# Assessment of Respiratory Function in Infants and Young Children Wearing Face Masks During the COVID-19 Pandemic

Riccardo Lubrano, MD, PhD; Silvia Bloise, MD; Alessia Testa, MD; Alessia Marcellino, MD; Anna Dilillo, MD, PhD; Saverio Mallardo, MD; Sara Isoldi, MD; Vanessa Martucci, MD; Maria Sanseviero, MD; Emanuela Del Giudice, MD, PhD; Concetta Malvaso, MD; Donatella Iorfida, MD; Flavia Ventriglia, MD, PhD

## Abstract

**IMPORTANCE** Face masks have been associated with effective prevention of diffusion of viruses via droplets. However, the use of face masks among children, especially those aged younger than 3 years, is debated, and the US Centers for Disease Control and American Academy of Physicians recommend the use of face mask only among individuals aged 3 years or older.

**OBJECTIVE** To examine whether the use of surgical facial masks among children is associated with episodes of oxygen desaturation or respiratory distress.

**DESIGN, SETTING, AND PARTICIPANTS** This cohort study was conducted from May through June 2020 in a secondary-level hospital pediatric unit in Italy. Included participants were 47 healthy children divided by age (ie, group A, aged ≤24 months, and group B, aged >24 months to ≤144 months). Data were analyzed from May through June 2020.

**INTERVENTIONS** All participants were monitored every 15 minutes for changes in respiratory parameters for the first 30 minutes while not wearing a surgical face mask and for the next 30 minutes while wearing a face mask. Children aged 24 months and older then participated in a walking test for 12 minutes.

**MAIN OUTCOMES AND MEASURES** Changes in respiratory parameters during the use of surgical masks were evaluated.

**RESULTS** Among 47 children, 22 children (46.8%) were aged 24 months or younger (ie, group A), with 11 boys (50.0%) and median (interquartile range [IQR]) age 12.5 (10.0-17.5) months, and 25 children (53.2%) were aged older than 24 months to 144 months or younger, with 13 boys (52.0%) and median (IQR) age 100.0 (72.0-120.0) months. During the first 60 minutes of evaluation in the 2 groups, there was no significant change in group A in median (IQR) partial pressure of end-tidal carbon dioxide ($P_{ETCO_2}$; 33.0 [32.0-34.0] mm Hg; *P* for Kruskal Wallis = .59), oxygen saturation ($Sa_{O_2}$; 98.0% [97.0%-99.0%]; *P* for Kruskal Wallis = .61), pulse rate (PR; 130.0 [115.0-140.0] pulsations/min; *P* for Kruskal Wallis = .99), or respiratory rate (RR; 30.0 [28.0-33.0] breaths/min; *P* for Kruskal Wallis = .69) or for group B in median (IQR) $P_{ETCO_2}$ (36.0 [34.0-38.0] mm Hg; *P* for Kruskal Wallis = .97), $Sa_{O_2}$ (98.0% [97.0%-98.0%]; *P* for Kruskal Wallis = .52), PR (96.0 [84.0-104.5] pulsations/min; *P* for Kruskal Wallis test = .48), or RR (22.0 [20.0-25.0] breaths/min; *P* for Kruskal Wallis = .55). After the group B walking test, compared with before the walking test, there was a significant increase in median (IQR) PR (96.0 [84.0-104.5] pulsations/min vs 105.0 [100.0-115.0] pulsations/min; *P* < .02) and RR (22.0 [20.0-25.0] breaths/min vs 26.0 [24.0-29.0] breaths/min; *P* < .05).

*(continued)*

### Key Points

**Question** Are surgical masks associated with episodes of oxygen desaturation or respiratory distress among children?

**Findings** In this cohort study of 47 infants and young children in Italy, wearing surgical face masks for 30 minutes was not associated with changes in respiratory parameters or clinical signs of respiratory distress.

**Meaning** These findings suggest that the use of surgical masks among children may be promoted during the coronavirus disease 2019 pandemic, especially in view of the reopening of schools.

*Abstract (continued)*

**CONCLUSIONS AND RELEVANCE**  This cohort study among infants and young children in Italy found that the use of facial masks was not associated with significant changes in $Sao_2$ or $Petco_2$, including among children aged 24 months and younger.

## Introduction

During the coronavirus disease 2019 (COVID-19 virus) pandemic, a large amount of useful data has provided a better understanding of virus behavior. Confronting the experiences of individual countries, we can evaluate the efficacy associated with preventive measures enforced during lockdowns. Based on these experiences, governments and public health agencies are now developing recommendations aimed at containing a possible peak of infection, especially in view of the reopening of schools.

