

BMJ Open Face masks while exercising trial (MERIT): a cross-over randomised controlled study

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ABSTRACT

Objectives Physical exertion is a high-risk activity for aerosol emission of respiratory pathogens. We aimed to determine the safety and tolerability of healthy young adults wearing different types of face mask during moderate-to-high intensity exercise.

Design Cross-over randomised controlled study, completed between June 2021 and January 2022.

Participants Volunteers aged 18–35 years, who exercised regularly and had no significant pre-existing health conditions.

Interventions Comparison of wearing a surgical, cloth and filtering face piece (FFP3) mask to no mask during 4×15 min bouts of exercise. Exercise was running outdoors or indoor rowing at moderate-to-high intensity, with consistency of distance travelled between bouts confirmed using a smartphone application (Strava). Each participant completed each bout in random order.

Outcomes The primary outcome was change in oxygen saturations. Secondary outcomes were change in heart rate, perceived impact of face mask wearing during exercise and willingness to wear a face mask for future exercise.

Results All 72 volunteers (mean age 23.9) completed the study. Changes in oxygen saturations did not exceed the prespecified non-inferiority margin (2% difference) with any mask type compared with no mask. At the end of exercise, the estimated average difference in oxygen saturations for cloth mask was –0.07% (95% CI –0.39% to 0.25%), for surgical 0.28% (–0.04% to 0.60%) and for FFP3 –0.21% (–0.53% to 0.11%). The corresponding estimated average difference in heart rate for cloth mask was –1.20 bpm (95% CI –4.56 to 2.15), for surgical 0.36 bpm (95% CI –3.01 to 3.73) and for FFP3 0.52 bpm (95% CI –2.85 to 3.89). Wearing a face mask caused additional symptoms such as breathlessness (n=13, 18%) and dizziness (n=7, 10%). 33 participants broadly supported face mask wearing during exercise, particularly indoors, but 22 were opposed.

Conclusion This study adds to previous findings (mostly from non-randomised studies) that exercising at moderate-to-high intensity wearing a face mask appears to be safe in healthy, young adults.

Trial registration number NCT04932226

INTRODUCTION

SARS-CoV-2 is an airborne virus that causes COVID-19. Transmission of SARS-CoV-2 is thought to vary based on multiple factors, including host viral load, indoor versus

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ This is the largest study to date assessing the safety and tolerability of exercising wearing a face mask.
- ⇒ The randomised cross-over design ensured that the effect of any fatigue from exercise was equal between mask types.
- ⇒ Some participants exercised outdoors and during cold weather when pulse oximeters were sometimes slow to provide readings, and this may have resulted in a recovery in oxygen levels and an underestimate of effect size.
- ⇒ We collected a limited amount of non-invasive physiological data and did not collect data on measures such as end-tidal carbon dioxide or muscle oxygenation.
- ⇒ We only included healthy young adults who exercised regularly in this study to minimise the risk of serious adverse events, but this may limit the generalisability of our findings to the wider population.

outdoor settings, ambient air flow, volume of speech and physical proximity.¹ A number of these risk factors are relevant to exercise, with previous outbreak clusters reported in boxing or fitness gyms, where people are likely to be talking loudly or breathing heavily in a confined, indoor space.^{2,3} Public health measures such as physical distancing can help reduce transmission risk,⁴ but heavy breathing or panting during exercise may still increase the risk of transmitting the SARS-CoV-2 virus, even when people are exercising outdoors.¹

Face masks can reduce transmission of SARS-CoV-2 (box 1). In a recent systematic review and meta-analysis, mask wearing was associated with a decrease in the incidence of COVID-19 (relative risk 0.47, 95% CI 0.29 to 0.75, I²=84%).⁵ However, there has been a lack of clear guidance on wearing face masks during exercise and a number of recent commentary pieces have suggested that face masks may interfere with an individual's exercise capacity.⁶ Exercise leads to physiological changes, such as an increase in heart and

**Box 1 Properties of different kinds of face covering**

A filtering face piece respirator (FFP) is personal protective equipment made to an industry standard and designed for occupational health use (eg, healthcare workers treating high-risk infectious patients). FFP3 (equivalent to the US standard N99) filters 99% of airborne particles of the relevant size.

A surgical mask is made of folded paper with waterproof backing. It is designed primarily to block egress (outward emission) of droplets such as saliva or sneezes. Surgical masks are not made to industry standards, nor are they designed to filter airborne particles. Poor fit is a commonly described problem with surgical masks, allowing air to escape through gaps.

The cloth face covering used in this study was a double-layer neck gaiter supplied by Buff. Cloth face coverings come in many materials and thicknesses; most have not been manufactured to any filtration standard.²³ They are thought to provide partial protection of others by reducing egress of particles and droplets.²⁴

The efficacy of masks depends heavily on fit and compliance.^{16 25}

Despite their limited efficacy, both surgical masks and cloth face coverings may contribute significantly to reducing SARS-CoV-2 transmission if a high proportion of the population wears them in high-risk settings (eg, indoors, crowded and at times of high prevalence of COVID-19).^{26 27}

In one laboratory study, a respirator reduced filtration of an artificial respiratory aerosol by 99%; a medical grade ('surgical') mask by 59% and a double neck gaiter by 60%.²⁸ A modelling study calculated that if two people are both wearing respirators, the risk of infection is reduced to 0.14% of the risk if neither are masked.¹⁶

breathing rates, to deliver more oxygen to the body. A face mask may theoretically interfere with gas exchange, potentially leading to an accumulation of carbon dioxide (CO₂) and lactate, with a reduction in oxygen saturation (SaO₂). This may depend in part on the type of mask worn.^{7 8} Cloth masks tend to capture moisture in exhaled breath to a greater extent than surgical or filtering face piece (FFP) respirator masks, which may particularly interfere with oxygen transfer.⁹

There have been a number of recent studies assessing the impact of wearing an FFP or surgical mask during exercise, but most of these included very small numbers of participants.^{10 11} As health and fitness facilities and physical therapy rehabilitation units reopen, it is important to determine to what extent wearing a face mask in these settings is feasible, in addition to other public health measures. We aimed to determine the safety and tolerability of healthy young adults wearing different types of face mask during moderate-to-high intensity exercise.

METHODS**Study design**

We conducted a randomised cross-over study, where all participants completed 4×15 min bouts of moderate-to-high intensity exercise wearing three different types of face mask (cloth, surgical or FFP3) and no face mask in a random order, with a 5 min rest period between each bout of exercise. The study team used an online simple random sequence generator to allocate mask order for

each participant, without blinding. Participants could state a preference for their choice of exercise, between either running, cycling or rowing.

Participants

People in the community were eligible for the study if they were aged between 18 and 35 years, exercised at least three times a week and were willing and able to give informed consent. We excluded anyone with a significant acute or longstanding medical illness that limited their exercise capacity. Volunteer participants were recruited through student groups at the University of Oxford, Nottingham University and King's College London.

Sample size

When planning the study, there was only limited existing research of changes in SaO₂ during exercise. A 2018 study assessed the effect of aerobic exercise on arterial blood SaO₂ among 36 healthy male volunteers. Mean pre-exercise SaO₂ was 97.3% (SD 1.3, range 95.0%–99.0%), compared with mean postexercise SaO₂ 96.2% (2.2, 92.0%–98.0%).¹² We made a conservative estimate that exercise with a face mask might produce a 1.5% margin of difference in peripheral SaO₂. Based on an SD of 2.6 and power of 80%, we calculated a minimum sample size of 55 people was needed, but aimed to recruit over 60 to allow for some participants dropping out and a 10% margin of error.

