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# BMJ Open

## **SARS-CoV-2 IgG antibodies in adolescent students and their teachers in Saxony, Germany (SchoolCoviDD19): persistent low seroprevalence and transmission rates between May and October 2020**

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Keywords:	COVID-19, EPIDEMIOLOGY, PAEDIATRICS, Paediatric infectious disease & immunisation < PAEDIATRICS

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3 **SARS-CoV-2 IgG antibodies in adolescent students and their teachers in Saxony, Germany**  
4 **(SchoolCoviDD19): persistent low seroprevalence and transmission rates between May and**  
5 **October 2020**  
6  
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8

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24 **Abstract:**

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26 Objective: To quantify the number of SARS-CoV-2 infections in secondary schools after their  
27 reopening in May 2020.  
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29  
30 Design: Repeated SARS-CoV-2 seroprevalence study after the reopening of schools and 4 months  
31 later.  
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34 Setting: Secondary school in Dresden/Germany

35  
36 Participants: 1538 Students grade 8-12 and 507 teachers from 13 schools.

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38 Interventions: Serial blood sampling and SARS-CoV-2 IgG antibody assessment.

39  
40 Primary and secondary outcome measure: Seroprevalence of SARS-CoV-2 antibodies in study  
41 population. Number of undetected cases.

42  
43 Results: 1538 students and 507 teachers were initially enrolled, and 1334 students and 445 teachers  
44 completed both study visits. The seroprevalence for SARS-CoV-2 antibodies was 0.6% in May/June  
45 and the same in September/October. Even in schools with reported Covid-19 cases before the  
46 lockdown of March 13th no clusters could be identified. Of 12 persons with positive serology 5 had a  
47 known history of confirmed COVID-19; 23 out of 24 participants with a household history of COVID-  
48 19 were seronegative.

49  
50 Conclusions: Schools do not play a crucial role in driving the SARS-CoV-2 pandemic in a low  
51 prevalence setting. Transmission in families occurs very infrequently, and the number of unreported  
52 cases is low in this age group. These observations do not support school closures as a strategy  
53 fighting the pandemic in a low prevalence setting.

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55 Trial registration: DRKS00022455  
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10 **Strengths and limitations of this study:**

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13 Strengths:

14 Seroprevalence can detect mildly- or asymptomatic SARS-CoV-2 infections

15 Longitudinal study designs tracks individuals over time

16 Older students with multiple social contacts are a relevant target for pandemic control measures

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21 Limitations:

22 Loss to follow up

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27 **Funding Statement:**

28 This study was supported by a grant from the state of Saxony

29 Grant name: CoviDD19

30 The funder of the study had no role in the study design, data collection, data analysis, data  
31 interpretation, or writing of the report. The corresponding authors had full access to all the data in  
32 the study and had final responsibility for the decision to submit for publication.  
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40 **Competing Interest statement:**

41 All Authors declare no competing interests.  
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## Introduction:

Since the identification of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) as the cause of COVID-19 in December 2019 [1], the virus spread rapidly around the world, leading to the declaration of a pandemic by the World Health Organization on March 12<sup>th</sup> 2020. By March 18<sup>th</sup> 2020, 126 countries—including Germany—had implemented school closures as part of their pandemic control measures, with the number of countries peaking at 194 on April 10<sup>th</sup> 2020 and more than 90% of the world's student population being affected at this point[2, 3].

These actions were mainly based on the assumption that children play a similar role in transmitting SARS-CoV-2 as they do in transmitting influenza during outbreaks, for which evidence exists that school closures reduce the peak of the outbreak[4]. However, there is reason to believe that children play a less significant role in SARS-CoV-2 transmission compared to influenza, making control measures focused on this age group less effective: Most countries—including Germany—report a much lower proportion of cases in children compared to their population size[5–7]. In addition, several tracing studies in schools in different countries could only identify minimal spread of SARS-CoV-2 in educational settings. [8–10]

However, currently available data is insufficient to rule out that children are as likely as adults to be infected by and to transmit SARS-CoV-2, but simply show little to no symptoms of the disease.

We therefore aimed to quantify the proportion of adolescent schoolchildren and teachers in Saxony, one of the eastern Federal States of Germany, that already have developed antibodies against SARS-CoV-2. Until autumn 2020, in Saxony, the infection rates were comparatively low with 245-laboratory-confirmed SARS-CoV-2 infections per 100,000 inhabitants as of October 13<sup>th</sup> 2020.

## Methods:

### *Study Design*

After the reopening of the schools in Saxony on May 18<sup>th</sup>, 2020 students grade 8–11 and their teachers in 13 secondary schools in eastern Saxony were invited to participate in the SchoolCoviDD19 study. After teachers, students, and their legal guardians provided informed consent, 5 mL of peripheral venous blood were collected from each individual during visits at each participating school between May 25<sup>th</sup> and June 30<sup>th</sup>, 2020. In addition, participants were asked to complete a questionnaire on age, household size, previously diagnosed SARS-CoV-2 infections in themselves or their household contacts, comorbidities and regular medication. Students were also asked about regular social contacts outside their household or classroom.

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3 A second visit and repeat blood sampling took place between September 15<sup>th</sup> and October 13<sup>th</sup> 2020.  
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#### 6 7 *Approval*

8 The SchoolCoviDD19 study was approved by the Ethics Committee of the Technische Universität (TU)  
9 Dresden (BO-EK-156042020) and was registered on July 23<sup>rd</sup> 2020 and assigned the clinical trial  
10 number DRKS00022455.  
11  
12

