unit)	Systematic Review	Population	Comparison	Participants (included studies)	Effect Size (95% CI)	Risk of Bias	Certainty of Evidence
Muscle oxygenation (%)	Shaw, 2021 (10)	Adults	Surgical mask vs. No mask	40 (3 RCT/crossover trials)	MD: -0.41 (-0.86 to 0.05)	Moderate	Low (due to inconsistency and imprecision)
Carbon dioxide partial pressure (mmHg)	Wangsan, 2022 (14)	Healthy adults	N95 respirator vs. No mask (high-intensity exercise)	51 (4 RCT/crossover trials)	SMD: 1.17 (0.70 to 1.64)	Moderate	Low (due to inconsistency and imprecision)
			N95 respirator vs. No mask (low- to moderate-intensity exercise)	54 (4 RCT/crossover trials)	SMD: 0.43 (0.08 to 0.79)	Moderate	Low (due to inconsistency and imprecision)
VCO_2 (mL/min)	Zheng, 2023 (7)	Healthy adults	Surgical mask vs. No mask	127 (4 RCT/crossover trials, 1 non-RCT)	SMD: -0.74 (-1.19 to -0.28)	Moderate	Low (due to inconsistency and imprecision)
			N95 respirator vs. No mask	28 (2 RCT/crossover trials)	SMD: -0.87 (-1.82 to 0.07)	Moderate	Low (due to inconsistency and imprecision)
Arterial CO_2 (milliequivalents per liter(mmol/L))	Shaw, 2021 (10)	Adults	Surgical mask vs. No mask	62 (1 RCT/crossover trial, 1 non-RCT)	MD: 0.41 (-2.15 to 1.33)	High	Very Low (due to high risk of bias and imprecision)
			N95 respirator vs. No mask	54 (3 RCT/crossover trials, 1 non-RCT)	MD: 1.33 (0.02;2.64)	High	Very Low (due to high risk of bias and imprecision)
End-tidal CO_2 (mmHg)	Zheng, 2023 (7)	Healthy adults	Surgical mask vs. No mask	269 (9 RCT/crossover trials)	MD: 2.32 (1.38;3.26)	High risk of bias	Very Low (due to high risk of bias and imprecision)
			N95 respirator vs. No mask	213 (9 RCT/crossover trials)	MD: 2.93 (2.01;3.86)	High	Very Low (due to high risk of bias, inconsistency and imprecision)

Outcome (measurement unit)	Systematic Review	Population	Comparison	Participants (included studies)	Effect Size (95% CI)	Risk of Bias	Certainty of Evidence
	Chen, 2022 (18)	COPD patients	Face mask vs. No mask	112 (1 RCT/crossover trial, 1 non-RCT)	MD: 0.10 (-1.57 to 1.78)	Moderate	Low (due to inconsistency and imprecision)
Lactate level (milliequivalents per liter (mmol/L))	Zheng, 2023 (7)	Healthy adults	Surgical mask vs. No mask	160 (7 RCT/crossover trials)	MD: -0.10 (-1.11;1.31)	Moderate	Low (due to inconsistency and imprecision)
			N95 respirator vs. No mask	28 (2 RCT/crossover trials)	MD: -1.02 (-2.09;0.05)	Moderate	Low (due to inconsistency and imprecision)
	Chen,2022 (18)	COPD patients	Face mask vs. No mask	27 (1 RCT/crossover trial)	MD: -0.90 (-1.73 to -0.07)	Moderate	Low (due to imprecision)

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

3.2.5 Exercise performance

3.2.5.1 Exercise performance

Data regarding exercise performance were reported in four systematic reviews (7, 10, 16, 18) that included 28 studies (25 crossover trials/RCTs, 2 non-RCTs, and 1 retrospective study) involving 1717 participants and showed significant reductions in exercise performance between those wearing and those not wearing face masks (SMD: -0.23 (-0.41 to -0.04)); similar results were noted in the subgroup analysis for those wearing N95 respirators (SMD: -0.42 (-0.76 to -0.08)). No change was noted in those wearing surgical masks (-0.12 (-0.39;0.15)) or cloth masks (-0.26 (-0.54;0.02)) **(Table 9)**. Furthermore, in the subgroup analysis by exercise type, a significant decrease in exercise performance was noted during progressive exercise (MD: -0.34 (-0.52 to -0.15)), with no significant difference noted during a steady exercise state (MD: 0.16 (-0.32 to 0.65)). The results remained consistent even after removing studies with high risk of bias.