Outcomes

The primary outcome was change in SaO₂ between different mask types. Secondary outcomes were change in heart rate during exercise, perceived impact of mask wearing during exercise and willingness to wear a mask for exercise in the future.

Data collection

SaO₂ and heart rate were measured using a finger pulse oximeter immediately prior to first commencing exercise, halfway through, on completion and 1 min after completion for each bout of exercise. Participants paused their exercise at the midway point of exercise to collect these data. Participants continued to wear their face mask for 1 min after completing the exercise, when the final recording for that bout of exercise was collected. Participants were asked to exercise at a consistent intensity between bouts of exercise. To confirm this was achieved, we measured the average speed and distance travelled during each bout of exercise using a Smartphone app (Strava) and assessed these data for significant differences across face mask type.

During each 5 min rest period, the participants stood and completed a study questionnaire. This asked them to rate the comfort, ease of exercise and ease of breathing during exercise with the face mask they had just worn on a 10-point Likert scale. At the end of the study session, we also asked participants to identify the face mask that they found most difficult to exercise wearing, record any symptoms that they felt during exercise that were different to

usual and free text comments regarding their willingness to exercise wearing a mask in the future (see online supplemental appendix 1).

Statistical analysis

We calculated the difference in SaO₂ and heart rate (bpm) between exercising with each of the three different face masks compared with no mask in each participant. We used differences rather than raw outcomes as these are more likely to be normally distributed. Dependency within subjects was accounted for by including a subject specific effect in a two-way analysis of variance. Average differences and 95% CIs for the three comparisons (cloth vs none, surgical mask vs none and FFP3 vs none) were calculated using estimated marginal means, averaging over subject. Based on prior literature, we prespecified a non-inferiority margin of a 2% reduction in SaO₂ and 7 bpm increase in heart rate. Non-inferiority was considered demonstrated if the lower bound of the 95% CI did not overlap the 2% margin for SaO₂ and if the upper bound of the 95% CI did not overlap 7 bpm for heart rate. We conducted a subgroup analysis to check for significant changes in SaO₂ or heart rate among participants with a low baseline SaO₂, defined as ≤98%. Comparisons of average distance travelled and ease of breathing while wearing different types of face mask compared with no mask were analysed using a Bradley-Terry Model for Paired Preferences.¹³ All analyses were done in R V.4.1.1 (2021-08-10).

Qualitative analysis

Free-text comments were grouped into categories using a predefined framework, based around positive, negative or neutral comments for each type of mask. Using a comment-by-comment coding approach in Excel, we then undertook thematic analysis to identify and group

common threads within these categories, seeking emergent as well as anticipated themes.^{14 15}

Patient and public involvement

No patients involved.

RESULTS

In total, 72 participants completed the study between June 2021 and January 2022, including 33 women (46%) and 39 men (54%). The mean age was 23.9 years (SD 3.55). Most participants exercised 3–4 (n=38, 54%) or 5–6 times per week (n=30, 42%), but 3 participants (4%) exercised every day. One participant was a smoker.

All 72 participants completed all four exercise sessions. One participant completed the exercise on an indoor rowing machine and 71 undertook running outdoors, largely due to restrictions on indoor gatherings and physical distancing that were in place because of the COVID-19 pandemic.

In a small number of participants at each time point, it was not possible to obtain either a SaO₂ or heart rate reading on the pulse oximeter and the numbers reported in tables 1 and 2 and the supplemental tables reflect this. We recruited beyond our minimum sample size to ensure the study retained sufficient statistical power for our primary analysis.

SaO₂ during exercise

Changes in SaO₂ did not exceed the non-inferiority margin at any point of exercise wearing any of the three masks (table 1). There was a small but statistically significant decrease in SaO₂ during exercise wearing either a cloth mask (estimated average difference (EAD) -0.78%, 95% CI -1.12% to -0.44%) or the FFP3 compared with no mask (-0.82%, 95% CI -1.16% to -0.47%), but not

Table 1 Changes in oxygen saturations (SaO₂) comparing different types of face mask worn during exercise

Comparison	Average oxygen saturation (%), with mask	Average oxygen saturation (%), no mask	Estimated average difference (%), 95% CI)	Non-inferior at 2% difference in SaO ₂
During exercise (N=69)				
Cloth—none	96.9	97.7	-0.78 (-1.12 to -0.44)	True
Surgical—none	97.4	97.7	-0.28 (-0.63 to 0.07)	True
FFP3—none	96.9	97.7	-0.82 (-1.16 to -0.47)	True
End of exercise (N=68)				
Cloth—none	97.0	97.1	-0.07 (-0.39 to 0.25)	True
Surgical—none	97.4	97.1	0.28 (-0.04 to 0.60)	True
FFP3—none	96.9	97.1	-0.21 (-0.53 to 0.11)	True
1 min after the end of exercise (N=67)				
Cloth—none	97.7	97.7	0.04 (-0.25 to 0.32)	True
Surgical—none	98.1	97.7	0.33 (0.05 to 0.61)	True
FFP3—none	97.9	97.7	0.15 (-0.13 to 0.43)	True
FFP, filtering face piece.				

**Table 2** Changes in heart rate comparing different types of face mask worn during exercise

Comparison	Average heart rate (bpm), with mask	Average heart rate (bpm), no mask	Estimated average difference (bpm, 95% CI)	Non-inferior @ +7 bpm
During exercise (N=69)				
Cloth—none	157.5	157.3	0.10 (−2.90 to 3.10)	True
Surgical—none	157.8	157.3	0.78 (−2.33 to 3.89)	True
FFP3—none	159.9	157.3	2.84 (−0.24 to 5.91)	True
End of exercise (N=69)				
Cloth—none	156.9	158.2	−1.20 (−4.56 to 2.15)	True
Surgical—none	158.7	158.2	0.36 (−3.01 to 3.73)	True
FFP3—none	158.9	158.2	0.52 (−2.85 to 3.89)	True
1 min after the end of exercise (N=67)				
Cloth—none	124.8	124.2	0.40 (−2.15 to 2.95)	True
Surgical—none	124.6	124.2	0.49 (−2.03 to 3.02)	True
FFP3—none	125.3	124.2	1.45 (−1.11 to 4.01)	True

FFP, filtering face piece.

when wearing the surgical mask (−0.28%, 95% CI −0.63% to 0.07%). There was no difference in SaO₂ comparing any mask type to no mask immediately after completing exercise. Surgical mask wearing was associated with a small increase in SaO₂ at 1 min post exercise (0.33%, 95% CI 0.05% to 0.61%).

In a subgroup analysis among those with lower baseline SaO₂, changes in SaO₂ still did not exceed the non-inferiority margin of 2% although SaO₂ during exercise was 1% lower among people wearing either the FFP3 (EAD −0.88, 95% CI −1.47 to −0.29) or cloth mask (−0.90, 95% CI −1.48 to −0.32) (online supplemental table 1a). Even those with SaO₂>98% at baseline had a small but statistically significant decrease in SaO₂ during exercise when wearing either the cloth or FFP3 mask (online supplemental table 1b).

Changes in heart rate, performance or additional symptoms during exercise

There was no difference in heart rate at any time point comparing the three types of mask to no mask (table 2) and changes in heart rate did not exceed the non-inferiority margin.