#### 13 14 15 *Laboratory Analysis*

16 We assessed SARS-CoV-2 IgG antibodies in all samples using a commercially available  
17 chemiluminescence immunoassay (CLIA) technology for the quantitative determination of anti-S1  
18 and anti-S2 specific IgG antibodies to SARS-CoV-2 (Diasorin LIAISON® SARS-CoV-2 S1/S2 IgG Assay).  
19 Antibody levels > 15.0 AU/ml were considered positive and levels between 12.0 and 15.0 AU/ml were  
20 considered equivocal.  
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23 All samples with a positive or equivocal LIAISON® test result, as well as all samples from participants  
24 with a reported personal or household history of a SARS-CoV-2 infection, were re-tested with two  
25 additional serological tests: These were a chemiluminescent microparticle immunoassay (CMIA)  
26 intended for the qualitative detection of IgG antibodies to the nucleocapsid protein of SARS-CoV-2  
27 (Abbott Diagnostics® ARCHITECT SARS-CoV-2 IgG ) (an index (S/C) of < 1.4 was considered negative  
28 whereas one  $\geq$  1.4 was considered positive) and an ELISA detecting IgG against the S1 domain of  
29 the SARS-CoV-2 spike protein (Euroimmun® Anti-SARS-CoV-2 ELISA) (a ratio < 0.8 was considered  
30 negative, 0.8–1.1 equivocal, > 1.1 positive)  
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33 Participants whose positive or equivocal LIAISON® test result could be confirmed by a positive test  
34 result in at least one additional serological test were considered having antibodies against SARS-CoV-  
35 2.  
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#### 38 *Statistical Analysis*

39 Analyses were performed using IBM SPSS 25.0 and Microsoft Excel 2010. Results for continuous  
40 variables are presented as medians with interquartile ranges (IQR) and categorical variables as  
41 numbers with percentages, unless stated otherwise.  
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#### 44 *Patient and Public Involvement:*

45 The public was not involved in the design, recruitment and conduct of the study. Participants are able  
46 to receive their personal serological test result upon request.  
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#### 50 51 **Results:**

52 A total of 1538 students and 507 teachers from 13 different schools participated in the first visit of  
53 the study, 1334 students and 445 teachers completed the second visit. Demographic data is shown in  
54 Table 1.  
55  
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57 Seroprevalence of SARS-CoV-2 antibodies was 0.6% (12/2045) at the initial visit (May/June) with  
58 twelve participants—eleven students and one teacher—having detectable antibodies against SARS-  
59 CoV-2 in at least two different assays and thus being considered seropositive. At the follow-up visit  
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3 (September/October) seroprevalence was 0.7% (12/1779) with still eleven seropositive students and  
4 one teacher. Remarkably, one participants who tested positive in 2 assays in the initial sample tested  
5 positive in only one assay at the second timepoint and one participant who had equivocal results  
6 initially did test positive 3 months later. In 7 out of 13 schools, seropositive participants could be  
7 identified, with four seropositive participants in one school as the maximum. The seroprevalence  
8 ranged from 0 to 2.2 per individual school.  
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11 Of the few participants with a personal history of a SARS-CoV-2 infection, 4/5 were seropositive, with  
12 the fifth showing only an equivocal test result in one of the assays. Of all participants with a  
13 household history of a SARS-CoV-2 infection, 23/24 were seronegative, with 22/24 showing negative  
14 results in all three assays and one showing an equivocal result in only one assay.  
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16 During the study period laboratory-confirmed SARS-CoV-2 infections per 100,000 inhabitants in  
17 Saxony increased from 139 to 245.  
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## 25 Discussion:

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27 The findings from this unique study in older students and their teachers indicate that the prevalence  
28 of IgG antibodies against SARS-CoV-2 was very low after the first wave of the corona pandemic in  
29 Germany and during the reopening of the schools in May 2020 and remained low after summer  
30 holidays 2020. While this finding is consistent with local surveillance data[11] that shows a  
31 prevalence of PCR-confirmed cases of 0.8%, it clearly indicates that schools did not develop into  
32 silent hotspots of SARS-CoV-2 transmission during the first wave of the pandemic and even more  
33 importantly after reopening of the schools in May 2020. Even more important is the fact, that there  
34 was no increase in seropositivity and infections, respectively, in the four months between May after  
35 reopening and October after the summer holidays and the first weeks of back to school in the fall  
36 period. It has to be pointed out, however, that the infection rate in Saxony was constantly low during  
37 this time period. Nevertheless, the most relevant observation is that infection rates do not increase  
38 silently in schools when infection rates in the population are low. Of course, this does not preclude  
39 that with increasing infection rates in the population, infection rates in schools may also increase  
40 which is an important reminder that the general population has to act prudently in order to keep  
41 schools open.  
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46 In fact, 5 of the 12 participants with antibodies against SARS-CoV-2 had a personal or household  
47 history of COVID-19, yielding a ratio of unidentified to identified cases of 1.4, which is much smaller  
48 than that previously assumed by some authors[12]. We could not detect a single cluster of infections  
49 in the participating schools, even though at least three schools did have confirmed SARS-CoV-2 cases  
50 before the March 13<sup>th</sup> lockdown in Saxony. This is consistent with findings from the 2003 SARS  
51 outbreak [13, 14], and calls the effectiveness of transmission control measures focused mainly on the  
52 student population into question. This is especially relevant since there are clearly described adverse  
53 effects of school closures, as loss of education, loss of social contacts and social control, nutritional  
54 problems in children who rely on school meals, increases in harm to child welfare in vulnerable  
55 populations, as well as economic harm caused by loss to productivity due to parents being forced  
56 from work to childcare[15, 16]. Additionally, even with school closures in place, social contacts  
57 continue as informal child care and non-school gatherings[17], thereby reducing the potential benefit  
58 of school closures further. Our data support this finding this finding since an overwhelming majority  
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3 of not less than 80% of the participating students in our study reported to have regular social  
4 contacts outside their household or classroom.  
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8 Close contact with COVID-19 patients—especially in the same household—has been shown to  
9 increase viral transmission[18]. However, in our study, only one out of 24 participants with a  
10 confirmed SARS-CoV-2 infection in the same household became indeed infected as measured by  
11 antibody production. This suggests that either the transmissibility of the virus is lower than  
12 previously assumed or that there are certain quarantine and separation measures than can  
13 effectively reduce the probability of viral transmission even in close contact situations.  
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16 It was reported recently, that SARS-CoV2 spike-reactive CD4+ T cells could be detected in 35% of  
17 SARS-CoV2 unexposed healthy blood donors arguing for a certain level of T-cell crossreactivity. Such  
18 reactions could arise from exposure to commonly encountered Corona viruses. With children being  
19 frequently exposed to common Corona viruses it might be hypothesized that they are less  
20 susceptible to SARS-CoV2 infection due to a background of T-cell crossreactivity[19].  
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23 Currently no gold standard serological testing strategy for SARS-CoV-2 exists. Even though  
24 immunoassays yield better performance than rapid point-of-care tests[18] and the targeted SARS-  
25 CoV-2 S protein and nucleoprotein show a similarity of less than 30% to endemic  
26 betacoronaviruses[20], false positive results are still a concern, especially in low-prevalence  
27 populations and when interpreting results on a personal rather than a population-based level. By  
28 using a combination of three different immunoassays and only regarding participants with at least  
29 two positive results as seropositive for SARS-CoV-2, we could exclude ten participants with a positive  
30 and six with an equivocal initial test by negative confirmatory testing. In our population, a positive  
31 predictive value of 42.9% could be observed which was nearby an expected PPV of 45.3% for a  
32 prevalence of 0.59% population and the given test characteristics (sensitivity 97.6%, specificity  
33 99.3%). By using this approach, we could reliably identify patients with confirmed seropositivity  
34 against SARS-CoV-2 in a low-prevalence population.  
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#### 40 Conclusion:

41 As for now, students and teacher do not seem to play a substantial role in driving the SARS-CoV-2  
42 pandemic in Germany when observing the period after reopening of schools in May as well as after  
43 summer holidays until early autumn 2020 before facing the second pandemic wave. Transmission in  
44 families appears to occur very infrequently, and the number of unreported cases obviously is low in  
45 this age group. For serological testing, a combination of different immunoassays seems to be  
46 effective to increase the number of true positive test results.  
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#### 51 Author contribution statements:

52 J.A, R.B. and A.D designed the study and wrote the protocol. J.A., M.U. and C.K. collected  
53 samples. A.D. and C.L. performed serological testing. J.A., M.U., C.K. and R.B. analyzed the  
54 data. J.A. and C.K. wrote the manuscript. M.U. A.D., C.L. and R.B. reviewed the manuscript.  
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28 **Table 1: Demographic data**

	first study visit (May/June)		second study visit (September/October)	
	students	teachers	students	teachers
participants	1538 (75.2%)	507 (24.8%)	1334 (75.0%)	445 (25.0%)
age (median)	15 (14–16)	51 (37–57)	15 (14-16)	50 (36-57)
female	802 (52%)	357 (70%)	680 (51%)	313 (70%)
household size	4 (3–5)	2 (2–4)	4 (3-5)	2 (2-4)
Seropositive	11	1	11	1
Regular social contacts outside the student's household/classroom during the March 2020 Lockdown	1230 (80%)			
respiratory symptoms between study visits			587 (44%)	71 (16%)
febrile illness between study visits			67 (5%)	4 (0.9%)

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## SARS-CoV-2 seroprevalence in students and teachers – a longitudinal study from May to October 2020 in German secondary schools

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<b>Primary Subject Heading</b>:	Epidemiology
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Keywords:	COVID-19, EPIDEMIOLOGY, PAEDIATRICS, Paediatric infectious disease & immunisation < PAEDIATRICS

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3 **SARS-CoV-2 SEROPREVALENCE in students and teachers – a longitudinal study from May to**  
4 **October 2020 in German secondary schools**  
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23 **Abstract:**  
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45 19 were seronegative.  
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47

48 Conclusions: Schools do not play a crucial role in driving the SARS-CoV-2 pandemic in a low  
49 prevalence setting. Transmission in families occurs very infrequently, and the number of unreported  
50 cases is low in this age group. These observations do not support school closures as a strategy  
51 fighting the pandemic in a low prevalence setting.  
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53 Trial registration: DRKS00022455  
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8 **Strengths and limitations of this study:**  
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10 Strengths:  
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12 Seroprevalence can detect mildly- or asymptomatic SARS-CoV-2 infections  
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14 Longitudinal study designs tracks individuals over time  
15

16 Older students with multiple social contacts are a relevant target for pandemic control measures  
17

18 Limitations:  
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20 Loss to follow up  
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25 **Funding Statement:**  
26

27 This study was supported by a grant from the state of Saxony  
28

29 Grant name: CoviDD19  
30

31 The funder of the study had no role in the study design, data collection, data analysis, data  
32 interpretation, or writing of the report. The corresponding authors had full access to all the data in  
33 the study and had final responsibility for the decision to submit for publication.  
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38 **Competing Interest statement:**  
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40 All Authors declare no competing interests.  
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## Introduction:

Since the identification of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) as the cause of COVID-19 in December 2019 [1], the virus spread rapidly around the world, leading to the declaration of a pandemic by the World Health Organization on March 12<sup>th</sup> 2020. By March 18<sup>th</sup> 2020, 126 countries—including Germany—had implemented school closures as part of their pandemic control measures, with the number of countries peaking at 194 on April 10<sup>th</sup> 2020 and more than 90% of the world's student population being affected at this point[2, 3].

These actions were mainly based on the assumption that children play a similar role in transmitting SARS-CoV-2 as they do in transmitting influenza during outbreaks, for which evidence exists that school closures reduce the peak of the outbreak[4]. However, there is reason to believe that children play a less significant role in SARS-CoV-2 transmission compared to influenza, making control measures focused on this age group less effective: Most countries—including Germany—report a much lower proportion of cases in children compared to their population size[5–7] and a recent review on population-based seroprevalence studies found no evidence of overrepresentation of schoolchildren [8] In addition, several tracing studies in schools in different countries could only identify minimal spread of SARS-CoV-2 in educational settings. [9–11]

However, currently available data is insufficient to rule out that children are as likely as adults to be infected by and to transmit SARS-CoV-2, but simply show little to no symptoms of the disease.

We therefore aimed to quantify the proportion of adolescent schoolchildren and teachers in Saxony, one of the eastern Federal States of Germany, that already have developed antibodies against SARS-CoV-2. Until autumn 2020, in Saxony, the infection rates were comparatively low with 245-laboratory-confirmed SARS-CoV-2 infections per 100,000 inhabitants as of October 13<sup>th</sup> 2020.