Currently, there is a consensus that the main route of transmission of COVID-19 virus is via droplets, although there is not complete agreement on details (eg, span, size, and virus concentration).[1-6] In fact, discrepancies have been observed in the general public and community settings in attitudes about containment measures, with different national guidelines proposed to slow the spread of COVID-19.[7]

Another issue that frequently arises in the debate is the role of individuals who have the disease but no symptoms in spreading the infection; 2 studies[8,9] found a high rate of positive pharyngeal molecular test results among individuals without symptoms, and that may become an important source of contagion in the pandemic.[10,11] Children have also been found to commonly carry the disease without symptoms.[12,13] This is more difficult to identify among children, because they commonly exhibit milder symptoms of COVID-19 compared with adults.[14]

However, the role of children in the spread of severe acute respiratory syndrome coronavirus 2 (SARS CoV-2) infection is still debated. Five studies[15-19] have found significantly decreased transmission of SARS-CoV-2 transmission associated with children compared with adults, with a susceptibility to infection among children that is about half of that of adults and a decreased likelihood of developing symptoms. However, 5 other studies[14,20-23] found that children can carry high levels of virus in their upper airways, particularly early in an acute SARS-CoV-2 infection, even if it is a mild infection or asymptomatic infection. Because of these findings on asymptomatic carrying, the main measures proposed for preventing the spread of SARS-CoV-2 are social distancing, handwashing, and mask-wearing,[24] not only for health care workers, but also for the general population. The association of surgical face masks with effective prevention of transmission was already found during the 2003 SARS virus epidemic.[25] Studies[26-28] published in 2020 found that the use of face masks is also associated with preventing transmission from individuals without symptoms. Furthermore, a mathematical model[29] has further suggested the protective role of masks, finding a linear association between the use of masks and a decreased rate of spread of COVID-19 infection.

Adverse outcomes associated with wearing face masks have been described in adult patients.[30,31] Among children, the US Centers for Disease Control and Prevention (CDC)[32] and the American Academy of Pediatrics (AAP)[33] do not recommend the use of face masks among individuals aged younger than 3 years. These organizations also recommend special precautions for children with severe cognitive or respiratory impairments. Children in these groups also experience problems with the use of face masks because poor motor skills and coordination may make it difficult to remove the mask. In addition to poor compliance with mask wearing expected in a pediatric population, these indications for the use of face masks among children aged younger than 3 years or children with disabilities are often misinterpreted and are associated with widespread public distrust of face mask use among children.

The evidence for adverse outcomes associated with face mask use among children is poor, and the benefits of preventing individuals without symptoms or with mild symptoms from spreading the infection is obvious. We therefore decided to examine the potential associations of the use of surgical face masks with changes in respiratory function among children, including those aged younger than 2 years.

## Methods

This cohort study was approved by the Pediatric Unit of Santa Maria Goretti Hospital, Latina—Sapienza University of Rome department institutional review board. For each child included in the study, informed written consent was obtained from available parents or caregivers. The study protocol conformed to the ethical guidelines of the 1975 Declaration of Helsinki as revised in 2000.[34] This report followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) reporting guideline for cohort studies.

The study's primary aim was to determine if the use of surgical mask among younger children was associated with changes in respiratory function, as measured by partial pressure of end-tidal carbon dioxide ($P_{ETCO_2}$), oxygen saturation ($Sao_2$), pulse rate (PR), and respiratory rate (RR), or with manifestation of clinical signs of respiratory distress. We monitored $P_{ETCO_2}$ using a microstream system. The secondary aim was to determine if the use of masks in this population was associated with a decrease in the perfusion index (PI).

From May 2020 to June 2020, we enrolled 47 healthy children (aged 4 to 144 months). Exclusion criteria were lung or cardiac disease, neuromuscular disorders, use of medications that could be associated with changes in the parameters examined, and age older than 144 months. Participants were divided into 2 groups: children aged older than 4 months to 24 months or younger (ie, group A) and children aged older than 24 months to 144 months or younger (ie, group B).

