Risk of infection and contribution to transmission of SARS-CoV-2 in school staff: a systematic review

Sudip Jung Karki 1, 2, Alexander Joachim, 2 Torben Heinson, 1, 3 Berit Lange 1, 3

ABSTRACT

Objective To summarise the comparative risk of infection in school staff and their contribution to SARS-CoV-2 transmission.

Design Systematic review using Preferred Reporting Items for Systematic Reviews and Meta-Analyses guideline.

Data sources MEDLINE, WHO COVID-19 database and preView were searched on 29 January 2021.

Eligibility criteria We included studies that reported risk of SARS-CoV-2 infection in school staff or transmission of SARS-CoV-2 in school settings.

Data extraction and synthesis Data extraction was done in duplicates. Data synthesis was qualitative. We report attack rates and infection risk in school settings for staff and students stratified by control measures taken and infection dynamics at the point of data collection.

Results Eighteen studies were included. Three studies in low incidence settings showed low attack rates similar for teachers and students. Five studies in medium incidence settings and two studies in high incidence settings showed secondary attack rates up to 16% in school staff. Seroprevalence studies, two in low and high incidence settings showed an infection risk of 0%–0.2% and 1.7%–28% for teachers. The risk of infection for teachers compared with students were similar in one study in low incidence setting, higher in three studies (RR 1.2–4.4) and lower in three studies in medium to high incidence settings. The risk of infection for teachers in a high infection environment is higher in face-to-face than in distance classes when compared with general population groups. The risk of infections as well as risk of hospitalisation both increased for teachers during school openings compared with school closure.

Conclusion While in low incidence settings there is little evidence for school staff to be at high risk of SARS-CoV-2 infection, in high incidence settings there is an increased risk of SARS-CoV-2 infection in school staff teaching face-to-face compared to staff teaching digitally and general population.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ The study results were stratified according to the prevalence of infection during data collection period and prevailing control measures in the school setting at that time.

⇒ The infection risk in teachers/school staff were compared with infection risk in students, general population and teachers.

⇒ The results from included studies were heterogeneous.

INTRODUCTION

COVID-19 is a global public health threat, caused by SARS-CoV-2. 1 Although people of all ages are affected, the severity of the clinical course increases with age (more severe in people >65 years of age). 2, 3 Children and adolescents most commonly experience a mild clinical course and show less severe outcomes compared with adults and ageing people. 4–7 When showing severe outcomes, long-term complications can be equal or worse in children than in adults. 5

Non-pharmaceutical interventions (NPIs) like isolation, quarantine and social distancing including large-scale school closures are applied near-universally to curb the transmission of SARS-CoV-2. 9–10 Such conventional public health measures appear to reduce the number of new infections. 10–11 However, school closures alone are not sufficient to prevent community transmission of SARS-CoV-2. 12–13

Several systematic reviews, meta-analyses and large ecological analyses have focused on effects and adverse effects of school closures mainly assessing endpoints concerning the effect on community transmission as well as effects on children. 9–14 15 Long-term school closures are a threat to the physical and mental health of children and adolescents and intensify the racial and socioeconomic gaps in society. 10–20

Nevertheless, keeping schools open when community transmissions are increasing may be posing a threat to school staff in particular, as their age leaves them more at risk of severe infections compared with students. Evaluating the risk to school staff as well their role in schools and community transmission is thus essential to an evidence-based approach to pandemic public health strategies.
In an umbrella review (Lange et al, submitted) we did not find any systematic review focusing on risk of and contribution to transmission of school staff.

The risk of infection in school staff in dynamic infection environments depends on the population infection dynamic as well as the infection dynamic within schools, the susceptibility of staff to the infection and the number of contacts of the staff at that time. An absolute estimate of the risk of infection is futile due to its dependence on the evolving context. We have therefore collated the existing evidence on the relative risk of infection compared with other population groups in original papers and existing reports and stratified by infection dynamic prevalent during the period of data collection.

**METHODS**

**Protocol and registration**

We followed Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines and registered this review with PROSPERO.

**Search strategy**

We searched MEDLINE and preView most recently on 29 January 2021 by using search terms “SARS-CoV-2”/“COVID-19” and “teacher”/“school” combinations with OR and AND Boolean operators. We also searched WHO COVID-19 database for relevant literatures.

We did not restrict our search to any study design or language of publication. Preprints are included in this search if available from preprint databases. We did not consider the preprint available only on homepages or institute websites.

**Eligibility criteria**

Studies reporting the risk of COVID-19 in teachers or any school staff or any kind of involvement of teacher or school staff in SARS-CoV-2 transmission were eligible for inclusion in the review. Articles published in peer-reviewed journals, preprints, technical reports and case reports were included. Studies and reports were also included based on expert suggestion.

Modelling studies, opinion analysis, media reports, reviews and meta-analysis were excluded. We also excluded studies reporting SARS-CoV-2 transmission in students and school staff but in different school settings and studies reporting solely risk factors for SARS-CoV-2 infection in teachers or students. The Patients/Population, Intervention, Comparison and Outcomes for the included studies is presented in table 1.