A systematic review by Chen et al. (18) that included one RCT with 27 participants assessed the impact of mask use on exercise performance in patients with COPD and showed no significant difference in the maximum working rate between COPD patients with and without face masks at exhaustion (MD: -9.90 (-28.20 to 8.40)) **(Table 9)**.

3.2.5.2 Time to exhaustion and perceived exertion

Three systematic reviews (7, 10, 20) that included 32 individual crossover trials involving 603 participants reported outcomes regarding perceived exertion and showed the rating of perceived exertion (RPE) was significantly higher for all mask types (SMD: 0.28 (0.17 to 0.39) and with surgical masks (SMD: 0.36 (0.21 to 0.52), while no significant effect was observed in those with

N95 respirators (SMD: 0.17 (-0.01 to 0.35)) or cloth masks (SMD: 0.22 (-0.13 to 0.57)) **(Table 9)**. The sensitivity analysis by exercise type showed a significant increase in RPE with progressive exercise (0.16 (0.05 to 0.28)) and a steady exercise state (0.51 (0.27 to 0.76)). Data regarding time to exertion were noted in one systematic review (20) that included nine individual studies and 210 participants and showed a slight reduction in time to exertion with the use of face masks when compared to the control group (SMD: -0.29 (-0.10 to -0.48)) **(Table 9)**.

3.2.5.3 Thermal sensation and facial skin temperature

Two systematic reviews (7, 15) including 11 crossover trials involving 176 participants reported information on thermal sensation, subjective rating of heat perception, and temperature of facial skin. Five studies that included 68 participants showed a significant increase in thermal sensation (SMD: 0.67 (0.22 to 1.12)); similar results were noted in the subgroup analysis of those with surgical masks (SMD: 0.46 (0.06 to 0.85)), though no significant difference was noted in the N95 respirator group (SMD: 0.97 (-0.05 to 2.00)) **(Table 9)**. The subgroup analysis by exercise type showed a significant increase in thermal sensation during a progressive exercise state (SMD: 1.59 (0.55 to 2.64)) and a steady exercise state (SMD: 0.35 (0.01 to 0.69)).

One systematic review with five crossover trials including 86 participants showed a significant increase in facial skin temperature during mask-wearing (SMD: 1.05 (0.48 to 1.63)). One systematic review (15) with four crossover trials that included 54 participants showed no significant difference in subjective rating of heat perception between the mask and no-mask groups (SMD: 1.04 (-0.12 to 2.19)) **(Table 9)**.

Table 9

Effect of respiratory protection mask use on exercise performance and quality of evidence for reported outcomes

Outcome	Systematic Review	Population	Comparison	Participants (included studies)	Effect Size (95% CI)	Risk of Bias	Certainty of Evidence
Exercise performance	Zheng, 2023 (7)	Healthy adults	Surgical mask vs. No mask	541 (20 RCTs/crossover trials)	SMD: -0.12 (-0.39 to 0.15)	Moderate	Low (due to inconsistency and imprecision)
			N95 respirator vs. No mask	232 (11 RCTs/crossover trials)	SMD: -0.42 (-0.76 to -0.08)	Moderate	Low (due to inconsistency and imprecision)
			Cloth mask vs. No mask	114 (5 RCTs/crossover trials)	SMD: -0.26 (-0.54 to 0.02)	Moderate	Low (due to to imprecision)
	Chen, 2022 (18)	COPD patients	Face mask vs. No mask	27 (1 crossover trial)	MD: -9.90 (-28.20 to 8.40)	Moderate	Very Low (due to imprecision)
Rating of perceived exertion	Zheng, 2023 (7)	Healthy adults	Surgical mask vs. No mask	424 (20 crossover trials/ RCTs)	SMD: 0.36 (0.21 to 0.52)	Moderate	Low (due to imprecision)
			N95 respirator vs. No mask	174 (10 crossover trials/RCTs)	SMD: 0.17 (-0.01 to 0.35)	Moderate	Low (due to imprecision)
			Cloth mask vs. No mask	161 (7 crossover trials/RCTs)	SMD: 0.22 (-0.13 to 0.57)	Moderate	Low (due to inconsistency and imprecision)
Time to exhaustion	Glanzel, 2022 (20)	Healthy adults	Face mask vs. No mask	210 (9 crossover trials/RCTs)	MD: -0.29 (-0.48 to -0.10)	Moderate	Low (due to imprecision)
Thermal sensation	Zheng, 2023 (7)	Healthy adults	Surgical mask vs. No mask	56 (4 RCTs/crossover trials)	SMD: 0.46 (0.06 to 0.85)	Moderate	Low (due to imprecision)
			N95 respirator vs. No mask	36 (3 RCTs/crossover trials)	SMD: 0.97 (-0.05 to 2.00)	Moderate	Low (due to imprecision)