For every child admitted to the study, we implemented the following steps: Two days before the study started, a pediatrician (A.T.) examined the child to verify the individual's state of wellness and to adjust the surgical face mask to fit comfortably; in particular, we tucked the edges into the inner surface and sewed them. We used single-use surgical masks (BYD Precision Manufacture) with 3 layers (ie, an outer layer of polypropylene spunbonded nonwoven fabric, a middle layer of polypropylene melt-blown nonwoven fabric, and an inner layer of polypropylene spunbonded nonwoven fabric), ear loops consisting of a polyester and nylon spandex blend, and a nasal clip consisting of metal wire with plastic covering. Then, doctors educated the parents about the correct way for the children to wear and take off the mask. After that, to achieve the best compliance from the child, parents encouraged the children to wear the mask at home as a game for short periods. Parents also showed children a promotional video sponsored by the Italian Society of Pediatric Emergency and Urgent Medicine and produced by the Italian Emergency Health Society to help children to get accustomed to surgical face masks.[35] On the evaluation day, parents and doctors also wore surgical masks to help obtain maximal compliance from the children.

The test consisted of two 30-minutes sessions, the first without a mask and the second with the surgical face mask in place. In both sessions, the children were encouraged to engage in their usual play activity. For group B, a third session was included, which consisted of walking for 12 minutes back and forth along a 40-m corridor while still wearing the mask. The instructions given for this last session were similar to those for the 12-minute walking test.[36] We used walking as a strain test because it better reflects a normal physical activity compared with other game activities. The children were encouraged by the supervising doctor to walk fast, and the distance traveled was recorded.

During the study, every child was connected to a Masimo patient-monitoring system (Rad-97 with NomoLine Capnography) to record $P_{ETCO_2}$ (measured in millimeters of mercury), $Sao_2$ (measured as percentage), PR (measured as pulsations/min), and PI (measured as percentage). The RR (measured as breaths/min) was detected manually by an observing doctor (A.T.). All parameters

were recorded every 15 minutes: at 15 minutes from the start, 30 minutes, 45 minutes, and 60 minutes. For group B, we did an additional evaluation during the 12-minute walking test, at 72 minutes from the start of the evaluation. The supervising physician (A.T.) was in charge of detecting any signs of respiratory distress, such as retractions, abnormal skin color, and use of accessory muscles.

## Statistical Analysis

For all parameters considered in the study, the approximation to normal of the distribution of the population was tested by Kolmogorov-Smirnov 1-sample test and statistics for kurtosis and symmetry. As results were asymmetrically distributed, nonparametric tests were used. Data are expressed as median and interquartile range (IQR). We used the Kruskal-Wallis nonparametric 1-way analysis of variance to examine the changes of each parameter within the subgroups; the null hypothesis was that the groups for the same parameter all came from the same distribution. Then, to exclude the eventuality of a type 1 error between groups for the same parameter, we determined the $P$ value associated with each of the comparisons using the Steel-Dwass method as a nonparametric test for multiple comparisons.

Data were analyzed from May through June 2020 using JMP statistical software version 14.3.0 (SAS Institute). $P$ values were 2-sided, and $P < .05$ was considered statistically significant.

## Results

A total of 47 children were included in the analysis. Group A consisted of 22 children (46.8%), with 11 (50.0%) boys and median (IQR) age 12.5 (10.0-17.5) months; 2 children (1 boy, aged 8 months, and 1 girl, aged 11 months) dropped out because of intolerance of the mask. Group B consisted of 25 children (53.2%), with 13 boys (52.0%) and median (IQR) age 100.0 (72.0-120.0) months (**Table 1**).