## Methods:

### *Study Design*

After the reopening of the schools in Saxony on May 18<sup>th</sup>, 2020 students grade 8–11 and their teachers in 13 secondary schools in eastern Saxony were invited to participate in the SchoolCoviDD19 study. Schools were chosen by the state office for schools and education without involvement of the study team and all eligible students and teachers were invited to participate at each school. Participation rates varied from 12%-50% per school.

After teachers, students, and their legal guardians provided informed consent, 5 mL of peripheral venous blood were collected from each individual during visits at each participating school between May 25<sup>th</sup> and June 30<sup>th</sup>, 2020. In addition, participants were asked to complete a questionnaire on



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3 age, household size, previously diagnosed SARS-CoV-2 infections in themselves or their household  
4 contacts, comorbidities and regular medication. Students were also asked about regular social  
5 contacts outside their household or classroom.  
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7 A second visit and repeat blood sampling of the same participants took place between September  
8 15<sup>th</sup> and October 13<sup>th</sup> 2020. Between the two study visits schools in Saxony remained open with the  
9 regular summer break from July 20<sup>th</sup> until August 28<sup>th</sup> 2020.  
10  
11

### 12 13 *Approval*

14 The SchoolCoviDD19 study was approved by the Ethics Committee of the Technische Universität (TU)  
15 Dresden (BO-EK-156042020) and was registered on July 23<sup>rd</sup> 2020 and assigned the clinical trial  
16 number DRKS00022455.  
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18

### 19 20 21 *Laboratory Analysis*

22 We assessed SARS-CoV-2 IgG antibodies in all samples using a commercially available  
23 chemiluminescence immunoassay (CLIA) technology for the quantitative determination of anti-S1  
24 and anti-S2 specific IgG antibodies to SARS-CoV-2 (Diasorin LIAISON<sup>®</sup> SARS-CoV-2 S1/S2 IgG Assay –  
25 Sensitivity 97.6%, Specificity 99.3%). Antibody levels > 15.0 AU/ml were considered positive and  
26 levels between 12.0 and 15.0 AU/ml were considered equivocal.  
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28

29 All samples with a positive or equivocal LIAISON<sup>®</sup> test result, as well as all samples from participants  
30 with a reported personal or household history of a SARS-CoV-2 infection, were re-tested with two  
31 additional serological tests: These were a chemiluminescent microparticle immunoassay (CMIA)  
32 intended for the qualitative detection of IgG antibodies to the nucleocapsid protein of SARS-CoV-2  
33 (Abbott Diagnostics<sup>®</sup> ARCHITECT SARS-CoV-2 IgG – Specificity 99.6%, Sensitivity 97,9%) (an index  
34 (S/C) of < 1.4 was considered negative whereas one  $\geq$  1.4 was considered positive) and an ELISA  
35 detecting IgG against the S1 domain of the SARS-CoV-2 spike protein (Euroimmun<sup>®</sup> Anti-SARS-CoV-2  
36 ELISA - Specificity 98,3%, Sensitivity 96,9%) (a ratio < 0.8 was considered negative, 0.8–1.1 equivocal,  
37 > 1.1 positive)  
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40 Participants whose positive or equivocal LIAISON<sup>®</sup> test result could be confirmed by a positive test  
41 result in at least one additional serological test were considered having antibodies against SARS-CoV-  
42 2.  
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### 45 46 *Statistical Analysis*

47 Analyses were performed using IBM SPSS 25.0 and Microsoft Excel 2010. Results for continuous  
48 variables are presented as medians with interquartile ranges (IQR) and categorical variables as  
49 numbers with percentages, unless stated otherwise.  
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51

### 52 53 *Patient and Public Involvement:*

54 The public was not involved in the design, recruitment and conduct of the study. Participants are able  
55 to receive their personal serological test result upon request.  
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### 58 59 **Results:**

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3 A total of 1538 students and 507 teachers from 13 different schools participated in the first visit of  
4 the study, 1334 students and 445 teachers completed the second visit. Demographic data is shown in  
5 Table 1.  
6

7 Seroprevalence of SARS-CoV-2 antibodies was 0.6% (12/2045) at the initial visit (May/June) with  
8 twelve participants—eleven students and one teacher—having detectable antibodies against SARS-  
9 CoV-2 in at least two different assays and thus being considered seropositive. At the follow-up visit  
10 (September/October) seroprevalence was 0.7% (12/1779) with still eleven seropositive students and  
11 one teacher. Remarkably, one participants who tested positive in 2 assays in the initial sample tested  
12 positive in only one assay at the second timepoint and one participant who had equivocal results  
13 initially did test positive 3 months later. Using more liberal ( $\geq 1$  test positive) or more conservative  
14 (3 tests positive) definitions for seropositivity does not change the persistent low seroprevalence in  
15 the study population. In 7 out of 13 schools, seropositive participants could be identified, with four  
16 seropositive participants in one school as the maximum. The seroprevalence ranged from 0 to 2.2 per  
17 individual school.  
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21 Of the few participants with a personal history of a SARS-CoV-2 infection, 4/5 were seropositive, with  
22 the fifth showing only an equivocal test result in one of the assays. Of all participants with a  
23 household history of a SARS-CoV-2 infection, 23/24 were seronegative, with 22/24 showing negative  
24 results in all three assays and one showing an equivocal result in only one assay.  
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27 During the study period laboratory-confirmed SARS-CoV-2 infections per 100,000 inhabitants in  
28 Saxony increased from 139 to 245 and 7-day incidence rates ranged from 1/100.000 to 30/100.000.  
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### 36 **Discussion:**