Among the subgroups with SaO₂≤98% or SaO₂>98% at baseline, there was no significant difference in average heart rate during or after exercise with any face mask (online supplemental tables 2a and b). However, for the subgroup with SaO₂≤98% the upper 95% CI did exceed the non-inferiority margin of 7bpm for the FFP3 mask compared with no mask at each time point measured, although the sample size for this analysis was small. This was also true for the surgical mask at the end of exercise and after a 1 min rest period (online supplemental table 2a). For the subgroup with SaO₂>98% the upper 95% CI exceeded the non-inferiority margin for the FFP3 and surgical masks compared with no mask during exercise only (online supplemental table 2b).

A post hoc sensitivity analysis excluding the one person who rowed rather than ran did not significantly alter the results for change in SaO₂ or heart rate (online supplemental table 3a and b).

Across participants, there was no significant difference in average speed or distance travelled when comparing any of the face masks to no mask, confirming participants had been able to exercise at a fairly consistent speed between bouts of exercise (table 3).

The most common symptoms participants reported feeling wearing a face mask during exercise were increased breathlessness (n=13, 18%), dizziness (n=7, 10%), ‘other’ symptoms (n=7, 10%) and fatigue (n=6, 8%). The ‘other’ symptoms recorded as free-text comments were feeling light-headed, facial discomfort, skin irritation, a runny nose, pressure in the eyes, cramping and a stitch. Four participants found wearing a mask claustrophobic and one developed a headache. No participants reported feeling anxious or drowsy and none had to stop during exercise due to side effects.

Perception of comfort, breathing and ease of exercise

When asked which face mask they found most difficult to exercise wearing, 40 (56%) participants said the cloth mask, 27 (38%) said FFP3 and 4 (6%) said the surgical mask. Participants felt that the surgical mask was the most comfortable (figure 1) and the easiest to breathe through (figure 2). In a direct comparison, the probability of a surgical mask being ranked easier to exercise in than a cloth mask was 0.81 (95% CI 0.72 to 0.88, p=0.00) and being easier than FFP3 was 0.80 (95% CI 0.73 to 0.86, p=0.00) (table 4). Surgical masks were also ranked easier to breathe through than the cloth mask (probability 0.86, 95% CI 0.78 to 0.91) or FFP3 (0.83, 95% CI 0.76 to 0.88). The FFP3 and

Table 3 Comparison of average distance travelled and speed while wearing different types of face mask compared with no mask

Comparison	Average distance travelled (kilometres) with mask	Average distance travelled (kilometres), no mask	Estimated average difference in distance (km, 95% CI)	Average speed (km/hour) with mask	Average speed (km/hour), no mask	Estimated average difference in speed (km/hour, 95% CI)
Distance travelled (km) during exercise (N=71)						
Cloth mask—no face mask	2.75	2.82	-0.07 (-0.15 to 0.01)	11.06	11.37	-0.31 (-0.64 to 0.02)
Surgical mask—no face mask	2.78	2.82	-0.04 (-0.12 to 0.04)	11.27	11.37	-0.10 (-0.43 to 0.22)
FFP3—no face mask	2.76	2.82	-0.06 (-0.14 to 0.02)	11.12	11.37	-0.24 (-0.57 to 0.08)

FFP, filtering face piece.

cloth mask were ranked equal for ease of exercise and breathing through.

In free-text comments (online supplemental table 4), participants commented on the cloth mask becoming ‘soaked through with sweat and water vapour’. A number commented on how the cloth mask ‘sucks in when breathing in’ or ‘kept getting in my mouth’, while others found it ‘kept slipping down’. One participant described running in the cloth mask as ‘like being waterboarded’. There were 35 negative free text comments about the cloth mask and one positive comment.

There were 15 negative free-text comments about the FFP3 mask, which some participants found

‘constraining’, ‘so tight fitting it felt difficult to breathe’ and caused ‘nose pain’. Some people found this made them feel ‘a bit dizzy’, ‘really lightheaded’ or ‘as though my heart was going really high when I was wearing it’. However, there were also 10 positive comments about wearing the FFP3, with these participants reporting ‘a good fit’, which ‘was very comfortable’, ‘amenable to glasses-wearing’ and which ‘did not shake at all while running, unlike the others’.

There were 11 positive comments about wearing the surgical mask, mostly reporting it was ‘fine’, the ‘easiest one’ or caused ‘little restriction’. The four negative comments about the surgical mask focused on glasses steaming up or the mask slipping.

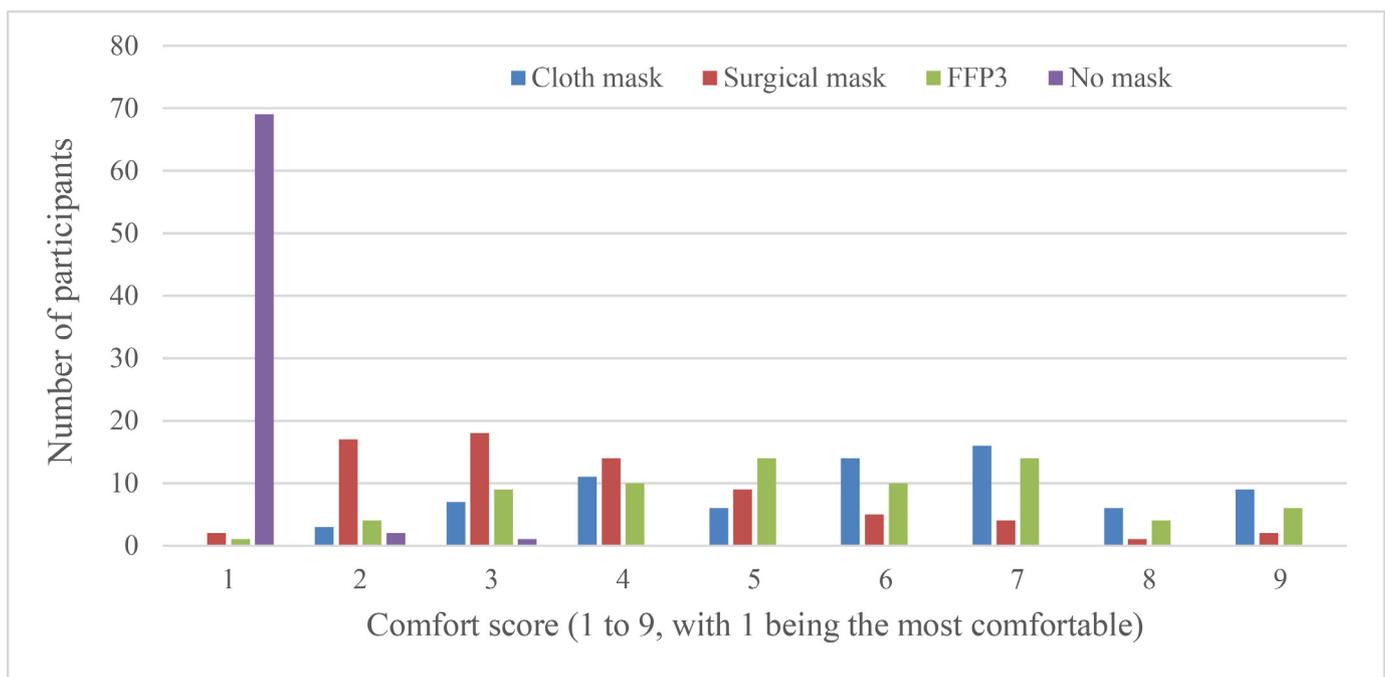


Figure 1 Reported comfort of wearing different types of face mask during exercise. The graph plots the number of participants who reported each comfort score, between 1 and 9, for each of the three different types of face mask or no mask. FFP, filtering face piece.