The analysis of the readings of $SaO_2$, $PETCO_2$, PR, RR, and PI at set recording times of the study in both groups are provided in **Table 2**. There was no statistically significant change during the study period in median (IQR) $SaO_2$ in group A (at 15 min: 98.0% [97.3%-98.0%]; at 30 min: 98.0% [98.0%-99.0%]; at 45 min: 98.0% [97.0%-98.8%]; at 60 min: 98.0% [97.5%-98.0%]; $P$ for Kruskal Wallis = .61) or group B [at 15 min: 98.0% [98.0%-98.0%]; at 30 min: 98.0% [97.0%-98.0%]; at 45 min: 98.0% [97.5%-98.0%]; at 60 min: 98.0% [97.0%-98.0%]; after walking test: 98.0% [97.0%-98.0%]; $P$ for Kruskal Wallis = .52); median (IQR) $PETCO_2$ in group A (at 15 min: 33.0 [32.3-35.0] mm Hg; at 30 min: 33.5 [32.3-34.8] mm Hg; at 45 min: 33.0 [32.0-34.0] mm HG; at 60 min: 32.5 [32.0-34.0] mm Hg; $P$ for Kruskal Wallis = .59) or group B (at 15 min: 37.0 [34.0-39.0] mm Hg; at 30 min: 36.0 [34.0-38.0] mm Hg; at 45 min: 36.0 [35.0-37.5] mm Hg; at 60 min: 36.0 [34.0-38.0] mm Hg; after walking test: 36.0 [35.0-37.5] mm Hg; $P$ for Kruskal Wallis = .97); or median (IQR) PI in group A (at 15 min: 3.5% [2.6%-4.5%)]; at 30 min: 2.9% [2.6%-4.3%]; at 45 min: 3.8% [2.6%-4.8%]; at 60 min: 3.6% [2.6%-4.5%]; $P$ for Kruskal Wallis = .89) or group B (at 15 min: 4.6% [3.0%-5.8%]; at 30 min: 4.3% [2.9%-6.5%]; at 45 min: 4.1% [2.6%-6.2%]; at 60 min: 4.3% [2.8%-5.9%]; after walking test: 3.5% [2.7%-5.0%]; $P$ for Kruskal Wallis = .77) (Table 2).

Table 1. Demographic Characteristics of Participants

| Characteristic | Participants by group, median (IQR) | |
| --- | --- | --- |
| | Group A (n = 22) | Group B (n = 25) |
| Boys, No. (%) | 11 (50.0) | 13 (52.0) |
| Age, mo | 12.5 (10.0-17.5) | 100.0 (72.0-120.0) |
| Weight, kg | 10.2 (9.0-11.7) | 38.0 (25.6-42.8) |
| Height, cm | 74.0 (70.6-81.8) | 133.5 (123.3-142.4) |
| BMI | 17.4 (16.4-18.9) | 20.3 (15.9-22.4) |

Abbreviations: BMI, body mass index (calculated as weight in kilograms divided by height in meters squared); IQR, interquartile range.

In addition, there was no significant change over the study period for group A in median (IQR) PR (at 15 min: 128.5 [113.5-140.0] pulsations/min; at 30 min: 128.5 [110.5-140.0] pulsations/min; at 45 min: 130.0 [118.5-140.0] pulsations/min; at 60 min: 130.0 [84.0-103.5] pulsations/min; $P$ for Kruskal Wallis = .99) or RR (at 15 min: 30.0 28.0-[31.5] breaths/min; at 30 min: 31.0 [28.0-33.0] breaths/min; at 45 min: 30.0 [26.5-33.8] breaths/min; at 60 min: 31.0 [26.5-32.0] breaths/min; $P$ for Kruskal Wallis = .69).

After the walking test in group B, there was a significant increase in median (IQR) PR (at 15 min: 90.0 [84.0-103.5] pulsations/min; at 30 min: 91.0 [85.0-98.5] pulsations/min; at 45 min: 90.0 [85.0-98.5] pulsations/min; at 60 min: 99.0 [83.0-102.0] pulsations/min; after walking test: 105.0 [100.0-115.0] pulsations/min; $P$ for Kruskal Wallis = .002) and median (IQR) RR (at 15 min: 20.0 [17.5-24.0] breaths/min; at 30 min: 21.0 [19.0-24.5] breaths/min; at 45 min: 22.0 [20.0-25.0] breaths/min; at 60 min: 24.0 [19.0-26.0] breaths/min; after walking test: 26.0 [24.0-29.0] breaths/min; $P$ for Kruskal Wallis = .002). In the Steel-Dwass test, there was a significant increase after the walking test compared with all previous time points for PR (at 15 min: $P < .04$; at 30 min: $P < .01$; at 45 min: $P < .01$; at 60 min: $P < .02$) and RR (at 15 min: $P < .001$; at 30 min: $P < .002$; at 45 min: $P < .01$; at 60 min: $P < .05$).

In group A, median (IQR) value for all parameter readings from 15 minutes after study start to 60 minutes after study start was 33.0 (32.0-34.0) mm Hg for $P_{ETCO_2}$, 98.0% (97.3%-99.0%) for $Sao_2$, 130.0 (115.0-140.0) pulsations/min for PR, 30.0 (28.0-33.0) breaths/min for RR, and 3.5% (2.5%-4.5%) for PI. In group B, the median (IQR) value for all readings was 36.0 (34.0-38.0) mm Hg for $P_{ETCO_2}$, 98.0% (97.0%-98.0%) for $Sao_2$, 96.0 (84.0-104.5) pulsations/min for PR, 22.0 (20.0-25.0) breaths/min for RR, and 4.3% (2.8%-5.8%) for PI.

