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MINI REVIEW

The impact of face masks on children—A mini review

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Abstract

Aim: Face masks are essential during the COVID-19 pandemic, and the United Nations Children's Fund and the World Health Organization, recommend that they are used for children aged six years and older. However, parents are increasingly expressing concerns about whether these might be physically harmful. This mini review assessed the evidence.

Method: We conducted a narrative review on the effects of mask wearing on physiological variables in children, using PubMed, the Cochrane Library and the World Health Organization COVID-19 Database up to 7 November 2020. The lack of paediatric studies prompted a second search for adult studies.

Results: We only found two paediatric studies, published in 2019 and 2020. The 2020 study was not related to COVID-19. Only one study, performed with N95 respirators, collected medical parameters, and this did not suggest any harmful effects of gas exchange. The eight adult studies, including four prompted by the pandemic and one on surgeons, reported that face masks commonly used during the pandemic did not impair gas exchange during rest or mild exercise.

Conclusion: International guidelines recommend face masks for children aged six years and older, but further studies are needed to provide evidence-based recommendations for different age groups.

KEYWORDS
coronavirus, COVID-19, face masks, gas exchange, pandemic

1 | INTRODUCTION

Face masks have become a crucial part of everyday life across the globe since COVID-19 was declared a pandemic. Surgical or medical masks are recommended by international and national institutions in order to prevent the spread of the virus that causes COVID-19.[1–3] In some countries, these are supported by government regulations. There is evidence that wearing masks has produced additional benefits, including the reduction in other viral diseases, such as influenza.[4,5]

Known from physiology, oxygen supply and ventilation are controlled by feedback loops. Both an increase in arterial carbon dioxide partial pressure (hypercapnia) and a decrease in oxygen partial pressure (hypoxemia) lead to an increase in minute ventilation, regulated via respiratory rate and tidal volume. In the feedback loop, hypercapnia represents the most relevant respiratory drive, hypoxemia corresponds also with an increase in heart rate. Both hypercapnia and hypoxemia have been associated with the use of face masks and are therefore of major interest in face mask studies.[6,7]

For the COVID-19 pandemic, there is still a lack of clarity about the role of children that they play in spreading the coronavirus and this results in the question whether they need to wear masks.

Recently, increasing numbers of parents have expressed concerns to clinicians and social media about whether masks may be

harmful for their children. Fake news about the negative effects of face masks has also been rising. This has included false reports about face masks causing an increasing number of illnesses and even deaths among children.[8] These reports argue that face masks may lead to increased rebreathing and accumulation of carbon dioxide, which could be harmful or even deadly. The Italian Paediatric Society published a statement describing face masks for children as harmless, but failed to provide scientific data to back this up.[9] In addition, a group of Portuguese paediatricians supported the use of face masks for children without providing sufficient evidence.[10]

The very limited information about the use of face masks, especially for children, was also highlighted in the advice issued by the United Nations Children's Fund (UNICEF) and the World Health Organization (WHO) on 21 August 2020.[5] This followed the principle of *do no harm* and stated that children aged five years and under should not wear masks. The guidance also states that young children probably do not have the fine motor coordination to use a face mask appropriately and are unlikely to be able to show the level of compliance required. The guidance recommends a risk-based approach for children aged 6–11 years of age and children aged 12 and over should be treated as adults when it comes to wearing masks.[5]

School closures due to the COVID-19 pandemic are a massive disruption to children's physical and mental well-being [11] and may have massive long-term effects.[12] As proposed by United Nations Children's Fund, keeping schools open should be a priority in order to minimise further harm.[13] Despite the lack of appropriate evidence, school children wearing masks also during lessons may be a promising element to guarantee open schools during the COVID-19 pandemic.

The aim of this narrative review was to describe the existing knowledge about children wearing face masks. We searched PubMed, the Cochrane Library and the World Health Organization COVID-19 Database up to 7 November 2020. Because paediatric studies on this subject were very limited, the search, which was limited to papers published in English, German or French, was extended to cover adults' studies as well.

Keynotes

- The United Nations Children's Fund and the World Health Organization recommend that face masks are used for children aged six years and older.
- Our mini review only found one paediatric study, and eight adult studies, which explored the medical parameters of mask wearing, and these did not report any harmful effects.
- Further studies are needed so that evidence-based recommendations can be produced for different age groups.