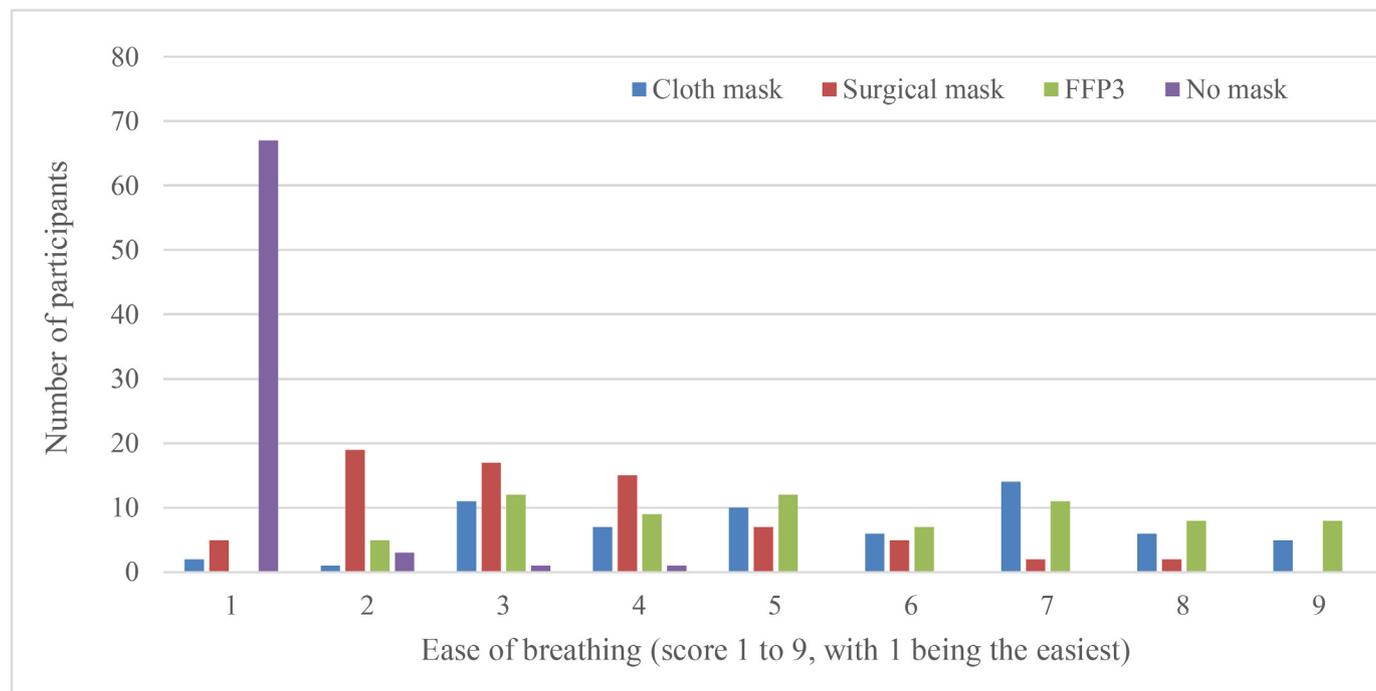


Figure 2 Reported ease of breathing wearing different types of face mask during exercise. The graph plots the number of participants who reported each ease of breathing score, between 1 and 9, for each of the three different types of face mask or no mask. FFP, filtering face piece.

Willingness to wear a face mask for exercise in the future

There were 33 participants who were accepting of the idea of mandatory face masks, 22 who were opposed and 17 who gave more neutral responses (online supplemental table 5). Positive replies included 'It would make no real impact to my exercise having to wear a face mask', 'Wouldn't bother me too much' and 'To be honest, if wearing a face mask during exercise will limit the spread of COVID-19 then I am happy to do so'. A number of participants mentioned they 'wouldn't mind doing so indoors', or 'only if it was the surgical mask'. In the neutral group there were comments such as 'I would tolerate it but not advocate it' and 'I would if I had to'.

Among those opposed people mentioned 'I would be annoyed, because I don't think that it's really needed for preventing transmission, especially outdoors' and that they 'would rather have a choice in the matter'. Some people compared favourably the experience of exercising with no mask compared with wearing any mask, with one saying 'When I ran with no mask at the end it felt like breathing in HD' (meaning high definition).

DISCUSSION

We found no clinically significant reduction in SaO₂ or heart rate with any of the three face masks, suggesting

Table 4 Comparison of reported comfort, ease of breathing and ease of overall exercise between the different types of face mask worn during exercise

Type 1	Type 2	Number rating type 1 lower	Number rating type 2 lower	Probability type 1 rated lower (95% CI)	P value
Ease of exercise, lower score=easier					
Surgical*	FFP3	51	12	0.80 (0.73 to 0.86)	0.00
Surgical	Cloth	50	12	0.81 (0.72 to 0.88)	0.00
Cloth	FFP3†	29	31	0.49 (0.38 to 0.60)	0.84
Ease of breathing, lower score=easier					
Surgical*	FFP3	55	11	0.83 (0.76 to 0.88)	0.00
Surgical	Cloth	59	10	0.86 (0.78 to 0.91)	0.00
Cloth	FFP3†	28	36	0.44 (0.34 to 0.55)	0.30

*Surgical is ranked first.

†FFP3 and cloth are equal second.

FFP, filtering face piece.

that exercising at moderate-to-high intensity wearing a face mask appears to be safe in healthy, young adults. However, around one in three participants reported additional symptoms when wearing a face mask, including feeling more breathless, dizzy or fatigued. Surgical face masks were experienced as the most comfortable, easiest to breathe through and had the least impact on exercise, though importantly we did not measure whether these masks were well-fitting and poor fit of surgical masks is common and greatly reduces protection.¹⁶ There was most support for wearing a surgical face mask during indoor exercise if needed to reduce the spread of COVID-19, though around a third of participants were opposed to mandatory wearing of face masks during exercise.

Strengths and limitations

To our knowledge, this is the largest study to date to investigate the safety and tolerability of wearing a face mask during exercise. We used a randomised cross-over design to ensure that the effect of any fatigue from exercise was equal between mask types. We asked participants to exercise at a consistent speed between study sessions and recorded their average speed and distance travelled, with no significant difference in exercise performance based on type of face mask worn.

We chose to recruit only healthy young participants to reduce the risk of serious adverse events, because of the limited pre-existing data demonstrating wearing a face mask during exercise was safe. However, our results may not be generalisable to people who have underlying health conditions or restricted exercise capacity and further research is needed in these populations.

We collected a limited amount of non-invasive physiological data from participants. Healthy young participants may maintain a constant SaO₂ and heart rate through compensatory mechanisms, such as increased respiratory rate, that we have not captured in our analysis. However, all of our participants were able to complete the exercise wearing each mask type with no significant change in their speed or distance travelled, supporting the finding that healthy young people can safely exercise wearing face masks.

Because of the COVID-19 pandemic and restrictions in social interaction, we conducted almost all of the study sessions outdoors. Study sessions took place across a range of seasons. During cold weather some participants had cold peripheries while exercising, meaning the pulse oximeters were not always able to record SaO₂ and heart rate or were slow to do so. Delays in obtaining accurate oximeter readings postexercise may have led to some recovery in heart rate and SaO₂ that would result in an underestimate of any change in these parameters. For these reasons, we also asked participants to fit their own face masks and we did not perform fitting tests. While this may have led to some discrepancy in mask fit between participants, it does reflect how face masks would be worn in practice. We had originally proposed to use FFP2 masks in our study protocol but there were supply issues

that impacted us ordering these and we changed to use FFP3 masks instead.