The mean (IQR) distance traveled by children during the walk test was 808.0 (920.0-557.8) m. Throughout the duration of the study, no child showed clinical signs of respiratory distress.

## Discussion

This cohort study found that use of surgical masks among children was not associated with episodes of oxygen desaturation or the development of clinical signs of respiratory distress during a walking test. We monitored $P_{ETCO_2}$ using a microstream system because this method is associated with greater accuracy. Because there is a temporal gap between the reduction of arterial oxygen pressure (ie, $Pao_2$) and its detection in the arterial blood,[37] this technical improvement may allow clinicians to more promptly detect a decrease in alveolar ventilation, a signal associated with impeding respiratory distress. In fact, studies[38,39] have found that clinical monitoring of oxygen saturation is not associated with early detection of alveolar hypoventilation and may therefore increase risks associated with hypoxemia and depression of respiratory activity. Five studies[40-44] have suggested the utility of $P_{ETCO_2}$ for hemodynamic monitoring, and $P_{ETCO_2}$ is defined as an early warning

Table 2. Respiratory Parameter Measures

| Parameter | Participants by group, median (IQR) | | | | | | | | |
| | Group A | | | | Group B | | | | |
| | At 15 min | At 30 min | At 45 min | At 60 min | At 15 min | At 30 min | At 45 min | At 60 min | After walking test |
|---|---|---|---|---|---|---|---|---|---|
| $Sao_2$, % | 98.0 (97.3-98.0) | 98.0 (98.0-99.0) | 98.0 (97.0-98.8) | 98.0 (97.5-98.0) | 98.0 (98.0-98.0) | 98.0 (97.0-98.0) | 98.0 (97.5-98.0-) | 98.0 (97.0-98.0) | 98.0 (97.0-98.0-) |
| $P_{ETCO_2}$, mm Hg | 33.0 (32.5-35.0) | 33.5 (32.3-34.8) | 33.0 (32.0-34.0) | 32.5 (32.0-34.0) | 37.0 (34.0-39.0) | 36.0 (34.0-38.0) | 36.0 (35.0-37.5) | 36.0 (34.0-38.0) | 36.0 (35.0-37.5) |
| PR, pulsations/min | 128.5 (113.5-140.0) | 128.5 (110.5-140.0) | 130.0 (118.5-140.0) | 130.0 (116.3-140.0) | 90.0 (84.0-103.5) | 91.0 (80.0-97.0) | 90.0 (85.0-98.5) | 99.0 (83.0-102.0) | 105.0 (100.0-115.0) |
| RR, breaths/min | 30.0 (28.0-31.5) | 31.0 (28.0-33.0) | 30.0 (26.5-33.8) | 31.0 (26.5-32.0) | 20.0 (17.5-24.0) | 21.0 (19.0-24.5) | 22.0 (20.0-25.0) | 24.0 (19.0-26.0) | 26.0 (24.0-29.0) |
| PI, % | 3.5 (2.6-4.5) | 2.9 (2.4-4.3) | 3.8 (2.6-4.8) | 3.6 (2.6-4.5) | 4.6 (2.9-5.8) | 4.3 (2.9-6.5) | 4.1 (2.6-6.2) | 4.3 (2.8-5.9) | 3.5 (2.7-5.0) |

Abbreviations: IQR, interquartile range; $P_{ETCO_2}$, partial pressure of end-tidal carbon dioxide; PI, perfusion index; PR, pulse rate; RR, respiratory rate; $Sao_2$, oxygen saturation.

system.[45] In our study, $P_{ETCO_2}$ remained in the reference range in both groups. Additionally, PI remained in the reference range during the study period. Use of face masks among children, therefore, was not associated with alveolar hypoventilation or hemodynamic instability.

Unfortunately, 2 children in group A dropped out because they refused to wear the surgical mask. We think that this may be associated with a possible bias, evaluated in a subsequent debriefing of our research group, associated with our initial inexperience. Among the children in group A, these 2 children were the first to be tested. After this initial failure, we had the parents conduct the training of their children instead of the doctor, which was associated with better compliance.