2 | CHILDREN STUDIES

Only two studies performed in children could be found.[14,15] Both studies aimed to assess the wearability of N95 respirators, which are designed for children's protection against air pollution. The first, published in 2019, assessed the safety, fit and comfort of the masks and the second, published in 2020, looked at the subjective wearability perceived by primary school children. In addition, eight studies performed in adults could be found. All 10 studies are summarised in Table 1, some details are mentioned as follows:

Goh et al performed a randomised, two-period crossover study on 106 children, aged 7–14 years, in Singapore to evaluate the safety of N95 respirators.[14] The children were asked to wear a mask both for five minutes while they were at rest reading and then when they walked on a treadmill for five minutes. When they were resting their mean end-tidal carbon dioxide was 30.9 ± 3.37 mmHg without a mask and 34.3 ± 3.32 mmHg when they were wearing a mask. During mild exercise, their end-tidal carbon dioxide values were 28.2 ± 2.8 mmHg and 32.0 ± 2.9 mmHg. All their physiological variables, including their heart rate and respiratory rate, were within acceptable ranges and the children's mean oxygen saturation was at least 99% in all cases. The authors reported that seven of the 106 (6.6%) children experienced mild breathing difficulties, but this subjective feeling was not correlated with the objective data provided on the physiological variables. The carbon dioxide levels were lower for N95 respirators with micro ventilators than for masks without filters.[14]

The second paediatric study, performed by Smart et al in London, UK, assessed the wearability of three different N95 respirators in 24 primary school children aged 8–11 years. The children were asked to walk for three minutes and run for three minutes. No physiological parameters were obtained, but the subjective perception of the children about comfort, breathability, heat and fit of the three masks while walking or running was assessed by using a Likert scale. The masks had no subjective negative impact on breathing during walking. When the children were running, one of the three masks had a slightly negative impact on their subjective perception of breathing. The main complaint was that their face was hot. Additionally, subjective discomfort was reported for one of three masks.[15]

3 | ADULT STUDIES

Due to the lack of further paediatric studies, we included eight studies carried out with adults (Table 1).[16–23] These included four studies published in 2020, which were prompted by the COVID-19 pandemic.[20,21,22,23] One of the eight studies was carried out on surgeons who performed operations lasting from one to four hours,[18] and the rest were on patients,[20] medical staff [17,20,22] or members of the public.[16,19,21,23] All the studies obtained oxygen saturation and heart rate data. Participants' respiratory rate and carbon dioxide levels were obtained in six of eight studies.[16,17,20,21,22,23] Of the eight studies, five provided data on controls without masks.[16,17,19,22,23]

TABLE 1 Characteristics of included studies[14–19] including four studies prompted by the COVID-19 pandemic[20,21,22,23]

