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Review

Face masks and protection against COVID-19 and other viral respiratory infections: Assessment of benefits and harms in children

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Educational aims

The reader will come to appreciate:

- The evidence landscape of potential benefits and harms of mask use by children for COVID-19 and other viral respiratory infections.
- The diversity of concerns that have arisen about mask requirements for children.
- The importance of prompt and transparent information accrual and communication by public health officials about the known benefits and potential harms of medical interventions, particularly for vulnerable populations.

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ABSTRACT

Mask mandates for children were implemented at schools and childcare centers during the COVID-19 pandemic, and the US continues to recommend masking down to the age of two in certain settings. Medical interventions should be informed by high-quality evidence and consider the possibility of harm (i.e., include harm-benefit analyses). In this review, we weigh the existing evidence for the effectiveness of mask mandates to protect against COVID-19 and other viral respiratory infections and the harms associated with face mask wearing in children.

There is a lack of robust evidence of benefit from masking children to reduce transmission of SARS-CoV-2 or other respiratory viruses. The highest quality evidence available for masking children for COVID-19 or other viral respiratory infections has failed to find a beneficial impact against transmission. Mechanistic studies showing reduced viral transmission from use of face masks and respirators have not translated to real world effectiveness. Identified harms of masking include negative effects on communication and components of speech and language, ability to learn and comprehend, emotional and trust development, physical discomfort, and reduction in time and intensity of exercise.

Effectiveness of child masking has not been demonstrated, while documented harms of masking in children are diverse and non-negligible and should prompt careful reflection. Recommendations for masking children fail basic harm-benefit analyses.

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INTRODUCTION

Child mask mandates were one of the most controversial public-health policies used during the COVID-19 pandemic. In many locations in North America, children as young as two years of age were required to wear face masks daily for multiple consecutive hours, both indoors and outdoors, in school and childcare settings [1,2]. This stood in stark contrast to European countries where masking was never recommended for children under the age of six and, in many countries, never under age twelve [3]. The United States Centers for Disease Control and Prevention (CDC)'s child masking recommendations deviated substantially from international guidelines [3–5]. The CDC continues to recommend masks for children down to age two in certain settings [1,6], and this is in the absence of strategies for exiting these restrictions. In the event of a future public health threat, clear and consistent communication from public health officials about the criteria that will be used to withdraw temporary public health recommendations while data are gathered could serve to ease public anxiety, lessen distrust, and facilitate a return to a more normal life wherein ineffective recommendations are promptly discarded.

To date, there is no robust evidence demonstrating that masking reduces the likelihood of respiratory infections in children [7–9]. A recent randomized study in adults found those assigned to community masking were significantly less likely to complete a survey about their symptoms precluding the ability to draw conclusions about differences in reported symptoms; this study was also underpowered to determine if there was a difference in documented infections [10]. There continues to be a lack of reliable data to support recommendations for children to wear masks to prevent respiratory infections. At the same time, there are numerous potential harms associated with mask wearing, especially in young children, some readily apparent and others more subtle and challenging to quantify.

In this review, we consider the reported harms and theoretical concerns about masking children in the context of the lack of high-quality evidence of protection against transmission of respiratory infections, including COVID-19.

MEDICAL ETHICS AND PUBLIC HEALTH INTERVENTIONS: SCIENTIFIC EVIDENCE AND HARM-BENEFIT ANALYSES

Medical interventions and public health policies, especially those directed at vulnerable populations, should be informed by high-quality evidence and consideration of possible harms, (i.e., include harm-benefit analyses). More than four years after the COVID-19 pandemic began, recommendations to mask, by both public and private institutions, remain in some countries, including the US, Spain, Japan, Taiwan, and Singapore. Individuals worldwide may choose to wear a face mask for various reasons. For the purposes of public recommendations and informed individual decision making, the public should be notified when a recommended intervention has not been found to be effective, especially if the intervention is associated with harm. This is particularly important when side effects of recommendations are likely to directly impact vulnerable groups, such as children or individuals otherwise dependent on others for decision making or who may lack the agency to refuse. As higher-quality randomized and observational studies accrue, failing to demonstrate reduced viral transmission from masking [7–9,11], there is a need to raise public awareness of the potential detrimental impacts of masking children. This continues to be relevant as masks are now recommended for other respiratory infections despite a similar lack of evidence of protection [8,9].