Overall, our findings suggest that recommendations against the use of surgical masks could be reconsidered in this age group, though our findings exclude possible adverse effects associated with gas exchange in children younger 24 months wearing face masks. However, CDC and AAP guidelines[32,33] state that infants and toddlers could have difficulty removing face masks and may not be able to communicate if they are having trouble breathing. Our findings may provide additional evidence suggesting that the use of face masks in this group of children in certain high-risk situations may not be associated with changes in respiratory function. However, constant supervision of adults would be needed.

## Limitations

This study has some limitations. The evaluation of parameters while children wore face masks was done for only 30 minutes. Further studies are needed to evaluate possible longer-term changes. Another limitation was the small sample size.

## Conclusions

This cohort study found that the use of surgical face masks among children was not associated with changes in respiratory function, including among children aged 24 months or younger. These findings may help promote the use of surgical masks among children, especially in view of the reopening of schools. Every precautionary measure against the diffusion of COVID-19 should be implemented. Furthermore, we think that children should be educated in the use of face masks by parents and school personnel. This may be associated with increased compliance with mask usage, especially among younger children. We do not know how long the present emergency will last, but we must prepare in case new lethal viruses should appear, possibly associated with increased adverse clinical outcomes among children.

**Corresponding Author:** Silvia Bloise, MD, Pediatric and Neonatology Unit, Maternal and Child Department, Sapienza University of Rome, Polo Pontino, Ospedale Santa Maria Goretti, Polo di Latina, Via Albenga 56, Rome 00186, Italy (silvia.bloise1989@gmail.com).

**Author Affiliations:** Pediatric and Neonatology Unit, Maternal and Child Department, Sapienza University of Rome, Polo Pontino, Rome Italy.

## REFERENCES

**1**. Zhang J, Litvinova M, Wang W, et al. Evolving epidemiology and transmission dynamics of coronavirus disease 2019 outside Hubei province, China: a descriptive and modelling study. *Lancet Infect Dis*. 2020;20(7):793-802. doi:10.1016/S1473-3099(20)30230-9

**2**. Shiu EYC, Leung NHL, Cowling BJ. Controversy around airborne versus droplet transmission of respiratory viruses: implication for infection prevention. *Curr Opin Infect Dis*. 2019;32(4):372-379. doi:10.1097/QCO.0000000000000563

**3**. Tellier R, Li Y, Cowling BJ, Tang JW. Recognition of aerosol transmission of infectious agents: a commentary. *BMC Infect Dis*. 2019;19(1):101. doi:10.1186/s12879-019-3707-y

**4**. World Health Organization. Modes of transmission of virus causing COVID-19: implications for IPC precaution recommendations. Updated October 20, 2020. Accessed April 3, 2020. https://www.who.int/emergencies/diseases/novel-coronavirus-2019/question-and-answers-hub/q-a-detail/q-a-how-is-covid-19-transmitted

**5**. Lewis D. Is the coronavirus airborne: experts can't agree. *Nature*. 2020;580(7802):175. doi:10.1038/d41586-020-00974-w

**6**. van Doremalen N, Bushmaker T, Morris DH, et al. Aerosol and surface stability of SARS-CoV-2 as compared with SARS-CoV-1. *N Engl J Med*. 2020;382(16):1564-1567. doi:10.1056/NEJMc2004973

**7**. Feng S, Shen C, Xia N, Song W, Fan M, Cowling BJ. Rational use of face masks in the COVID-19 pandemic. *Lancet Respir Med*. 2020;8(5):434-436. doi:10.1016/S2213-2600(20)30134-X

**8**. Day M. Covid-19: identifying and isolating asymptomatic people helped eliminate virus in Italian village. *BMJ*. 2020;368:m1165. doi:10.1136/bmj.m1165

**9**. Day M. Covid-19: four fifths of cases are asymptomatic, China figures indicate. *BMJ*. 2020;369:m1375. doi:10.1136/bmj.m1375

**10**. Zhou F, Yu T, Du R, et al. Clinical course and risk factors for mortality of adult inpatients with COVID-19 in Wuhan, China: a retrospective cohort study. *Lancet*. 2020;395(10229):1054-1062. doi:10.1016/S0140-6736(20)30566-3

**11**. Rothe C, Schunk M, Sothmann P, et al. Transmission of 2019-nCoV infection from an asymptomatic contact in Germany. *N Engl J Med*. 2020;382(10):970-971. doi:10.1056/NEJMc2001468

**12**. Qiu H, Wu J, Hong L, Luo Y, Song Q, Chen D. Clinical and epidemiological features of 36 children with coronavirus disease 2019 (COVID-19) in Zhejiang, China: an observational cohort study. *Lancet Infect Dis*. 2020;20(6):689-696. doi:10.1016/S1473-3099(20)30198-5