Outcome	Systematic Review	Population	Comparison	Participants (included studies)	Effect Size (95% CI)	Risk of Bias	Certainty of Evidence
Facial skin temperature	Litwinowicz, 2022 (15)	Healthy adults	N95 respirator vs. No mask	86 (5 RCTs/crossover trials)	SMD: 1.05 (0.48 to 1.63)	Moderate	Low (due to imprecision)
Subjective rating of heat perception	Litwinowicz, 2022 (15)	Healthy adults	N95 respirator vs. No mask	54 (4 RCTs/crossover trials)	SMD: 1.04 (-0.12-2.19)	Moderate	Low (due to imprecision)

COPD, chronic obstructive pulmonary disease; MD, mean difference; RCT, randomized controlled trial; SMD, standardized mean difference.

3.3 Q2. Cognitive Influence of Respiratory Protection Mask Use

3.3.1 Key points

- Mixed results on cognitive function; some studies report reduced mental workload, others show no significant effect or decreased performance.
- Varied impact on attention, errors, and reaction time with different masks.

In a non-randomized control study by Braun-Trocchio (23) that included 54 healthy individuals, participants wearing a face covering were more internally focused across the duration of the stepping exercise task when compared to the no-mask group. Similar results were noted in a cross-sectional study by Slimani et al. (27) that included 17 participants and assessed the impact of face masks on cognitive function during exercise; it showed a significant positive effect of face mask-wearing on cognitive function, with a lower total number of errors among the face mask group compared to controls. Additionally, a randomized controlled study by Deng et al. (21) that included 20 healthy participants demonstrated a reduced mental workload with face mask use; however, mask use was associated with lower performance, with less correct number or correct rate **(Table 10)**.

This was contrary to the results reported in the quasi-experimental study by Jahangiri et al. (25) that included 40 participants and showed no significant difference between face masks and N95 respirators on cognitive performance, number of correct responses, or response time. Additionally, the results of the randomized control trial by Grimm et al. (22) that included 23 participants showed no significant effect of mask-wearing on cognitive performance during rest or exercise. Likewise, self-perceived arousal and ability to concentrate ratings were not affected by mask-wearing during rest or exercise. Moreover, a cross-sectional study by Tornero-Aguilera (29) that included 50 university students showed no significant effect with the use of surgical face masks on mental fatigue perception or reaction time **(Table 10)**.

When assessing the results of different types of face mask use, a cross-sectional study by Ipek et al. (12) that included 34 healthcare workers showed a significantly higher rate of attention deficit and difficulty in concentrating among the N95 respirator group compared to the face mask group (P<0.001) **(Table 10)**.