37 The findings from this unique study in older students and their teachers indicate that the prevalence  
38 of IgG antibodies against SARS-CoV-2 was very low after the first wave of the corona pandemic in  
39 Germany and during the reopening of the schools in May 2020 and remained low after summer  
40 holidays 2020. While this finding is consistent with local surveillance data[12] that shows a  
41 prevalence of PCR-confirmed cases of 0.8%, it clearly indicates that schools did not develop into  
42 silent hotspots of SARS-CoV-2 transmission during the first wave of the pandemic and even more  
43 importantly after reopening of the schools in May 2020. Even more important is the fact, that there  
44 was no increase in seropositivity and infections, respectively, in the four months between May after  
45 reopening and October after the summer holidays and the first weeks of back to school in the fall  
46 period. Therefore, herd immunity in the population of students and teachers appears not to  
47 contribute substantially to protection in a low prevalence setting.  
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50  
51 It has to be pointed out, however, that the infection rate in Saxony was constantly low during this  
52 time period. Nevertheless, the most relevant observation is that infection rates do not increase  
53 silently in schools when infection rates in the population are low. Of course, this does not preclude  
54 that with increasing infection rates in the population, infection rates in schools may also increase  
55 which is an important reminder that the general population has to act prudently in order to keep  
56 schools open.  
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59 In fact, 5 of the 12 participants with antibodies against SARS-CoV-2 had a personal or household  
60 history of COVID-19, yielding a ratio of unidentified to identified cases of 1.4, which is much smaller

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3 than that previously assumed by some authors[13]. We could not detect a single cluster of infections  
4 in the participating schools, even though at least three schools did have confirmed SARS-CoV-2 cases  
5 before the March 13<sup>th</sup> lockdown in Saxony. This is consistent with findings from the 2003 SARS  
6 outbreak [14, 15], and calls the effectiveness of transmission control measures focused mainly on the  
7 student population into question. This is especially relevant since there are clearly described adverse  
8 effects of school closures, as loss of education, loss of social contacts and social control, nutritional  
9 problems in children who rely on school meals, increases in harm to child welfare in vulnerable  
10 populations, as well as economic harm caused by loss to productivity due to parents being forced  
11 from work to childcare[16, 17]. Additionally, even with school closures in place, social contacts  
12 continue as informal child care and non-school gatherings[18], thereby reducing the potential benefit  
13 of school closures further. Our data support this finding this finding since an overwhelming majority  
14 of not less than 80% of the participating students in our study reported to have regular social  
15 contacts outside their household or classroom.  
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21 While close contact with COVID-19 patients—especially in the same household—has been shown to  
22 increase viral transmission[19] a review of household transmission studies found secondary attack  
23 rates of only 0.17 [20] with underage household members being less likely affected compared to  
24 adults. Our finding that only one out of 24 participants with a confirmed SARS-CoV-2 infection in the  
25 same household became indeed infected as measured by antibody production supports these  
26 findings as well as findings that children in general appear to be less susceptible to SARS-CoV-2  
27 compared to adults [21, 22]. In addition, these results support studies showing that certain  
28 quarantine and separation measures than can effectively reduce the probability of viral transmission  
29 even in close contact situations [23].  
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33 The fact that we could not detect one additional seropositive participant in over 4 months is  
34 surprising even in a low prevalence setting, given that the reported cases doubled in the same period  
35 of time in Saxony. One explanation might be the recently reported detection of SARS-CoV2 spike-  
36 reactive CD4+ T cells in 35% of SARS-CoV2 unexposed healthy blood donors arguing for a certain level  
37 of T-cell crossreactivity. Such reactions could arise from exposure to commonly encountered Corona  
38 viruses. With children being frequently exposed to common Corona viruses it might be hypothesized  
39 that they are less susceptible to SARS-CoV2 infection due to a background of T-cell crossreactivity  
40 [24].  
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43 Currently no gold standard serological testing strategy for SARS-CoV-2 exists. Even though  
44 immunoassays yield better performance than rapid point-of-care tests[19] and the targeted SARS-  
45 CoV-2 S protein and nucleoprotein show a similarity of less than 30% to endemic  
46 betacoronaviruses[25], false positive results are still a concern, especially in low-prevalence  
47 populations and when interpreting results on a personal rather than a population-based level. By  
48 using a combination of three different immunoassays and only regarding participants with at least  
49 two positive results as seropositive for SARS-CoV-2, we could exclude ten participants with a positive  
50 and six with an equivocal initial test by negative confirmatory testing. In our population, a positive  
51 predictive value of 42.9% could be observed which was nearby an expected PPV of 45.3% for a  
52 prevalence of 0.59% population and the given test characteristics (sensitivity 97.6%, specificity  
53 99.3%). By using this approach, we could reliably identify patients with confirmed seropositivity  
54 against SARS-CoV-2 in a low-prevalence population.  
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58 There are several limitations to our study. We cannot provide information on eligible but  
59 nonparticipating students and teachers in the selected schools requiring additional caution when  
60 generalizing these results. In addition, there is a relevant loss of participants in the follow-up

sampling. While we do not have information why certain individuals dropped out, the fact that the second study visit took place in a before the beginning of the second wave (7-day incidence rates around 30/100.000) makes it unlikely that personal illness or widespread quarantine measures were responsible for this drop in participation

### Conclusion:

As for now, students and teacher do not seem to play a substantial role in driving the SARS-CoV-2 pandemic in Germany when observing the period after reopening of schools in May as well as after summer holidays until early autumn 2020 before facing the second pandemic wave. Transmission in families appears to occur very infrequently, and the number of unreported cases obviously is low in this age group. For serological testing, a combination of different immunoassays seems to be effective to increase the number of true positive test results.

### Author contribution statements:

J.A, R.B. and A.D designed the study and wrote the protocol. J.A., M.U. and C.K. collected samples. A.D. and C.L. performed serological testing. J.A., M.U., C.K. and R.B. analyzed the data. J.A. and C.K. wrote the manuscript. M.U. A.D., C.L. and R.B. reviewed the manuscript.