**13**. Lu X, Zhang L, Du H, et al; Chinese Pediatric Novel Coronavirus Study Team. SARS-CoV-2 infection in children. *N Engl J Med*. 2020;382(17):1663-1665. doi:10.1056/NEJMc2005073

**14**. Dong Y, Mo X, Hu Y, et al. Epidemiology of COVID-19 among children in China. *Pediatrics*. 2020;145(6):e20200702. doi:10.1542/peds.2020-0702

**15**. Esposito S, Principi N. School closure during the coronavirus disease 2019 (COVID-19) pandemic: an effective intervention at the global level? *JAMA Pediatr*. 2020;174(10):921-922. doi:10.1001/jamapediatrics.2020.1892

**16**. Wu Z, McGoogan JM. Characteristics of and important lessons from the coronavirus disease 2019 (COVID-19) outbreak in China: summary of a report of 72 314 cases from the Chinese Center for Disease Control and Prevention. *JAMA*. 2020;323(13):1239-1242. doi:10.1001/jama.2020.2648

**17**. Davies NG, Klepac P, Liu Y, Prem K, Jit M, Eggo RM; CMMID COVID-19 working group. Age-dependent effects in the transmission and control of COVID-19 epidemics. *Nat Med*. 2020;26(8):1205-1211. doi:10.1038/s41591-020-0962-9

**18**. Esposito S, Principi N. Debates around the role of school closures in the coronavirus 2019 pandemic-reply. *JAMA Pediatr*. 2021;175(1):107-108. doi:10.1001/jamapediatrics.2020.3552

**19**. Götzinger F, Santiago-García B, Noguera-Julián A, et al; ptbnet COVID-19 Study Group. COVID-19 in children and adolescents in Europe: a multinational, multicentre cohort study. *Lancet Child Adolesc Health*. 2020;4(9): 653-661. doi:10.1016/S2352-4642(20)30177-2

**20**. Yonker LM, Neilan AM, Bartsch Y, et al. Pediatric severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2): clinical presentation, infectivity, and immune responses. *J Pediatr*. 2020;227:45-52.e5. doi:10.1016/j.jpeds.2020.08.037

**21**. Huff HV, Singh A. Asymptomatic transmission during the COVID-19 pandemic and implications for public health strategies. *Clin Infect Dis*. 2020;ciaa654. Published online May 28, 2020. doi:10.1093/cid/ciaa654

**22**. Kam KQ, Yung CF, Cui L, et al. A well infant with coronavirus disease 2019 with high viral load. *Clin Infect Dis*. 2020;71(15):847-849. doi:10.1093/cid/ciaa201

**23**. Heald-Sargent T, Muller WJ, Zheng X, Rippe J, Patel AB, Kociolek LK. Age-related differences in nasopharyngeal severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) levels in patients with mild to moderate coronavirus disease 2019 (COVID-19). *JAMA Pediatr*. 2020;174(9):902-903. doi:10.1001/jamapediatrics.2020.3651

**24**. Ma Q-X, Shan H, Zhang H-L, Li G-M, Yang R-M, Chen J-M. Potential utilities of mask-wearing and instant hand hygiene for fighting SARS-CoV-2. *J Med Virol*. 2020;92(9):1567-1571. doi:10.1002/jmv.25805

**25**. Lau JT, Tsui H, Lau M, Yang X. SARS transmission, risk factors, and prevention in Hong Kong. *Emerg Infect Dis*. 2004;10(4):587-592. doi:10.3201/eid1004.030628

**26**. Chan KH, Yuen KY. COVID-19 epidemic: disentangling the re-emerging controversy about medical facemasks from an epidemiological perspective. *Int J Epidemiol*. 2020;49(4):1063-1066. doi:10.1093/ije/dyaa044

**27**. Li R, Pei S, Chen B, et al. Substantial undocumented infection facilitates the rapid dissemination of novel coronavirus (SARS-CoV-2). *Science*. 2020;368(6490):489-493. doi:10.1126/science.abb3221

**28**. He X, Lau EHY, Wu P, et al. Temporal dynamics in viral shedding and transmissibility of COVID-19. *Nat Med*. 2020;26(5):672-675. doi:10.1038/s41591-020-0869-5

**29**. Eikenberry SE, Mancuso M, Iboi E, et al. To mask or not to mask: modeling the potential for face mask use by the general public to curtail the COVID-19 pandemic. *Infect Dis Model*. 2020;5:293-308.