Table 10

Effect of respiratory protection mask use on cognitive performance and quality of evidence for reported outcomes

Author, Year of Publication	Participants (study design)	Outcome	Risk of Bias	Certainty of Evidence
Braun-Trocchio, 2022 (23)	54 (Non-randomized study)	Participants wearing a face covering were more internally focused across the duration of the stepping exercise task when compared to the no-mask group	High	Very Low (due to risk of bias and imprecision)
Deng, 2022 (21)	20 (RCT)	Reduced mental workload with face mask use; however, mask use was associated with worse performance with less correct number or correct rate	Moderate	Low (due to imprecision)
Grimm, 2022 (22)	23 (RCT)	No significant effect of mask-wearing on cognitive performance, self-perceived arousal, or ability to concentrate ratings during rest or exercise	Moderate	Low (due to imprecision)
Ipek, 2021 (12)	34 (Cross-sectional study)	Higher rate of attention deficit and difficulty in concentrating among the N95 respirator group compared to the face mask group	High	Very Low (due to risk of bias and imprecision)
Jahangiri, 2022 (25)	40 (Quasi-experimental study)	No significant difference noted between face mask and N95 respirator groups in cognitive performance, number of correct responses, or response time	High	Very Low (due to risk of bias and imprecision)
Slimani, 2021 (27)	17 (Cross-sectional study)	Significant positive effect of face mask-wearing on cognitive function, with a lower total number of errors among the face mask group compared to controls	High	Very Low (due to risk of bias and imprecision)
Tornero-Aguilera, 2021 (29)	50 (Cross-sectional study)	No significant effect with use of surgical face mask on mental fatigue perception or reaction time	High	Very Low (due to risk of bias and imprecision)

RCT, randomized controlled trial.

3.4 Q3. Psychological Impact Associated with Respiratory Protection Mask Use

3.4.1 Key points

- Claustrophobia reported in a small percentage of healthcare workers wearing face masks, surgical masks, or N95 respirators.
- No significant difference in depression or anxiety rates among individuals wearing surgical masks or N95 respirators.

In a cross-sectional study by Chong et al. (24) that included 93 healthcare workers with an average age of 38.1 years (8.4), claustrophobia was noted in 3% of the participants while wearing face masks. Similar results were noted while wearing an N95 respirator or surgical mask, contrary to the reported results by Khalid et al. (26) that showed a higher rate of claustrophobia among the N95 respirator group when compared to the face mask group. In a cross-sectional study by Su et al. (28) that included 68 healthcare workers, no significant difference was noted in depression or anxiety rates among the surgical mask or N95 respiratory group.

Table 11

Psychological impact of respiratory protection mask use and quality of evidence for reported outcomes

Author, Year of Publication	Participants (study design)	Outcome	Risk of Bias	Certainty of Evidence
Chong, 2022 (24)	93 (Cross-sectional study)	Claustrophobia was noted in 3% of the participants while wearing face masks. Similar results were noted while wearing an N95 respirator or surgical mask.	High	Very Low (due to risk of bias and imprecision)
Khalid, 2021 (26)	12 (Cross-sectional study)	Higher rate of claustrophobia among the N95 respirator group when compared to the face mask group	High	Very Low (due to risk of bias and imprecision)
Su, 2021 (28)	68 (Cross-sectional study)	No significant difference was noted in depression or anxiety rates among the surgical mask or N95 respiratory group.	High	Very Low (due to risk of bias and imprecision)

4. Conclusion

This systematic review sheds light on the physiological, cognitive, and psychological impact of respiratory protection mask use. While our findings suggest that various masks generally do not significantly affect key physiological parameters at rest or during exercise, subtle changes are observed in certain metrics, such as minute ventilation, oxygen saturation, and exercise performance. However, the available evidence is of limited quality. Moreover, the impact on cognitive function is inconclusive, as some studies suggest a decrease in mental workload, while others report no significant effects or improved performance. However, the evidence regarding cognitive and psychological outcomes remains inconclusive due to the small sample sizes, non-longitudinal nature, and high risk of bias in existing studies.

Given the critical role of mask-wearing in public health interventions, our review underscores the need for further research addressing the impact of mask use on various aspects of human health and well-being. This includes more extensive, longitudinal studies with rigorous methodologies to better understand the long-term implications of mask-wearing. As policymakers and healthcare professionals continue to navigate the complexities of respiratory protection measures, future recommendations and policies must be informed by robust evidence to ensure an optimal balance between public health protection and individual well-being.

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6. 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 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.	1941052
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 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.	30554
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)

#	Searches	Results
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