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Table 1: Demographic data

	first study visit (May/June)		second study visit (September/October)	
	students	teachers	students	teachers
participants	1538 (75.2%)	507 (24.8%)	1334 (75.0%)	445 (25.0%)
age (median)	15 (14–16)	51 (37–57)	15 (14-16)	50 (36-57)
female	802 (52%)	357 (70%)	680 (51%)	313 (70%)
household size	4 (3–5)	2 (2–4)	4 (3-5)	2 (2-4)
Seropositive	11	1	11	1
Regular social contacts outside the student's household/classroom during the March 2020 Lockdown	1230 (80%)			
respiratory symptoms between study visits			587 (44%)	71 (16%)
febrile illness between study visits			67 (5%)	4 (0.9%)

Supplemental table 1: seroprevalence based on different seropositivity definitions

	first study visit (May/June)	second study visit (September/October)
$\geq 1$ serological test positive	22/2045 (1.1%)	25/1779 (1.4%)
$\geq 2$ serological tests positive	12/2045 (0.6%)	12/1779 (0.7%)
3 serological tests positive	9/2045 (0.4%)	5/1779 (0.3%)

For peer review only



# BMJ Open

## SARS-CoV-2 seroprevalence in students and teachers – a longitudinal study from May to October 2020 in German secondary schools

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3 **SARS-CoV-2 seroprevalence in students and teachers – a longitudinal study from May to October**  
4 **2020 in German secondary schools**  
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8 Carolin Kirsten<sup>1</sup>, Manja Unrath<sup>1</sup>, Christian Lück<sup>2</sup>, Alexander H. Dalpke<sup>2</sup>, Reinhard Berner<sup>1</sup>, Jakob P.  
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20  
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22

23 **Abstract:**  
24

25 Objective: To quantify the number of SARS-CoV-2 infections in secondary schools after their  
26 reopening in May 2020.  
27

28 Design: Repeated SARS-CoV-2 seroprevalence study after the reopening of schools and 4 months  
29 later.  
30

31 Setting: Secondary school in Dresden/Germany  
32

33 Participants: 1538 Students grade 8-12 and 507 teachers from 13 schools.  
34

35 Interventions: Serial blood sampling and SARS-CoV-2 IgG antibody assessment.  
36

37 Primary and secondary outcome measure: Seroprevalence of SARS-CoV-2 antibodies in study  
38 population. Number of undetected cases.  
39

40 Results: 1538 students and 507 teachers were initially enrolled, and 1334 students and 445 teachers  
41 completed both study visits. The seroprevalence for SARS-CoV-2 antibodies was 0.6% in May/June  
42 and the same in September/October. Even in schools with reported Covid-19 cases before the  
43 lockdown of March 13th no clusters could be identified. Of 12 persons with positive serology 5 had a  
44 known history of confirmed COVID-19; 23 out of 24 participants with a household history of COVID-  
45 19 were seronegative.  
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48 Conclusions: Schools do not play a crucial role in driving the SARS-CoV-2 pandemic in a low  
49 prevalence setting. Transmission in families occurs very infrequently, and the number of unreported  
50 cases is low in this age group. These observations do not support school closures as a strategy  
51 fighting the pandemic in a low prevalence setting.  
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53 Trial registration: DRKS00022455  
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8 **Strengths and limitations of this study:**  
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10 Strengths:  
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12 Seroprevalence can detect mildly- or asymptomatic SARS-CoV-2 infections  
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14 Longitudinal study designs tracks individuals over time  
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16 Older students with multiple social contacts are a relevant target for pandemic control measures  
17

18 Limitations:  
19

20 Loss to follow up  
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26

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28

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30

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32 interpretation, or writing of the report. The corresponding authors had full access to all the data in  
33 the study and had final responsibility for the decision to submit for publication.  
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## Introduction:

Since the identification of the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) as the cause of COVID-19 in December 2019 [1], the virus spread rapidly around the world, leading to the declaration of a pandemic by the World Health Organization on March 12<sup>th</sup> 2020. By March 18<sup>th</sup> 2020, 126 countries—including Germany—had implemented school closures as part of their pandemic control measures, with the number of countries peaking at 194 on April 10<sup>th</sup> 2020 and more than 90% of the world's student population being affected at this point[2, 3].

These actions were mainly based on the assumption that children play a similar role in transmitting SARS-CoV-2 as they do in transmitting influenza during outbreaks, for which evidence exists that school closures reduce the peak of the outbreak[4]. However, there is reason to believe that children play a less significant role in SARS-CoV-2 transmission compared to influenza, making control measures focused on this age group less effective: Most countries—including Germany—report a much lower proportion of cases in children compared to their population size[5–7] and a recent review on population-based seroprevalence studies found no evidence of overrepresentation of schoolchildren [8] In addition, several tracing studies in schools in different countries could only identify minimal spread of SARS-CoV-2 in educational settings. [9–11]

However, currently available data is insufficient to rule out that children are as likely as adults to be infected by and to transmit SARS-CoV-2, but simply show little to no symptoms of the disease.

We therefore aimed to quantify the proportion of adolescent schoolchildren and teachers in Saxony, one of the eastern Federal States of Germany, that already have developed antibodies against SARS-CoV-2. Until autumn 2020, in Saxony, the infection rates were comparatively low with 245-laboratory-confirmed SARS-CoV-2 infections per 100,000 inhabitants as of October 13<sup>th</sup> 2020.

## Methods:

### *Study Design*

After the reopening of the schools in Saxony on May 18<sup>th</sup>, 2020 students grade 8–11 and their teachers in 13 secondary schools in eastern Saxony were invited to participate in the SchoolCoviDD19 study. Schools were chosen by the state office for schools and education without involvement of the study team out of the 537 secondary schools in Saxony. Only the selected schools were contacted, none of them declined participation. All eligible students and teachers were invited to participate at each school. Participation rates varied from 12%-50% per school.