Study	Study design	Population, recruiting	Exposure duration	Control group	Mask or respirator	Outcomes measured	Findings
Goh et al Singapore Published 2019[14]	Randomised, crossover study	106 children (7–14 years)	Five minutes rest and five minutes walking	Yes, crossover design	N95	$ETCO_2$, $FICO_2$, SpO_2, HR, RR, comfort	No differences in RR, HR, SpO_2. Marginal increase in $ETCO_2$ and $FICO_2$. 7% reported discomfort.
Smart et al UK Published 2020[15]	Randomised, crossover study	24 children (8–11 years)	Three minutes walking and three minutes running	No	N95	Comfort, breathability, hotness, fit	Main complaint hotness. One-third had a negative subjective perception of breathing.
Samannan et al USA Published 2020[20]	Clinical observation	15 adults from medical house staff and 15 COPD patients	30 minutes rest and six minutes walking	No	Surgical	$ETCO_2$, SpO_2, HR, RR; COPD patients: pCO_2 and pO_2	No differences in RR, HR, SpO_2 and $ETCO_2$. Decrease in oxygenation after walking in COPD patients.
Roberge et al USA Published 2012[16]	Nonrandomised, crossover study	20 adults from public	one hour walking	Yes, crossover design	Surgical	$P_{tc}CO_2$, SpO_2, HR, RR, temperature, comfort	Mild increases of HR, RR and $P_{tc}CO_2$ without clinical significance.
Butz Germany Published 2005[17]	Randomised crossover study	15 adults from medical staff	30 minutes rest	Yes, crossover design	Surgical	$P_{tc}CO_2$, SpO_2, HR, RR, CO_2 concentration under mask, comfort	Significant increase in $P_{tc}CO_2$. No change in SpO_2, HR and RR. CO_2 accumulation under mask.
Beder et al Turkey Published 2008[18]	Clinical observation	53 surgeons	Operations between one and four hours	No	Surgical	SpO_2, HR	Decrease in SpO_2. Slight increase in HR compared with preoperative values.
Dattel et al USA Published 2020[21]	Clinical observation	32 pilots from Aeronautical University	90 minutes flight simulator (altitude of 5,000 feet)	No	Surgical, cloth	$ETCO_2$ and, SpO_2, HR, RR	No significant changes or differences between mask types. $ETCO_2$and SpO_2 within acceptable range.
Person et al France Published 2018[19]	Randomised, cross over study	44 adults from public	Six minutes walking	Yes, crossover design	Surgical	Distance, HR, SpO_2, dyspnea	No differences in distance, HR or SpO_2. Significantly more dyspnea.
Fikenzer et al Germany Published 2020[22]	Randomised, cross over study	12 adults from medical staff	Ergo-spirometry (incremental exertion test)	Yes, crossover design	Surgical, N95	HR, RR, pCO_2, pO2, VE, VT, Pmax, VO_2max/kg	No significant changes with surgical masks. Pulmonary parameters and maximum power decreased significantly with N95 respirators.
Epstein et al Israel Published 2020[23]	Randomised, cross over study	16 adults, from public	Cycle ergometry (incremental exertion test)	Yes, crossover design	Surgical, N95	$ETCO_2$, SpO_2, HR, RR, time to exhaustion	Significant increase in $ETCO_2$ with N95 respirators. No significant changes in SpO_2, HR, RR and time to exhaustion.

COPD, chronic obstructive pulmonary disease; $ETCO_2$, end-tidal carbon dioxide; $FICO_2$, fractional concentration of inspired carbon dioxide; $P_{tc}CO_2$, transcutaneous carbon dioxide; RR, respiratory rate; SpO_2 = oxygen saturation; HR, heart rate; P, power; VO_2, oxygen uptake; VE, minute ventilation; VT, tidal volume; pCO_2, partial pressure of carbon dioxide; pO_2, partial pressure of oxygen; VO_2max/kg, maximal oxygen consumption per kilogram bodyweight.

The adult studies showed no evidence of harmful effects when surgical or cotton masks were worn. For example, there was no significant impairment of oxygen uptake, in terms of oxygen saturation, when the participants wore the masks.[16-21] One pre-pandemic study showed a mild increase in heart rate and respiratory rate after one hour of walking when using a surgical mask.[16] However, five other studies did not detect a compensatory increase in heart rate,[17–21] including two of the four studies prompted by the pandemic,[20,21] and the study related to surgeons.[18]

One study prompted by the pandemic, Fikenzer et al, performed ergo-spirometry in adults to measure their cardiorespiratory responses during heavy exercise while wearing a surgical face mask or an N95 respirator. The results were compared with controls without masks. Pulmonary function parameters, such as forced vital capacity and peak expiratory flow, were significantly lower when surgical masks were worn. However, no significant difference in minute ventilation volume and respiratory rate could be proven while wearing a surgical mask. At the peak of the power exertion test, there were no crucial differences in gas exchange parameters, such as the partial pressure of oxygen or the partial pressure of carbon dioxide. A decrease in maximum achievable power was observed when the participants used an N95 respirator, but not when surgical masks were used. Discomfort was significantly higher with any mask.[22]

Another study prompted by the pandemic, by Epstein et al, used cycle ergometry to induce physical activity without a mask, with a surgical mask and with an N95 respirator. Heart rate, respiratory rate, oxygen saturation and time to exhaustion did not differ significantly under different conditions. There were no differences in end-tidal carbon dioxide in the no mask controls, and those who wore surgical masks, except for the last and heaviest workout stage. However, a significant end-tidal carbon dioxide increase was found when N95 respirators were worn.[23]