Two of the main pillars of medical ethics are nonmaleficence and autonomy. As young children lack autonomy, nonmaleficence of any medical intervention is particularly important. Children are also at a vulnerable stage in their physical and emotional development and may disproportionately suffer negative consequences of masking. Children with hearing or speaking impairments and those with special needs and communication challenges, such as autism, as well as those communicating in a non-native language may suffer disproportionate harm from prolonged masking [12]. Similarly, children who suffer from anxiety or who have decreased lung capacity may feel greater physical discomfort from facial coverings.

Recommendations for infectious disease interventions should be based on robust scientific data with a low risk of bias. Public health officials should be aware of the high risk of bias of most observational studies of masking [7,13] and avoid setting coercive policies based on uncertain benefit, particularly when downsides are not only possible but evident. The long-term goals of the intervention and the beneficiaries of the intervention should be clearly defined. Interventions with plausible efficacy should not be presumed to work before supportive rigorous and reproducible evidence has been generated, preferably through randomized controlled trials (RCTs) [14]. Decision making about masking children should not be based on evidence that is anecdotal, low-quality, or politicized.

BENEFITS OF CHILD MASKING ARE UNPROVEN

In a systematic review assessing the evidence of benefit from child masking for protection against COVID-19, it was found that no high-quality evidence demonstrating the real-world effectiveness of child mask mandates exists and no RCTs have been performed to assess the effectiveness of mask wearing in children for COVID-19 prevention [7]. One subsequent RCT in Guinea Bissau included children and failed to find evidence of benefit but, due to widespread population masking at the time of the study, conclusions about masking effectiveness could not be drawn [15]. Two Cochrane reviews of RCTs of masking for upper respiratory infections including adults, and some with children down to the age of three, did not find evidence of reduced SARS-CoV-2 transmission from medical grade masking in the community, household, or healthcare setting [8,9]. A total of four RCTs evaluating household transmission of influenza (also an enveloped RNA virus with virions measuring 80–120 nm) included populations comprised of children and adults [16–18]. The details of these studies are listed in Table 1. None detected significant mask efficacy when using the standard, unadjusted intention-to-treat analysis. The two studies that assessed harms separately found higher rates of side effects from mask wearing in children than in adults [17,18] (Table 1).

EVIDENCE OF HARMS OF CHILD MASKING

1) Speech, language, and learning: Humans rely on visual information provided by a speaker's face to decode speech. Seeing mouth movements and facial gestures accelerates recognition of words and enhances speech comprehension [12,19–21]. The integration of audio and facial information is crucial to speech perception and development. Visually impaired children often have delays in speech and language development [22], which may be due, at least in part, to reduced ability to perceive facial cues. Seeing faces is crucial for communication in children with hearing loss, and the proportion of time spent looking at the mouth during speech correlates with lip reading accuracy [23]. Word identification and speech intelligibility are reduced when the speaker wears a face mask [24–26]. Treatment of speech-sound disorders requires the child to imitate the clinician, observe the clinician's mouth movements in a mirror, and manipulate articulators with hands and tools to facilitate acquisition of new speech sounds; masking

Table 1
Characteristics of selected studies reporting harm of child masking.

First author, Year of Study	Study Design	Child Age Groups	Sample Size	Primary Outcome	Main Findings	Comments: Strength of Evidence and Weaknesses
Transmission efficacy studies						
Canini, 2010 [18]	C-RCT[a]	38% of masked population 5–15 years	n = 411	Efficacy and physical adverse effects and discomfort	Mask wearing caused discomfort in 75% of participants, and children more frequently reported pain with mask wearing. No evidence of efficacy.	High-quality RCT (high participation rate; per protocol and intention-to-treat outcomes both negative). Discomfort among controls was not elicited.
Suess, 2012 [17]	C-RCT	43% of masked population 4–14 years	n = 302	Efficacy and physical adverse effects and discomfort	Side effects of mask wearing included heat, pain, and shortness of breath, and children more frequently reported side effects than adults (50% vs 29%). No evidence of efficacy in the unadjusted intention-to-treat analysis.	Side effects were not compared to the control group. Per protocol and post-hoc adjustments potentially detecting efficacy of questionable value in an RCT and may reintroduce bias.
Larson, 2010 [16]	C-RCT	48% 4–17 years	n = 2,788	Effects on incidence and secondary transmission	No significant differences in infection rates by intervention group in multivariate analyses; no adverse events were reported.	Side effects were not studied, but no adverse events were reported. Low mask adherence.
Cowling, 2008 [71]	C-RCT	23% 3–16 years	n = 287	Effects on incidence and secondary transmission	No adverse effects were reported. No evidence of efficacy.	Side effects were not studied, but no adverse events were reported. Low mask adherence.
Speech, language, and learning						
Sfakianaki, 2021 [24]	Pre-post study	6–7 years	n = 20	Effect on word recognition	Word identification was compromised when produced with a mask, with more pronounced negative effects for children listening in noise.	
Lipps, 2021 [25]	Pre-post study	3–7 years	n = 13	Effect on word recognition	Masks hampered word recognition, even in quiet conditions, in children with hearing impairment.	
Singh, 2021 [72]	Pre-post study	2-years	n = 24	Effect on word recognition	Clear masks reduced language comprehension in infants more than opaque masks.	Conducted in a laboratory setting, without background noise and with low need for granular phonological skills. Only utilized current semantic knowledge and no other aspects of language learning, such as learning new words.
Singh, 2023 [73]	Pre-post study	3 years	n = 28	Effect on word recognition	Using a surgical mask did not affect word recognition in bilingual children but using a face shield did.	Same as [72].
Schlegtendal, 2022 [31]	RCT	11–13 years	n = 133	Effect on cognitive performance	No difference in attention and executive functions between groups with and without masks.	Assessment performed after two lessons only; unlikely a representation of long-term masking environments.
UK Department of Education, 2022 [32]	Survey	7–13 years	n = 6,359	Impact on communication, teaching	Masking made learning and communication more difficult.	