After teachers, students, and their legal guardians provided informed consent, 5 mL of peripheral venous blood were collected from each individual during visits at each participating school between

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3 May 25<sup>th</sup> and June 30<sup>th</sup>, 2020. In addition, participants were asked to complete a questionnaire on  
4 age, household size, previously diagnosed SARS-CoV-2 infections in themselves or their household  
5 contacts, comorbidities and regular medication. Students were also asked about regular social  
6 contacts outside their household or classroom.  
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9 A second visit and repeat blood sampling of the same participants took place between September  
10 15<sup>th</sup> and October 13<sup>th</sup> 2020. Between the two study visits schools in Saxony remained open with the  
11 regular summer break from July 20<sup>th</sup> until August 28<sup>th</sup> 2020.  
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### 13 14 15 *Approval*

16 The SchoolCoviDD19 study was approved by the Ethics Committee of the Technische Universität (TU)  
17 Dresden (BO-EK-156042020) and was registered on July 23<sup>rd</sup> 2020 and assigned the clinical trial  
18 number DRKS00022455.  
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### 20 21 22 23 *Laboratory Analysis*

24 We assessed SARS-CoV-2 IgG antibodies in all samples using a commercially available  
25 chemiluminescence immunoassay (CLIA) technology for the quantitative determination of anti-S1  
26 and anti-S2 specific IgG antibodies to SARS-CoV-2 (Diasorin LIAISON<sup>®</sup> SARS-CoV-2 S1/S2 IgG Assay –  
27 Sensitivity 97.6%, Specificity 99.3%). Antibody levels > 15.0 AU/ml were considered positive and  
28 levels between 12.0 and 15.0 AU/ml were considered equivocal.  
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31 All samples with a positive or equivocal LIAISON<sup>®</sup> test result, as well as all samples from participants  
32 with a reported personal or household history of a SARS-CoV-2 infection, were re-tested with two  
33 additional serological tests: These were a chemiluminescent microparticle immunoassay (CMIA)  
34 intended for the qualitative detection of IgG antibodies to the nucleocapsid protein of SARS-CoV-2  
35 (Abbott Diagnostics<sup>®</sup> ARCHITECT SARS-CoV-2 IgG – Specificity 99.6%, Sensitivity 97,9%) (an index  
36 (S/C) of < 1.4 was considered negative whereas one  $\geq$  1.4 was considered positive) and an ELISA  
37 detecting IgG against the S1 domain of the SARS-CoV-2 spike protein (Euroimmun<sup>®</sup> Anti-SARS-CoV-2  
38 ELISA - Specificity 98,3%, Sensitivity 96,9%) (a ratio < 0.8 was considered negative, 0.8–1.1 equivocal,  
39 > 1.1 positive)  
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43 Participants whose positive or equivocal LIAISON<sup>®</sup> test result could be confirmed by a positive test  
44 result in at least one additional serological test were considered having antibodies against SARS-CoV-  
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### 47 48 *Statistical Analysis*

49 Analyses were performed using IBM SPSS 25.0 and Microsoft Excel 2010. Results for continuous  
50 variables are presented as medians with interquartile ranges (IQR) and categorical variables as  
51 numbers with percentages, unless stated otherwise.  
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53 A sample size calculation was performed based on a expected seroprevalence of 1% with 5%  
54 precision and a 95% confidence level which yielded a minimum sample size of 500 participants which  
55 we exceeded at both timepoints.  
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### 57 58 *Patient and Public Involvement:*

59 The public was not involved in the design, recruitment and conduct of the study. Participants are able  
60 to receive their personal serological test result upon request.

## Results:

A total of 1538 students and 507 teachers from 13 different schools participated in the first visit of the study, 1334 students and 445 teachers completed the second visit. Demographic data is shown in Table 1.

Seroprevalence of SARS-CoV-2 antibodies was 0.6% (12/2045) at the initial visit (May/June) with twelve participants—eleven students and one teacher—having detectable antibodies against SARS-CoV-2 in at least two different assays and thus being considered seropositive. At the follow-up visit (September/October) seroprevalence was 0.7% (12/1779) with still eleven seropositive students and one teacher. Remarkably, one participant who tested positive in 2 assays May tested positive in only one assay in October and was therefore no longer considered seropositive per study definition, while one participant with equivocal results initially did test positive in two serological tests 3 months later. The remaining 11 seropositive participants had no changes in their test results. Using more liberal ( $\geq 1$  test positive) or more conservative (3 tests positive) definitions for seropositivity does not change the persistent low seroprevalence in the study population. In 7 out of 13 schools, seropositive participants could be identified, with four seropositive participants in one school as the maximum. The seroprevalence ranged from 0 to 2.2 per individual school.

Of the few participants with a personal history of a SARS-CoV-2 infection, 4/5 were seropositive, with the fifth showing only an equivocal test result in one of the assays. Of all participants with a household history of a SARS-CoV-2 infection, 23/24 were seronegative, with 22/24 showing negative results in all three assays and one showing an equivocal result in only one assay.

During the study period laboratory-confirmed SARS-CoV-2 infections per 100,000 inhabitants in Saxony increased from 139 to 245 and 7-day incidence rates ranged from 1/100.000 to 30/100.000.

## Discussion:

The findings from this unique study in older students and their teachers indicate that the prevalence of IgG antibodies against SARS-CoV-2 was very low after the first wave of the corona pandemic in Germany and during the reopening of the schools in May 2020 and remained low after summer holidays 2020. While this finding is consistent with local surveillance data[12] that shows a prevalence of PCR-confirmed cases of 0.8%, it clearly indicates that schools did not develop into silent hotspots of SARS-CoV-2 transmission during the first wave of the pandemic and even more importantly after reopening of the schools in May 2020. Even more important is the fact, that there was no increase in seropositivity and infections, respectively, in the four months between May after reopening and October after the summer holidays and the first weeks of back to school in the fall period. Therefore, herd immunity in the population of students and teachers appears not to contribute substantially to protection in a low prevalence setting.