**30**. Kyung SY, Kim Y, Hwang H, Park JW, Jeong SH. Risks of N95 face mask use in subjects with COPD. *Respir Care*. 2020;65(5):658-664. doi:10.4187/respcare.06713

**31**. Lazzarino AI, Steptoe A, Hamer M, Michie S. Covid-19: important potential side effects of wearing face masks that we should bear in mind. *BMJ*. 2020;369:m2003. doi:10.1136/bmj.m2003

**32**. US Centers for Disease Control and Prevention. Guidance for K-12 school administrators on the use of masks in schools. Updated December 18, 2020. Accessed April 9, 2020. https://www.cdc.gov/coronavirus/2019-ncov/community/schools-childcare/cloth-face-cover.html

**33**. American Academy of Pediatrics. Cloth face coverings for children during COVID-19. Accessed April 9, 2020. https://www.healthychildren.org/English/health-issues/conditions/COVID-19/Pages/Cloth-Face-Coverings-for-Children-During-COVID-19.aspx

**34**. World Medical Association. World Medical Association Declaration of Helsinki: ethical principles for medical research involving human subjects. *JAMA*. 2013;310(20):2191-2194. doi:10.1001/jama.2013.281053

**35**. Italian Society of Pediatric Emergency and Urgent Medicine. COVID-19 and masks in children. Accessed January 25, 2021. https://www.facebook.com/SIMEUP/videos/2636235849928388

**36**. Cazzola M, Biscione GL, Pasqua F, et al. Use of 6-min and 12-min walking test for assessing the efficacy of formoterol in COPD. *Respir Med*. 2008;102(10):1425-1430. doi:10.1016/j.rmed.2008.04.017

**37**. Verhoeff F, Sykes MK. Delayed detection of hypoxic events by pulse oximeters: computer simulations. *Anaesthesia*. 1990;45(2):103-109. doi:10.1111/j.1365-2044.1990.tb14271.x

**38**. Coté CJ, Notterman DA, Karl HW, Weinberg JA, McCloskey C. Adverse sedation events in pediatrics: a critical incident analysis of contributing factors. *Pediatrics*. 2000;105(4 Pt 1):805-814. doi:10.1542/peds.105.4.805

**39**. Malviya S, Voepel-Lewis T, Tait AR. Adverse events and risk factors associated with the sedation of children by nonanesthesiologists. *Anesth Analg*. 1997;85(6):1207-1213. doi:10.1213/00000539-199712000-00005

**40**. Poirier MP, Gonzalez Del-Rey JA, McAneney CM, DiGiulio GA. Utility of monitoring capnography, pulse oximetry, and vital signs in the detection of airway mishaps: a hyperoxemic animal model. *Am J Emerg Med*. 1998; 16(4):350-352. doi:10.1016/S0735-6757(98)90125-5

**41**. Napolitano N, Nishisaki A, Buffman HS, Leffelman J, Maltese MR, Nadkarni VM. redesign of an open-system oxygen face mask with mainstream capnometer for children. *Respir Care*. 2017;62(1):70-77. doi:10.4187/respcare.04751

**42**. Lightdale JR, Goldmann DA, Feldman HA, Newburg AR, DiNardo JA, Fox VL. Microstream capnography improves patient monitoring during moderate sedation: a randomized, controlled trial. *Pediatrics*. 2006;117(6): e1170-e1178. doi:10.1542/peds.2005-1709

**43**. Soto RG, Fu ES, Vila H Jr, Miguel RV. Capnography accurately detects apnea during monitored anesthesia care. *Anesth Analg*. 2004;99(2):379-382. doi:10.1213/01.ANE.0000131964.67524.E7

**44**. Vargo JJ, Zuccaro G Jr, Dumot JA, Conwell DL, Morrow JB, Shay SS. Automated graphic assessment of respiratory activity is superior to pulse oximetry and visual assessment for the detection of early respiratory depression during therapeutic upper endoscopy. *Gastrointest Endosc*. 2002;55(7):826-831. doi:10.1067/mge.2002.124208

**45**. Blankush JM, Freeman R, McIlvaine J, Tran T, Nassani S, Leitman IM. Implementation of a novel postoperative monitoring system using automated Modified Early Warning Scores (MEWS) incorporating end-tidal capnography. *J Clin Monit Comput*. 2017;31(5):1081-1092. doi:10.1007/s10877-016-9943-4