Table 1 (*continued*)

First author, Year of Study	Study Design	Child Age Groups	Sample Size	Primary Outcome	Main Findings	Comments: Strength of Evidence and Weaknesses
Mental health and social-emotional well-being						
Ruba, 2020 [41]	Pre-post study	7–13 years	n = 81	Effect on emotion inferences	Children made less accurate emotional interpretations when faces were covered, and accuracy declined with younger age.	
Gori, 2021 [42]	Pre-post study	3–8 years	n = 119	Effect on emotion inferences	Mask use limited the ability to read facially expressed emotions in people of all ages but were most pronounced in 3–5-years-olds.	
UK Department of Education, 2022 [32]	Survey	7–13 years	n = 6,359	Impact on mental and physical health	Masking made children feel anxious.	
Powell, 2022 [43]	Survey	11–18 years	n = 462	Impact on physical, mental, emotional and social well-being	Unmasked children were less concerned about transmitting or developing disease.	
Physiological impact and impediment to exercise and play						
Martellucci, 2022 [54]	Pre-post study	10–18 years	n = 104	Effect on CO_2 in inhaled air	CO_2 content in inhaled air was quickly elevated beyond acceptable safety levels, and levels were higher in children than adults.	
Brooks, 2023 [74]	Pre-post study	2–14 years	n = 119	Effect on CO_2 in inhaled air	CO_2 content in inhaled air was quickly elevated, and the increase was highest in the youngest age group (2–to7–year–olds).	
Shaw, 2021 [57]	C-RCT	8–11	n = 16	Effect on performance and physiological measures	Mask wearing among hockey players caused decreased tissue oxygenation and increased perceived exertion, especially in females.	Assessed effects in controlled setting and not during actual hockey games.
Goh, 2019 [58]	C-RCT	7–14 years	n = 106	Effect on physiological measures	Mask wearing caused increased end tidal CO_2 and $FiCO_2$ in children.	

[a] *RCT= randomized controlled trial

during speech therapy may impede the ability to teach and evaluate the child's speech productions using these methods [27]. The link between observation of the mouth and language processing is supported by children paying most attention to a speaker's mouth during critical stages of speech development, and people of all ages continue to focus on the mouth when listening to non-native speech [28]. Among US school children, almost a quarter are English-language learners [29]. The sensitive period for language development is through age five, but development of connected speech is ongoing until after age ten [30].

In one study analyzing cognitive performance in children during school lessons (computerized tests for visual attention and executive functions such as task switching), the authors measured no difference in groups with and without masks, but the study was conducted after only two lessons [31]. In a study from the UK, almost 50% of students age 7–13 stated that wearing a face covering made learning more difficult, and two thirds found that masking made communication difficult [32]. Children simply *perceiving* learning to be more difficult is important even if the impact has not been measured in a randomized way as this perception may lead to frustration with learning and the educational system. Communication difficulties have also been reported extensively as a side effect of mask usage among adults, including in RCTs and observational studies [33]. In an observational study performed in a school setting in 2007 [34], teachers reported masks were distracting and made reading facial expressions difficult, and some teachers stated they would need to change their teaching style if masking were required in the future.