Comparison with other studies

Our results support the findings of a recent systematic review and meta-analysis, which assessed the impact of wearing a face mask during exercise.¹⁷ This reported no significant difference in exercise performance among studies of surgical face masks (standard mean difference (SMD) -0.05 , 95% CI -0.16 to 0.07) or N95 masks (-0.16 , 95% CI -0.54 to 0.22).¹⁷ Patients did have increased ratings of perceived exertion (0.33 , 95% CI 0.09 to 0.58) and dyspnoea (0.60 , 95% CI 0.30 to 0.90) with all masks.¹⁷ In contrast to this review, we include cloth masks in the comparison of face masks types. The exercise tested in these studies was heterogeneous, ranging from 1-hour treadmill walks at low intensity, to strength training with half-squats and progressive exercise training on a bicycle. Our results demonstrate the principal findings of this review are applicable to healthy young adults during moderate-to-high intensity exercise.

A second recent systematic review of face mask wearing during rest, work or exercise identified 14 cross-over trials with 25 independent intervention arms.¹⁸ There were a total of 246 participants across these studies. High intensity exercise was associated with a small reduction in SaO₂ (SMD -0.40 , 95% CI -0.70 to -0.09) and lower respiratory rates (-0.25 , 95% CI -0.44 to -0.06), particularly when wearing an FFP2 or N95 face mask.¹⁸ However, there was no association with mask wearing and change in exercise performance, heart rate or exhaled CO₂. This review suggests that undertaking exhausting exercise wearing FFP-type face masks may reduce SaO₂ but supports our finding that mask wearing appears to be safe and does not negatively affect overall performance.

Implications for policy and research

Governments globally are having to decide which public health measures to continue in response to changing incidence of COVID-19. Interventions that can contribute towards reducing transmission, while allowing people to return to normal life, are particularly important. Face masks can reduce transmission of the SARS-CoV-2 virus and appear to be safe to wear among young, healthy adults during exercise. Public health messaging could support their use in higher risk settings, such as indoor settings with poor ventilation or outdoor exercise among large volumes of people. Surgical masks appear to be the least restrictive type of mask to wear and may help reduce transmission by preventing the forward propulsion of a large jet of exhaled aerosol particles. Cloth masks and the FFP3 were ranked similarly by participants in our study in terms of ease of exercise and breathing through. This suggests that policy makers could consider recommending either surgical masks or the more secure FFP3, as opposed to cloth masks, should face masks be required during exercise. However, the comparative effectiveness of different mask types in reducing the risk



of transmission of SARS-CoV-2 does remains uncertain and could be a focus for future research. Future research could also examine the safety and tolerability of wearing a face mask during exercise among people with underlying health conditions, as results may differ from our healthy population. For example, a previous study of 97 people with chronic obstructive pulmonary disease performing a 6 min walking test wearing an N95 mask reported that those with more significant disease were more likely to experience dyspnoea or breathing discomfort.¹⁹

Wearing a face mask during exercise does not negatively impact exercise performance. It is possible there may even be benefits for longer-term endurance exercise performance if face mask wearing did induce mild hypoxia. Hypoxic exercise training has previously been reported to improve cardiac haemodynamics and exercise capacity,^{20 21} though these studies typically recruited only small numbers of participants and have not been consistently replicated.²² Further research into the long-term impact on exercise performance of wearing a face mask during exercise could help better inform athletes of the relative risks and benefits of this intervention.

CONCLUSION

In this randomised cross-over trial, we found that healthy young adults were able to exercise at moderate-to-high intensity wearing either a surgical, cloth or FFP face mask without significant restriction on exercise performance or physiological limitation. However, wearing a face mask during exercise made some participants feel more breathless, dizzy or fatigued and most people felt it was less comfortable and enjoyable than exercising without a mask. There was limited support for wearing a face mask to exercise across all settings, but these results could support the use of face mask wearing while exercising in a limited number of high-risk settings as a safe intervention to reduce the risk of SARS-CoV-2 transmission.

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Supplemental Table 1a. Changes in oxygen saturations comparing different mask types worn during exercise. Sub-group analysis of participants with resting oxygen saturations of $\leq 98\%$

Comparison	Average oxygen saturations (%) with mask	Average oxygen saturations (%), no mask	Estimated average difference (% 95% confidence interval)	Non-inferior @ -2%
<i>During exercise (N = 30)</i>				
Cloth - None	96.5	97.4	-0.90 (-1.48 to -0.32)	TRUE
Surgical - None	97.3	97.4	-0.12 (-0.72 to 0.49)	TRUE
FFP3 - None	96.5	97.4	-0.88 (-1.47 to -0.29)	TRUE
<i>End of exercise (N = 29)</i>				
Cloth - None	96.9	97.0	-0.07 (-0.57 to 0.43)	TRUE
Surgical - None	97.0	97.0	-0.03 (-0.55 to 0.49)	TRUE
FFP3 - None	97.0	97.0	0.00 (-0.52 to 0.52)	TRUE
<i>1 minute after the end of exercise (N = 30)</i>				
Cloth - None	97.6	97.7	-0.11 (-0.61 to 0.39)	TRUE
Surgical - None	97.9	97.7	0.18 (-0.32 to 0.67)	TRUE
FFP3 - None	97.6	97.7	-0.08 (-0.57 to 0.42)	TRUE

Supplemental Table 1b. Changes in oxygen saturations comparing different mask types worn during exercise. Sub-group analysis of participants with resting oxygen saturations of > 98%

Comparison	Average oxygen saturations (%) with mask	Average oxygen saturations (%), no mask	Estimated average difference (% 95% confidence interval)	Non-inferior @ -2%
<i>During exercise (N = 39)</i>				
Cloth - None	97.3	97.9	-0.69 (-1.11 to -0.27)	TRUE
Surgical - None	97.5	97.9	-0.40 (-0.83 to 0.03)	TRUE
FFP3 - None	97.2	97.9	-0.77 (-1.19 to -0.35)	TRUE
<i>End of exercise (N = 39)</i>				
Cloth - None	97.2	97.2	-0.07 (-0.48 to 0.35)	TRUE
Surgical - None	97.7	97.2	0.51 (0.11 to 0.92)	TRUE
FFP3 - None	96.9	97.2	-0.36 (-0.76 to 0.05)	TRUE
<i>1 minute after the end of exercise (N = 37)</i>				
Cloth - None	97.8	97.7	0.16 (-0.18 to 0.49)	TRUE
Surgical - None	98.2	97.7	0.46 (0.13 to 0.79)	TRUE
FFP3 - None	98.1	97.7	0.32 (-0.01 to 0.66)	TRUE

Supplemental Table 2a. Changes in heart rate comparing different mask types worn during exercise. Sub-group analysis of participants with resting oxygen saturations of $\leq 98\%$

