

Research Letter

June 30, 2021

Experimental Assessment of Carbon Dioxide Content in Inhaled Air With or Without Face Masks in Healthy ChildrenA Randomized Clinical Trial

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JAMA Pediatr. Published online June 30, 2021. doi:10.1001/jamapediatrics.2021.2659

Many governments have made nose and mouth covering or face masks compulsory for schoolchildren. The evidence base for this is weak.^{1,2} The question whether nose and mouth covering increases carbon dioxide in inhaled air is crucial. A large-scale survey³ in Germany of adverse effects in parents and children using data of 25 930 children has shown that 68% of the participating children had problems when wearing nose and mouth coverings.

The normal content of carbon dioxide in the open is about 0.04% by volume (ie, 400 ppm). A level of 0.2% by volume or 2000 ppm is the limit for closed rooms according to the German Federal Environmental Office, and everything beyond this level is unacceptable.⁴

Methods

We measured carbon dioxide content in inhaled air with and without 2 types of nose and mouth coverings in a well-controlled, counterbalanced, short-term experimental study in volunteer children in good health (details are in the eMethods in [Supplement 1](#)). The study was conducted according to the Declaration of Helsinki and submitted to the ethics committee of the University Witten/Herdecke. All children gave written informed consent, and parents also gave written informed consent for children younger than 16 years. A 3-minute continuous measurement was taken for baseline carbon dioxide levels without a face mask. A 9-minute measurement for each type of mask was allowed: 3 minutes for measuring the carbon dioxide content in joint inhaled and exhaled air, 3 minutes for measuring the carbon dioxide content during inhalation, and 3 minutes for measuring the carbon dioxide content during exhalation. The carbon dioxide content of ambient air was always kept well under 0.1% by volume through multiple ventilations. The sequence of masks was randomized, and randomization was blinded and stratified by age of children. We analyzed data using a linear model for repeated measurements with $P < .05$ as the significance threshold. The measurement protocol (trial protocol in [Supplement 2](#)) is

available online.⁵ Data were collected on April 9 and 10, 2021, and analyzed using Statistica version 13.3 (TIBCO).

Results

The mean (SD) age of the children was 10.7 (2.6) years (range, 6-17 years), and there were 20 girls and 25 boys. Measurement results are presented in the [Table](#). We checked potential associations with outcome. Only age was associated with carbon dioxide content in inhaled air ($y = 1.9867 - 0.0555 \times x$; $r = -0.39$; $P = .008$; [Figure](#)). Hence, we added age as a continuous covariate to the model. This revealed an association (partial $\eta^2 = 0.43$; $P < .001$). Contrasts showed that this was attributable to the difference between the baseline value and the values of both masks jointly. Contrasts between the 2 types of masks were not significant. We measured means (SDs) between 13 120 (384) and 13 910 (374) ppm of carbon dioxide in inhaled air under surgical and filtering facepiece 2 (FFP2) masks, which is higher than what is already deemed unacceptable by the German Federal Environmental Office by a factor of 6. This was a value reached after 3 minutes of measurement. Children under normal conditions in schools wear such masks for a mean of 270 (interquartile range, 120-390) minutes.³ The [Figure](#) shows that the value of the child with the lowest carbon dioxide level was 3-fold greater than the limit of 0.2 % by volume.⁴ The youngest children had the highest values, with one 7-year-old child's carbon dioxide level measured at 25 000 ppm.

Discussion

The limitations of the study were its short-term nature in a laboratory-like setting and the fact that children were not occupied during measurements and might have been apprehensive. Most of the complaints reported by children³ can be understood as consequences of elevated carbon dioxide levels in inhaled air. This is because of the dead-space volume of the masks, which collects exhaled carbon dioxide quickly after a short time. This carbon dioxide mixes with fresh air and elevates the carbon dioxide content of inhaled air under the mask, and this was more pronounced in this study for younger children.

This leads in turn to impairments attributable to hypercapnia. A recent review⁶ concluded that there was ample evidence for adverse effects of wearing such masks. We suggest that decision-makers weigh the hard evidence produced by these experimental measurements accordingly, which suggest that children should not be forced to wear face masks.

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Article Information

Accepted for Publication: June 7, 2021.

Published Online: June 30, 2021. doi:[10.1001/jamapediatrics.2021.2659](https://doi.org/10.1001/jamapediatrics.2021.2659)

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Author Contributions: Dr Walach (principal investigator) had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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Critical revision of the manuscript for important intellectual content: Walach, Weikl, Prentice, Diemer, Kappes, Hockertz.

Statistical analysis: Walach.

Administrative, technical, or material support: Weikl, Prentice, Diemer, Traindl, Kappes, Hockertz.

Supervision: Weikl, Diemer, Traindl, Kappes, Hockertz.

Other—liaising with all other authors: Walach.

Conflict of Interest Disclosures: None reported.

Funding/Support: Mediziner und Wissenschaftler für Gesundheit, Freiheit und Demokratie eV, a public charity, has organized this study and covered only essential expenses, such as travel.

Role of the Funder/Sponsor: The funder had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Data Sharing Statement: See [Supplement 3](#).

References

1.

Xiao J, Shiu EYC, Gao H, et al. Nonpharmaceutical measures for pandemic influenza in nonhealthcare settings —personal protective and environmental measures. *Emerg*

Infect Dis. 2020;26(5):967-975. doi:[10.3201/eid2605.190994](https://doi.org/10.3201/eid2605.190994)[PubMedGoogle ScholarCrossref](#)

2.

Matuschek C, Moll F, Fangerau H, et al. Face masks: benefits and risks during the COVID-19 crisis. *Eur J Med Res.* 2020;25(1):32. doi:[10.1186/s40001-020-00430-5](https://doi.org/10.1186/s40001-020-00430-5)[PubMedGoogle ScholarCrossref](#)

3.

Schwarz S, Jenetzky E, Krafft H, Maurer T, Martin D. Corona children studies “Co-Ki”: first results of a Germany-wide registry on mouth and nose covering (mask) in children. Published 2021. Accessed June 15, 2021. <https://www.researchsquare.com/article/rs-124394/v1>

4.

Mitteilungen der Ad-hoc-Arbeitsgruppe Innenraumrichtwerte der Innenraumlufthygiene-Kommission des Umweltbundesamtes und der Obersten Landesgesundheitsbehörden. [Health evaluation of carbon dioxide in indoor air]. *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz.* 2008;51(11):1358-1369. doi:[10.1007/s00103-008-0707-2](https://doi.org/10.1007/s00103-008-0707-2)[PubMedGoogle ScholarCrossref](#)

5.

Walach H, Weigl R, Traindl H, et al. Is carbon dioxide content under nose-mouth covering in children without potential risks? a measurement study in healthy children. Published April 14, 2021. Accessed June 15, 2021. https://osf.io/yh97a/?view_only=df003592db5c4bd1ab183dad8a71834f

6.

Kisielinski K, Giboni P, Prescher A, et al. Is a mask that covers the mouth and nose free from undesirable side effects in everyday use and free of potential hazards? *Int J Environ Res Public Health.* 2021;18(8):4344. doi:[10.3390/ijerph18084344](https://doi.org/10.3390/ijerph18084344)[PubMedGoogle ScholarCrossref](#)