2) Mental health and social-emotional well-being: Infants' ability to recognize faces and read facial expressions appears to be intrinsically linked to the development of communication and to both the interpretation and expression of emotions [21,35,36]. Information is more often interpreted correctly when one can see and interpret facial expressions, and face masks have been found to impair recognition of emotional expressions, trustworthiness judgments, and faces [37,38]. Children with special-education needs and with autism may be disproportionately impacted by mask requirements as they rely more heavily on reading facial expressions to pick up social cues [39]. Misinterpretation of facial expressions has been found to increase anxiety and depression in individuals with anxiety disorders, or may even be the cause of it [40].

In a study measuring emotional interpretation in 7-to-13-year-olds who interacted with masked adults, children were less accurate when faces were covered and accuracy declined more with younger age [41]. Another study found that mask use was linked to a diminished ability to read facially expressed emotions in people of all ages, but was most pronounced in children age three to five [42]. One German study found masking faces to be associated with decreased ability to read emotional expression and decreased perceptions of closeness, trustworthiness, and likeability [38]. A study of students under age 12 in the UK, for whom masking was not required, found students were comparatively less fearful about transmitting SARS-CoV-2 or developing disease [43]. Though there are many potential social confounders, mask wearing also appears to correlate with increased anxiety in the learning environment [43]. One UK survey reported 21% of children age 7–13 stated that wearing a face covering made them feel anxious [32].

There has been an increase in anxiety and depressive disorders during the COVID-19 pandemic, with children and adolescents having experienced disproportionately worse mental-health outcomes than adults [44–46]. Researchers have even defined a novel disorder directly associated with the pandemic, the COVID-19 anxiety syndrome, which manifests as avoidance, symptom checking, worrying, and threat monitoring [47].

It is important to note that a number of the studies assessing emotional and mental well-being are limited to a small number of participants and observational designs, thus prone to multiple potential biases and confounders. Whether the heightened anxiety, impaired communication, and decreased closeness [38], associated with masking played a causal role in the increase in mental health disorders remains speculative.

3) Physiological impact and impediment to exercise and play: Mask wearing can unquestionably have untoward physiological effects, including both self-reported and measured breathing difficulties, headaches, dermatitis, and general discomfort [9,17,18,33,33,48–51], many of which are more frequently reported in children than in adults [9,17,18]. These self-reported and documented effects may have multiple negative downstream effects, including reduced time and intensity of exercise, additional sick days, reduced learning capacity, and increased anxiety. There is also concern that masks are a source of potentially harmful micro- and nanoparticles, lead and other heavy metals, and potentially toxic substances with health threatening and carcinogenic properties [52,53], which may pose greater health threats to young children.

The freedom to exercise is critical to child health and development. Multiple studies, some of which are listed below, have reported masks as a barrier to exercise. In a study comparing no masks, surgical masks, and respirator masks, researchers found that within a few minutes of usage at rest, 40% of children using surgical masks and 99% of children using respirator masks had an additional 30% increase in parts per million (ppm) measurements of CO_2 over adult counterparts; also, 90% of child mask wearers and 100% of pediatric respirator mask wearers had higher than the 5000-ppm acceptable exposure threshold recommended in standards for healthy adult workers [54]. For reference, CO_2 levels in outdoor air typically range from 300 to 400 ppm [55]. Adult threshold standards are not appropriate for more sensitive groups such as children. In addition, CO_2 increases were most prominent when respiratory rates were higher, such as occur with exertion.

Additional studies suggest masks inhibit exercise. One recent systematic review and meta-analysis of randomized crossover studies found that masking during exercise resulted in unfavorable changes in gas exchange and pulmonary function, decreases in exercise performance, and caused subjective discomfort [56]. A randomized trial of children age 8–11 years playing hockey with masks found decreased tissue oxygenation and increased rate of perceived exertion [57]. Another trial of masked healthy children age 7–14 years found increased end-tidal CO_2 and increased $FiCO_2$ with brisk treadmill walking [58]. A particularly thorough randomized study in young healthy adult athletes found decreased performance, increased lactate, increased glucose, increased rate of exertion, and higher perceived stress during maximal running wearing a surgical mask [59]. Similar findings were reported across numerous studies of cycling and running in healthy young adults wearing surgical or cloth masks [56]. These studies highlight how masking children, adolescents, and young adults can create barriers to running and more intense efforts in play, which are critical components of physical fitness and a source of shared joy with peers.