Contrast	Average heart rate (%) with mask (beats per minute)	Average heart rate (%), no mask (beats per minute)	Estimated average difference (bpm, 95% confidence interval)	Non-inferior @ +7bpm
<i>During exercise (N = 29)</i>				
Cloth - None	156.4	158.0	-1.69 (-6.55 to 3.17)	TRUE
Surgical - None	155.9	158.0	-1.41 (-6.57 to 3.75)	TRUE
FFP3 - None	159.5	158.0	2.21 (-2.95 to 7.37)	FALSE
<i>End of exercise (N = 29)</i>				
Cloth - None	151.5	155.9	-4.17 (-10.89 to 2.54)	TRUE
Surgical - None	156.5	155.9	0.36 (-6.59 to 7.31)	FALSE
FFP3 - None	158.4	155.9	2.04 (-4.91 to 8.99)	FALSE
<i>1 minute after the end of exercise (N = 29)</i>				
Cloth - None	123.5	123.2	0.15 (-4.47 to 4.77)	TRUE
Surgical - None	125.4	123.2	2.74 (-1.88 to 7.36)	FALSE
FFP3 - None	125.7	123.2	2.82 (-1.96 to 7.60)	FALSE

Supplemental Table 2b. Changes in heart rate comparing different mask types worn during exercise. Sub-group analysis of participants with resting oxygen saturations of > 98%

Contrast	Average heart rate (%) with mask (beats per minute)	Average heart rate (%), no mask (beats per minute)	Estimated average difference (bpm, 95% confidence interval)	Non-inferior @ +7bpm
<i>During exercise (N = 39)</i>				
Cloth - None	158.4	156.8	1.59 (-2.22 to 5.40)	TRUE
Surgical - None	160.1	156.8	3.39 (-0.49 to 7.27)	FALSE
FFP3 - None	161.6	156.8	4.74 (0.93 to 8.55)	FALSE
<i>End of exercise (N = 39)</i>				
Cloth - None	162.2	159.9	2.11 (-1.03 to 5.26)	TRUE
Surgical - None	160.5	159.9	0.54 (-2.54 to 3.62)	TRUE
FFP3 - None	159.8	159.9	-0.18 (-3.26 to 2.90)	TRUE
<i>1 minute after the end of exercise (N = 37)</i>				
Cloth - None	126.2	125.3	0.71 (-2.31 to 3.73)	TRUE
Surgical - None	124.5	125.3	-0.97 (-3.93 to 1.99)	TRUE
FFP3 - None	125.7	125.3	0.73 (-2.23 to 3.69)	TRUE

Supplemental Table 3a. Changes in oxygen saturations comparing different mask types worn during exercise. Sensitivity analysis excluding the one participant who completed the exercise rowing instead of running

Comparison	Average oxygen saturations (%) with mask	Average oxygen saturations (%), no mask	Estimated average difference (%), 95% confidence interval)	Non-inferior @ -2%
<i>During exercise (N = 68)</i>				
Cloth - None	97.0	97.7	-0.75 (-1.09 to -0.41)	TRUE
Surgical - None	97.5	97.7	-0.27 (-0.63 to 0.08)	TRUE
FFP3 - None	96.9	97.7	-0.81 (-1.16 to -0.47)	TRUE
<i>End of exercise (N = 67)</i>				
Cloth - None	97.1	97.1	-0.05 (-0.38 to 0.27)	TRUE
Surgical - None	97.4	97.1	0.30 (-0.02 to 0.63)	TRUE
FFP3 - None	96.9	97.1	-0.21 (-0.54 to 0.11)	TRUE
<i>1 minute after the end of exercise (N = 66)</i>				
Cloth - None	97.7	97.7	0.05 (-0.24 to 0.34)	TRUE
Surgical - None	98.1	97.7	0.35 (0.07 to 0.64)	TRUE
FFP3 - None	97.9	97.7	0.16 (-0.12 to 0.45)	TRUE

Supplemental Table 3b. Changes in heart rate comparing different mask types worn during exercise. Sensitivity analysis excluding the one participant who completed the exercise rowing instead of running

Contrast	Average heart rate (%) with mask (beats per minute)	Average heart rate (%), no mask (beats per minute)	Estimated average difference (bpm, 95% confidence interval)	Non-inferior @ +7bpm
<i>During exercise (N = 68)</i>				
Cloth - None	157.6	157.4	0.09 (-2.95 to 3.13)	TRUE
Surgical - None	157.8	157.4	0.67 (-2.49 to 3.83)	FALSE
FFP3 - None	160.0	157.4	2.85 (-0.27 to 5.97)	FALSE
<i>End of exercise (N = 68)</i>				
Cloth - None	157.0	158.6	-1.58 (-4.98 to 1.83)	TRUE
Surgical - None	158.8	158.6	0.07 (-3.35 to 3.49)	TRUE
FFP3 - None	159.1	158.6	0.22 (-3.20 to 3.64)	TRUE
<i>1 minute after the end of exercise (N = 66)</i>				
Cloth - None	124.9	124.3	0.50 (-2.07 to 3.07)	TRUE
Surgical - None	124.7	124.3	0.55 (-1.99 to 3.09)	TRUE
FFP3 - None	125.7	124.3	1.81 (-0.77 to 4.39)	TRUE

Supplemental table 4. Participants free text comments regarding the ease of exercising wearing different mask types. These have been categorised as either positive, negative or neutral comments and by facemask type.

Positive comments	Neutral comments	Negative comments
Any mask		
<p>It wasn't actually that much worse than exercising with no mask and it did keep my face warm on a very cold day.</p> <p>Didn't find that any mask slowed me down.</p>	<p>Inconvenient but bearable</p> <p>As the exercise went on it became easier to breathe with a mask on</p> <p>It is relevant whether the mask is stable</p> <p>It was slightly more uncomfortable than not wearing a mask, but not too bad.</p> <p>All were warmer than no mask</p>	<p>Considerably more difficult than normal</p> <p>With all of them I didn't actually become short of breath it was more discomfort.</p> <p>With the cloth one and the surgical one slightly the main issue was due to them being flexible the fabric would go into my mouth when breathing in.</p> <p>Masks get in the way, maybe not on the actual performance. Placebo effect</p> <p>All of the masks made my face extra sweaty</p> <p>I'd prefer not to exercise with a mask. There was a lot of humidity with the tighter fitting masks and it makes you much more aware of your breathing.</p> <p>The buff and surgical masks were similar - not too bad but a lot worse than no mask. It was harder across the 15 minutes with condensation from the mask. You feel you overheat and there is steaming up of your glasses</p> <p>The humidity was unpleasant rather than being difficult to breathe. I found it harder to breathe through my mouth wearing any of the masks.</p> <p>It wasn't that much more difficult wearing a mask but the sweatiness was unpleasant</p> <p>Surprised to cover roughly the same distance each time even when it more difficult in some of the masks than others - the cloth and FFR.</p> <p>the FFP and cloth mask were much worse</p>
Cloth		
<p>Cloth was good for me as I wear glasses and allowed me to breathe through my nose and mouth more easily</p>		<p>Cloth mask was surprisingly uncomfortable - about as bad as wearing the FFP2 mask. Noticed that the cloth mask quickly became soaked through with sweat and water vapour which made it very difficult to breathe through the nose.</p>

The cloth mask was particularly uncomfortable as it clung to my face and was very distracting every time you breathe. This was a particular problem as I was breathing through my mouth during the exercises

None were great. The cloth had the added disadvantage of making the rest of your face hot

Cloth mask gets very moist and gets inhaled and falls a lot. Breathing pattern altered with masks - not breathing in, out, in, out but more in, in, out, in, in, out...

Cloth mask felt quite claustrophobic

Cloth mask tight and hot around face

Cloth mask got wet

Cloth mask is distracting (slips a lot).

It was hard to breathe through my mouth with the cloth mask

Wearing cloth mask was hardest because the cloth became humid and block air from entering and exiting mouth.

Cloth mask is the worst to wear when I do exercise

Cloth mask so very hard to breathe in

The cloth mask was annoying because it kept slipping down.