4 | DISCUSSION

This mini review identified a lack of information on the consequences of children wearing face masks. This gap in the knowledge was also highlighted in the advice issued by the United Nations Children's Fund and the World Health Organization on 21 August 2020.[5]

The paediatric study by Goh et al, published in 2019, showed that children did not experience any harmful physical effects when they wore N95 respirators. However, this study had several limitations. The resting and walking tests only lasted five minutes each and did not correspond to usual wearing time. This means that no conclusions on the long-term effects can be reached.[14] Having said that, similar adult studies that had a longer duration of mask use did not report significantly different results about gas exchange.[17,21]

The study published by Smart et al in 2020, which related to air pollution not the pandemic, focussed on subjective perceptions and did not provide any information about physiological parameters. The authors reported that the primary school children did not feel discomfort or strong breathing impairment neither during walking nor during running.[15]

The eight studies conducted with adults were heterogenous in terms of study design and evaluated parameters. The pandemic-inspired study by Fikenzer et al reported that wearing surgical masks during heavy physical exercise negatively affected minute ventilation volume, cardiopulmonary exercise capacity and comfort, but not blood gas parameters and power performance.[22] Another pandemic-inspired study by Epstein et al used cycle ergometry to provoke heavy physical exercise and reported a significant rise in carbon dioxide. However, this finding was not interpreted as potentially harmful.[23]

Despite the lack of academic studies, the paediatric literature frequently recommends wearing face masks, especially to control infections during the COVID-19 pandemic. For example, a paper by Esposito et al stated that children wearing masks played a necessary role in the fight against the pandemic.[24] Responding to the Esposito et al paper in a letter to the editor, Jin et al warned that children wearing masks during physical exercise could be compromised through asphyxia. Additionally, the authors recommend surgical masks rather than N95 respirators.[25] Recently, also the German Society of Paediatrics and Adolescent Medicine published recommendations suggesting that children use masks in order to prevent an infection with SARS-CoV-2.[26]

Another important issue is whether masks are available that are the right size and fit for children. Van der Sande et al argued that using face masks that were not specifically designed for children could lead to significantly inferior protection and unwanted side effects.[27] The letter by Jin et al also recommended face masks that were specially designed for children, arguing that they would provide the best functionality and safety.[25]

The two paediatric studies mentioned above [14,15] examined the use of N95 respirators in a setting of air pollution. No studies exist thus far concerning the use of surgical or cotton masks in children. Compared with adults, children's maximal inspiratory and expiratory pressures are lower than those in adults,[28] showing a positive correlation between biometric data and age.[29] In a pre-pandemic study conducted by Lee et al, it is shown that wearing an N95 respirator leads to a 126% increase of inspiratory and a 122% increase of expiratory flow resistances.[30] Consequently, N95 respirators or FFP2 masks are recommended particularly for high-risk children. Most other children wear surgical or cloth masks for which no studies exist thus far.

A commentary by Scheid et al discussed several studies about the physiological and psychological effects on adults wearing face masks.[31] The authors concluded that face masks did not cause any clinically relevant changes in oxygen or carbon dioxide concentrations. However, others have argued that frequently wearing face masks might have a negative impact on basic psychological needs, like individual autonomy. These may, in turn, reduce mask wearing compliance in society.[31] This aspect should also be considered in upcoming paediatric studies that are likely to be performed in near future.

5 | LIMITATIONS

This review was restricted to potential physiological alterations induced by conventional face masks and did not cover the psychological and social consequences. Only two studies were available that dealt with the potential harmful effects in children and more information had to be obtained from adult studies. None of these studies examines periods as long as a full school day.

6 | CONCLUSION

Information about the influence of commonly used face masks on physiological variables is very limited, especially for children. The few existing studies suggested that surgical and cloth masks did not significantly compromise ventilation and oxygen supplies in healthy individuals and may, therefore, be considered as not harmful. Physical exercise and pre-existing respiratory problems may cause hypoxaemia and hypercapnia. As using face masks could be a long-term preventive measure in the COVID-19 era, further studies are needed, particularly to explore the impact on pre-existing respiratory problems in children and adults.

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CONFLICTS OF INTEREST

The authors have no conflicts of interest to declare.

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