With respect to long-term environmental impacts, the production and distribution processes of face masks consume petroleum-based materials and release greenhouse gasses, the routine use of face masks generates an alarming increase in plastic waste and microplastic pollution globally, and the disposal of face masks poses challenges in various ecosystems [60], all of which future generations will need to live with and address.

PUBLIC-THREAT RESPONSES: LACK OF EXIT STRATEGIES AND THE DISPROPORTIONAL RESTRICTION OF CHILDREN

Disease mitigation strategies implemented to temporarily protect a population from threats are relatively easy to implement

but notoriously difficult to remove; clear and consistent strategies for removing restrictions are often absent [61]. During the Ebola outbreak in 2014, some West-African countries closed their school systems for prolonged periods and banned some students from attending school for five years, with devastating consequences [62]. In the US, some public-transportation restrooms were closed after 9/11 as a public-threat response and stayed closed for over 20 years [63]. More recently, during the COVID-19 pandemic, many US schools were closed for almost 1.5 years although it was known that school closures had little, if any, effect on the community spread of SARS-CoV-2 [64,65]. Schools in many other countries remained open, or closed only briefly, during the pandemic [66].

When a public threat is identified, early and rapid interventions may be critical to mounting an effective public response. Requirements for evidence-based policies in the acute phase are, appropriately, deprioritized. However, easing unproven restrictions can be challenging. Reasons for this vary: 1) RCTs may not be run in a timely manner; 2) Some sectors of the public may continue to express heightened safety concerns and request that mandates are kept in place, even if a similar risk level was previously tolerated; 3) Policymakers and community leaders may want to avoid being held responsible for any threat-specific adverse outcomes when lifting restrictions, but less inclined to consider long-term negative impacts; 4) Restrictions may be forgotten by decision makers but continue to impact the public; and 5) Decision makers and citizens may be subject to the "sunk cost fallacy," a tendency to continue an endeavor after an investment in money, effort, time, or prestige has been made, regardless of benefits, as a justification for the original investment [67]. All these phenomena have been observed in policies involving children, including school closures, restrictions on extra-curricular activities, and mask mandates.

Education and childcare are often disproportionately affected by restrictions during infectious disease outbreaks. Similar to the aforementioned Ebola outbreak, school closures instituted during the 1916 polio outbreak impacted the educational and economic attainment of children for years [68]. This disproportionate impact on children was particularly evident and irrational with COVID-19 where transmission from children in schools was not a significant driver of the pandemic [69] and children faced a mortality risk that was orders of magnitude lower than older adults [70]. Despite this, children in many areas of the world endured the most stringent policies. Restrictions targeting children have the potential for considerable negative impact on learning, mental health, and development. Policies for which benefits cannot be shown to exceed harms should not be initiated and promptly discontinued once identified.

FUTURE OUTBREAKS OF VIRAL RESPIRATORY INFECTIONS

During future respiratory virus seasons or other periods of increased viral transmission, any reintroduction of public health mitigation recommendations should be evidence-based. Transparency regarding evidence of benefit and whether potential harms have been thoroughly assessed must be clearly communicated to the public, to inform individual decision making regarding the masking of children and other vulnerable groups. Considering the documented and potential negative impacts of masking children may reduce unjustified developmental and learning delays, negative impacts on physical, verbal and emotional development, and harmful psychological sequelae including stress, social isolation, and anxiety.

CONCLUSIONS

There is a lack of robust evidence of benefit from masking children to reduce transmission of SARS-CoV-2 or other respiratory viruses. In this review, we have, however, identified multiple studies, both randomized and observational, which report that masking may lead to a variety harms in children of all ages. Recommendations for masking children, therefore, fail even the most basic harm-benefit analyses. The current evidence does not support the recommendation of masks for children to prevent infection or transmission of respiratory viruses.

FUTURE RESEARCH

- Medical interventions and public health recommendations should be informed by high-quality evidence considering both potential benefits and harms.
- Any new intervention should not be assumed to work but be tested expeditiously with randomized controlled trials and recommendations promptly updated accordingly.
- Cluster randomized trials of recommendations to mask vs not mask could be run in different schools within the same district or county to assess for pre-specified relative reductions in cases or hospitalizations.
- Future studies should also aim to compare differences in terms of short- and long-term physical, psychological, and educational harms.
- Results should be communicated transparently to the public so informed decisions can be made based on high-quality data and so that continued research can be undertaken to verify initial findings and assess ongoing areas of uncertainty.

CONSENT FOR PUBLICATION

All authors had full access to all the data in the study and had final responsibility for the decision to submit for publication.

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