Cloth face mask kept falling down

Cloth mask kept going in my mouth

Running with the mask fogged up my glass, which was annoying. This was worst with the cloth mask

The buff cloth masked pressed down on my nose, which meant I had to breathe through my nose (not a good thing).

Dont make people wear a cloth mask, it sucks in when breathing and it's difficult to breathe.

The cloth mask kept falling and was terrible.

The buff mask was worse as it would suck into your mouth.

I was surprised that I found the cloth mask harder

Cloth was uncomfortable due to the stickiness

Cloth mask felt very close and humid.

Cloth mask was the worst, got very wet, like being waterboarded, sweaty, incompatible with glasses.

Cloth mask kept slipping down and being sucked in when breathing in

Didn't like cloth mask - too hot, too close to mouth, claustrophobic

Buff was generally horrible

Cloth mask didn't fit well with glasses, kept slipping.

Cloth mask was very sticky, stuck straight to nose and mouth, really uncomfortable, no gap to breathe.

Cloth mask kept getting in my mouth, couldn't out of nose well.

Cloth mask kept going in my mouth.

FFR better than cloth more room to breathe

The buff was claustrophobic

Cloth mask was hardest, kept sliding down, and going in to mouth when breathing.

Cloth kept sliding down and made face hot but otherwise didn't mind.

Cloth gets in mouth when breathing in, kept having to pull it up.

FFP3

I was surprised the FFR was easier than the others - it helped that it doesn't move around much

FFR was very comfortable

The FFR was a good fit

Found FFR similar to the surgical mask - both were fine

Liked the FFP - less annoying, better than expected, didn't move, didn't interfere with glasses.

FFR easiest to breathe in

Found FFR to be the same as normal FFR didn't shake at all whilst running unlike the others. Didn't really notice I was wearing the FFR mask, although got quite

Exercising in the FFR wasn't as bad as I thought it'd be

The FFR was extremely difficult to exercise with compared to the rest - I was out of breath constantly and I had to slow down or switch to walking just to catch my breath. While wearing the FFR mask, I also felt a lot of strain (pressure) in my eyes.

Got nose pain from metal on resp mask

FFR mask is constraining.

It was hard to breathe through my nose with the FFR mask.

Felt dizzy with FFR mask

The FFR was definitely the worst, it was so tight fitting it felt difficult to breathe The FFR mask was very tight fitting and it felt as though my heart rate was going very high when I was wearing it.

It felt like the FFR restricted your breathing

warm
FFR was amenable to glasses-wearing, the fixed gap made it easier to breathe, found it fine in general.

I felt close to normal in the FFP

FFR worse than surgical.
FFR wasn't as bad as I thought it'd be, although still quite bad and the worse one for me. I found the shape around the nose made it more difficult to breathe
Felt really lightheaded and struggled to breathe when wearing FFR, really uncomfortable.
felt a bit dizzy wearing FFR
FFR sweaty, made face really hot, but was FFR was easier to breathe in compared to cloth
FFR - nose trapped, couldn't breathe as easily, bad smell to mask.
FFR - tight around nose, hard to breathe at times.

Surgical

<p>The surgical mask was fine breathing I wouldn't choose to wear a mask but the surgical mask was definitely best. The surgical mask was best- I could run with that. Found FFR similar to the surgical mask - both were fine No mask and surgical felt the same Surgical mask wasn't too bad, worked better with glasses than FFR. Found surgical mask fine. Surgical mask felt same as no mask don't really notice you're wearing it, although may think differently in the summer. There was little restriction with the surgical mask Hospital was best.</p>	<p>Cloth mask was ok, surgical was slightly better. Surgical was fine but sweaty. Surgical mask was ok Hospital mask was fine, bearable.</p>	<p>Surgical mask moves around a lot and does not feel very helpful in filtering air supply. The surgical mask accumulated a lot of water vapour and steamed my glasses. Surgical mask moved around a lot on my face, uncomfortable. Didn't like surgical - steamed up glasses</p>
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Surgical mask was fine, easiest one.

Supplemental table 5. Participants written, free-text responses to the question, ‘Overall, how would you feel about being required to exercise wearing a face mask to limit the spread of COVID-19?’ These were categorised as being either supportive, against or neutral.

Supportive

If it was in the interests of public health and safety, I would have no issues wearing a mask to limit the spread of COVID-19. Of the masks worn, my strong preference would be for the FFP3 mask as it was by far the most comfortable

Would wear surgical mask if it was necessary

It would make no real impact to my exercise having to wear a face mask or not
It would be fine if it is moderate intensity exercise. If I was pushing extremely hard it may slightly limit me. If I was in a poorly ventilated gym I would feel more comfortable wearing a face mask

Fine with it
Only would wear surgical mask

I would be happy to but it’s a lot less enjoyable

Fine if indoors and high risk setting but not so keen outdoors in large open spaces.

Against

Do not feel it's worth the hassle

Not great. I would wear the surgical mask though

Negative
At least for exercise that significantly increase oxygen requirement, I would find it very challenging and would try to avoid
I think its a really bad idea to have to wear a mask while exercising as it can make you very out of breath and I would fear it could even be fatal in some circumstances.

Wouldn't exercise

Would rather have a choice in the matter
I would feel annoyed because outside its useless. It would make sense just inside

Neutral

Was unpleasant exercising with any of the face coverings on but if I had to pick one to wear it would definitely be the surgical mask.

Mixed, the best mask was the respirator one but those are expensive to get. However, as an issue of public safety I wouldn't have a problem wearing one if told it was the best thing to do.

It would depends on what type of mask I had. I would probably look into perhaps a running mask if such a thing exists. Failing that maybe a surgical one but it would certainly limit the exercise I would want to do as it is noticeably harder and less enjoyable to at least run in a mask.

Not keen but would do it

Fine but not ideal
Wouldn't mind if had to but would prefer not to
Outside, I would not like it but it would be more pleasant as the wind is blowing on the rest of your face reducing the heat. Inside I would not like it due to the heat. It would definitely put me off exercising.

Surgical face masks would be a bit inconvenient but definitely an option especially in a gym context

I would be ok to exercise with the surgical mask, but none of the other ones

I think it is important to have a mask on when running in crowded public areas, otherwise it should not be required.

Fine, just takes a while to adjust to wearing a face mask

I would and have only used a surgical mask when required to wear one

It is OK for me to wear a surgical mask (during exercise)

I agree to wear a face mask to do the exercise for safety, and the surgical mask did not interfere with my breathing

I wouldn't mind if it was the surgical mask but it would definitely make me go slower

Exercising wearing a mask would be OK if we had to

Happy to wear the surgical face mask, but not the FFR or Cloth face mask

Wouldn't mind having to wear the surgical mask
Felt it was possible to exercise in all 3, but less comfortable in FFR

Would not support it at all. 2 out of 10

I believe we don't need to wear any face mask outdoors

I would still exercise but I wouldn't be happy. I'd also be annoyed because I don't think that it's really needed for preventing transmission, especially outdoors.

I'd rather not unless I had to

I would prefer not to

I'd prefer not to. If I had to I'd wear the surgical mask.

I wouldn't be happy with this, wearing a mask to exercise is uncomfortable and sweaty. When you're wearing one to exercise outdoor people give you looks, no one wears one outdoors

Would prefer not to, if had to would wear FFR as didn't make glasses steam up

Would rather not, but would if really had to. Would choose to wear surgical. Would rather not, would choose to wear surgical mask if had to, if forced to wear the others (cloth or FFR) I would choose not to exercise

Would prefer not to, wouldn't mind wearing surgical or cloth although not

I would do what is necessary to protect others. However, with current evidence pointing towards the conclusion that isolated outdoors exercise would not effect COVID spread like eating in a pub would, I'm not inclined to wear one.