It has to be pointed out, however, that the infection rate in Saxony was constantly low during this time period. Nevertheless, the most relevant observation is that infection rates do not increase silently in schools when infection rates in the population are low. Of course, this does not preclude that with increasing infection rates in the population, infection rates in schools may also increase

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3 which is an important reminder that the general population has to act prudently in order to keep  
4 schools open.  
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6 In fact, 5 of the 12 participants with antibodies against SARS-CoV-2 had a personal or household  
7 history of COVID-19, yielding a ratio of unidentified to identified cases of 1.4, which is much smaller  
8 than that previously assumed by some authors[13]. We could not detect a single cluster of infections  
9 in the participating schools, even though at least three schools did have confirmed SARS-CoV-2 cases  
10 before the March 13<sup>th</sup> lockdown in Saxony. This is consistent with findings from the 2003 SARS  
11 outbreak [14, 15], and calls the effectiveness of transmission control measures focused mainly on the  
12 student population into question. This is especially relevant since there are clearly described adverse  
13 effects of school closures, as loss of education, loss of social contacts and social control, nutritional  
14 problems in children who rely on school meals, increases in harm to child welfare in vulnerable  
15 populations, as well as economic harm caused by loss to productivity due to parents being forced  
16 from work to childcare[16, 17]. Additionally, even with school closures in place, social contacts  
17 continue as informal child care and non-school gatherings[18], thereby reducing the potential benefit  
18 of school closures further. Our data support this finding this finding since an overwhelming majority  
19 of not less than 80% of the participating students in our study reported to have regular social  
20 contacts outside their household or classroom.  
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27 While close contact with COVID-19 patients—especially in the same household—has been shown to  
28 increase viral transmission[19] a review of household transmission studies found secondary attack  
29 rates of only 0.17 [20] with underage household members being less likely affected compared to  
30 adults. Our finding that only one out of 24 participants with a confirmed SARS-CoV-2 infection in the  
31 same household became indeed infected as measured by antibody production supports these  
32 findings as well as findings that children in general appear to be less susceptible to SARS-CoV-2  
33 compared to adults [21, 22]. In addition, these results support studies showing that certain  
34 quarantine and separation measures than can effectively reduce the probability of viral transmission  
35 even in close contact situations [23].  
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38 The fact that we could not detect one additional seropositive participant in over 4 months is  
39 surprising even in a low prevalence setting, given that the reported cases doubled in the same period  
40 of time in Saxony. One explanation might be the recently reported detection of SARS-CoV2 spike-  
41 reactive CD4+ T cells in 35% of SARS-CoV2 unexposed healthy blood donors arguing for a certain level  
42 of T-cell crossreactivity. Such reactions could arise from exposure to commonly encountered Corona  
43 viruses. With children being frequently exposed to common Corona viruses it might be hypothesized  
44 that they are less susceptible to SARS-CoV2 infection due to a background of T-cell crossreactivity  
45 [24].  
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48 Currently no gold standard serological testing strategy for SARS-CoV-2 exists. Even though  
49 immunoassays yield better performance than rapid point-of-care tests[19] and the targeted SARS-  
50 CoV-2 S protein and nucleoprotein show a similarity of less than 30% to endemic  
51 betacoronaviruses[25], false positive results are still a concern, especially in low-prevalence  
52 populations and when interpreting results on a personal rather than a population-based level. By  
53 using a combination of three different immunoassays and only regarding participants with at least  
54 two positive results as seropositive for SARS-CoV-2, we could exclude ten participants with a positive  
55 and six with an equivocal initial test by negative confirmatory testing. In our population, a positive  
56 predictive value of 42.9% could be observed which was nearby an expected PPV of 45.3% for a  
57 prevalence of 0.59% population and the given test characteristics (sensitivity 97.6%, specificity  
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99.3%). By using this approach, we could reliably identify patients with confirmed seropositivity against SARS-CoV-2 in a low-prevalence population.

There are several limitations to our study. We cannot provide information on eligible but nonparticipating students and teachers in the selected schools requiring additional caution when generalizing these results. In addition, there is a relevant loss of participants in the follow-up sampling. While we do not have information why certain individuals dropped out, the fact that the second study visit took place in a before the beginning of the second wave (7-day incidence rates around 30/100.000) makes it unlikely that personal illness or widespread quarantine measures were responsible for this drop in participation

#### Conclusion:

As for now, students and teacher do not seem to play a substantial role in driving the SARS-CoV-2 pandemic in Germany when observing the period after reopening of schools in May as well as after summer holidays until early autumn 2020 before facing the second pandemic wave. Transmission in families appears to occur very infrequently, and the number of unreported cases obviously is low in this age group. For serological testing, a combination of different immunoassays seems to be effective to increase the number of true positive test results.

#### Author contribution statements:

J.A, R.B. and A.D designed the study and wrote the protocol. J.A., M.U. and C.K. collected samples. A.D. and C.L. performed serological testing. J.A., M.U., C.K. and R.B. analyzed the data. J.A. and C.K. wrote the manuscript. M.U. A.D., C.L. and R.B. reviewed the manuscript.

#### *Ethics approval statement*

The SchoolCoviDD19 study was approved by the Ethics Committee of the Technische Universität (TU) Dresden (BO-EK-156042020) and was registered on July 23<sup>rd</sup> 2020 and assigned the clinical trial number DRKS00022455. All participants and their legal guardians – when applicable - provided informed consent.

#### *Data availability statement*

Data are available upon reasonable request. Proposals should be submitted to corresponding author (jakob.armann@uniklinikum-dresden.de).

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33 Table 1: Demographic data

	first study visit (May/June)		second study visit (September/October)	
	students	teachers	students	teachers
participants	1538 (75.2%)	507 (24.8%)	1334 (75.0%)	445 (25.0%)
age (median)	15 (14–16)	51 (37–57)	15 (14-16)	50 (36-57)
female	802 (52%)	357 (70%)	680 (51%)	313 (70%)
household size	4 (3–5)	2 (2–4)	4 (3-5)	2 (2-4)
Seropositive	11	1	11	1
Regular social contacts outside the student's household/classroom during the March 2020 Lockdown	1230 (80%)			
respiratory symptoms between study visits			587 (44%)	71 (16%)
febrile illness between study visits			67 (5%)	4 (0.9%)

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54 Demographic and clinical Characteristics at baseline and follow-up. Data is presented as numbers  
55 with percentages except for age which is presented as median with interquartile range  
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Supplemental table 1: seroprevalence based on different seropositivity definitions

	first study visit (May/June)	second study visit (September/October)
$\geq 1$ serological test positive	22/2045 (1.1%)	25/1779 (1.4%)
$\geq 2$ serological tests positive	12/2045 (0.6%)	12/1779 (0.7%)
3 serological tests positive	9/2045 (0.4%)	5/1779 (0.3%)

Number of seropositive participants based on different definitions. Data is presented as numbers with percentages.

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