If indoors - makes sense. Outdoors - a bit silly for me

I would if I had to.

I would rather not though if it was a rule I would do it to continue to exercise.

I'd wear the surgical mask if I had to wear something.

I would if needed to inside, don't see the point of having to wear one whilst exercising outside

Would it have to, would choose the FFP

I wouldn't like to but would wear the surgical mask if we had to

I would tolerate it but not advocate it.

I'd be happy to do it in an indoor gym if required to do so.

I would be okay with it

Only if it was the surgical mask
I would be fine with that.
I would be happy to wear the surgical mask
Having done so for the study, I wouldn't mind.
Would choose to wear the surgical mask.
Wouldn't mind doing so indoors, wouldn't mind wearing surgical or FFR
Wouldn't mind doing so indoors, think it'd be unnecessary outdoors
Wouldn't bother me too much, would choose to wear surgical.
Not sure how they'd be in more intense exercise or hotter conditions. Would be fine on a run but more difficult if required to communicate in team sports e.g. football
Would wear surgical mask, possibly buff for short distances were cardio is concerned
Overall it was close to normal exercising wearing a mask. I would feel okay about doing this if it was not the cloth mask.
To be honest if wearing a face mask during exercise will limit the spread of Covid then I am happy to do so

ideal. Wouldn't wear FFR

Wouldn't want to, hated it
Wouldn't do it, would just go outside to exercise instead. Would consider hospital mask as that was the best.
I wouldn't be happy. When I ran with no mask at the end it felt like breathing in HD

Face masks and exercise (c29.9.20)

Page 1: Face masks and oxygen levels - what happens during exercise?

Introduction

Thank you for completing your exercise session, wearing the different face masks. We hope that you are now ready to upload your results. This should take around 10 minutes.

There are no right or wrong answers to any of the questions. Please be as honest as possible when answering. Your answers will be confidential and will not be shared with anyone other than the research team. We will not be collecting any identifiable information at this stage to protect your privacy.

By completing this questionnaire, you are consenting to your anonymous information being used for research on the impact of wearing a face mask whilst exercising.

Thank you again for supporting this research.

If you have any questions, please contact:

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Page 2: Basic details

1. How old are you?

2. Which gender do you identify with?

3. How many days do you usually exercise per week?

4. Do you smoke?

4.a. If you smoke, how many cigarettes a day do you smoke on average?

5. What type of exercise did you do?

6. When did you complete the exercise session?

Please enter a date and time in the format 'DD/MM/YYYY HH:MM', for example 27/03/1980 15:43.



(dd/mm/yyyy hh:mm)

COVID screening questions

7. Where did you complete the study session?

- London
- Oxford
- Nottingham

8. Please confirm you do not have any symptoms of possible COVID-19 on the day of the study session

- No symptoms
- I have a fever
- I have a cough
- I have a change in sense of smell or taste

9. To the best of your knowledge, are other members of your household free from symptoms of COVID-19?

- Yes
- No

IF YOU OR SOMEONE YOU LIVE WITH HAVE ANY SYMPTOMS OF COVID-19, YOU MUST NOT TAKE PART IN THE STUDY TODAY. PLEASE LET A MEMBER OF THE STUDY TEAM KNOW AS SOON AS POSSIBLE.

Page 3: Oxygen saturations

The following questions will require you to input the oxygen saturation levels you recorded at different time points during each of the four exercise periods. Please also add your oxygen saturations at the start of exercise / resting oxygen saturations below.

10. What are your resting oxygen saturation levels?

11. Please record your oxygen saturations during exercise at each of the following time points. You should input an answer into every box.

	Oxygen levels 7 and a half minutes into exercise	Oxygen levels at the end of exercise	Oxygen levels 1 minute after ending exercise
No face mask	Please select ▼	Please select ▼	Please select ▼
Cloth face mask	Please select ▼	Please select ▼	Please select ▼
Surgical face mask	Please select ▼	Please select ▼	Please select ▼
FFR (respirator) face mask	Please select ▼	Please select ▼	Please select ▼

Page 4: Heart rate and exercise

The following questions will require you to input your heart rate levels, which you recorded at different time points during each of the four exercise periods. Please also add your heart rate at the start of exercise / resting heart rate below.

12. What is your resting heart rate?

13. Please record your heart rate during exercise at each of the following time points. You should input an answer into every box.

	Heart rate 7 and a half minutes into exercise	Heart rate at the end of exercise	Heart rate 1 minute after ending exercise
No face mask	Please select ▼	Please select ▼	Please select ▼
Cloth face mask	Please select ▼	Please select ▼	Please select ▼
Surgical face mask	Please select ▼	Please select ▼	Please select ▼
FFR (respirator) face mask	Please select ▼	Please select ▼	Please select ▼

Page 5: Distance travelled

Please record data here regarding the distance you travelled during exercise, including average speed data if available (please provide units).

14. Distance travelled exercising wearing **no face mask**

15. Average speed exercising with **no face mask**

16. Distance travelled exercising wearing a **cloth face mask**

17. Average speed exercising wearing a **cloth face mask**

18. Distance travelled exercising wearing a **surgical face mask**

19. Average speed exercising wearing a **surgical face mask**

20. Distance travelled exercising wearing a **FFR (respirator) face mask**

21. Average speed exercising wearing a **FFR (respirator) face mask**

Page 6: Comfort of wearing a face mask

22. How comfortable was the mask (or no mask) during this exercise session? (Rate from 1 to 9, 1= extremely comfortable, 9= extremely uncomfortable)

	Comfort level
No face mask	Please select <input type="text"/>
Cloth face mask	Please select <input type="text"/>
Surgical face mask	Please select <input type="text"/>
FFR (respirator) face mask	Please select <input type="text"/>

22.a. Were you able to complete all four exercises sessions? If not please state which you did not complete and why.

23. How easy did you find it to exercise during each session? (Rate from 0 to 10; 0=rest, 1=really easy, 2=easy, 3=moderate, 4=sort of hard, 5=hard, 7= really hard, 9= really, really hard, 10= maximal) [Borg Scale]

	Ease of exercise										
	0	1	2	3	4	5	6	7	8	9	10
No face mask	<input type="checkbox"/>										
Cloth face mask	<input type="checkbox"/>										
Surgical face mask	<input type="checkbox"/>										
FFR (respirator) mask	<input type="checkbox"/>										

24. Which face mask did you find most difficult to exercise wearing?

Please don't select more than 1 answer(s) per row.

	Cloth mask	Surgical mask	FFR (respirator) mask
Please select one	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

25. How easy was it to breath during each exercise session? Please rate from 1 to 9, 1 = extremely easy, 9 = extremely difficult)

	1	2	3	4	5	6	7	8	9
No face mask	<input type="checkbox"/>								
Cloth face mask	<input type="checkbox"/>								
Surgical face mask	<input type="checkbox"/>								
FFR (respirator) face mask	<input type="checkbox"/>								

25.a. Please add any relevant comments you have on the ease of exercising wearing a face mask

26. Did you feel any other symptoms during exercise that were different to usual?

Headache

More breathless

Claustrophobia

Anxiety

Fatigued

Drowsy

Dizzy

Other

26.a. If other please specify

27. Overall, how would you feel about being required to exercise wearing a face mask to limit the spread of COVID-19?