**Synthesis of results**

Qualitative data synthesis was performed by describing study characteristics and main research questions, with the main conclusions of included studies presented narratively and in table format. The findings were presented based on the different type of SARS-CoV-2 transmission found in the school setting. When absolute numbers were available, we calculated (secondary) attack rates. When authors already calculated the attack rate we report them as given. Where infections risk is given by either seroprevalence or PCR-based

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Patients/Population, Intervention, comparison and Outcome for included studies</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Transmission of SARS-CoV-2 in school</strong></td>
<td><strong>School staff, any contacts of school staff</strong></td>
</tr>
</tbody>
</table>

**Study selection**

Two reviewers (SJK and AJ) screened the title and abstracts and read the full-text independently based on the predefined eligibility criteria. Inconsistencies and disagreements in the judgement were resolved by consultation with a third reviewer (BL).

**Patient and public involvement**

Patients or the public were not involved in any stage of this systematic review.

**Data extraction**

Two reviewers (SJK and AJ) independently extracted the data from included studies into a prespecified form. Disagreements in the data extraction process were resolved by consultation with the third reviewer (BL). Data related to study characteristics (source, name of first author, study design/type, date of data collection), study population (population of staff, population of students and population of contacts), main issue, study setting, comparator, attack rate in staff, attack rate in student, infection risk in student, infection risk in staff, outcome and results were extracted.

**Quality appraisal**

The Agency for Healthcare Research and Quality checklist was adapted to assess the quality of included studies. The risk of bias domains used were selection bias, performance bias, attrition bias, detection bias, reporting bias and information bias. The overall risk of bias for included studies was classified as high, unclear, medium or low risk of bias. The criteria for high risk of bias for included studies are high risk of bias in any one of the domains. Studies with unclear risk of bias in any one of the key domains and no high risk of bias in any other domain were deemed unclear risk of bias. Studies with medium risk of bias in any one of the domains and low risk of bias in all other domains were deemed medium risk of bias and those with low risk of bias in all the domains were deemed low risk of bias.
testing, we report them as given. All outcomes are reported stratified by infection environment and NPIs measures in place during data collection periods.

RESULTS
Study selection and study characteristics
The search yielded 1784 studies. Of these, eight met the inclusion criteria. A further 10 studies were found through screening references of systematic reviews, meta-analyses and following expert suggestions. Eighteen studies were included in the review; the selection process is described in figure 1.

Almost all of the included studies were conducted in 2020. Ten of the included studies had a data collection/analysis period from January to June.25-34 Three studies have collected data from April to July,35 in June/July,36 or in July only.37 One study collected data from July to September,38 and two studies had data collection periods from August to November.39,40 One study uses data from March 2020 to January 2021,41 and the remaining study analysed data from 12 March 2020.42 During the data collection period, the total number of SARS-CoV-2 cases in the countries of study ranged from 1.44 cases/million to 26 802 cases/million and SARS-CoV-2-related deaths from 0.03 deaths/million to 339.68 deaths/million.43 Similarly, the number of new cases per day at the start of the study interval ranges from 0 to 169.71 cases per million per day. At the end of the study period the incidence ranges from 0.29 to 423.22 cases per million per day.43

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**Figure 1** Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram.
The studies were originated in Australia, France, Germany, Ireland, Italy, Panama, Singapore, Sweden, the UK, Scotland and the USA. Among them three were reports published by the Public Health Agency of Sweden and by the National Centre for Immunization Research and Surveillance, New South Wales, Australia. Five were published in preprint with the remaining ten studies published in peer-review journals.

All included studies provide information about either risk of SARS-CoV-2 infection in teachers and/or students, transmission of SARS-CoV-2 in school settings or seroprevalence of SARS-CoV-2 IgG antibodies in school staff or school settings. Most of the included studies report attack rates. Of the remaining seven studies, six reported attack rates of 0%–13% following index cases, and up to 13% of students.\(^{27} 32 39\) was reported that up to 16% of school staff developed infection was in the medium range, reported that 0%–4.4% of school staff and 0%–6.5% of students developed secondary infections following index cases.\(^{29} 30 36 38 40\) Two studies conducted while population infection incidence was reported that up to 16% of school staff developed infections following index cases, and up to 15% of students.\(^{32} 39\)

Regarding seroprevalence studies, two studies conducted during a medium incidence of infection show an infection risk of 0% and 0.2% for teachers\(^{25} 26\) whereas two studies conducted during a higher incidence of infection showed a seroprevalence of 1.7% and 28%.\(^{28} 37\)

### Findings

#### Attack rates in school staff and students

Eleven studies reported data on attack rates in schools.\(^{27} 29 30 32 34-36 38-40 42\) The detailed information is provided in online supplemental table 2.

Four studies found no secondary transmission in schools following index cases.\(^{27} 34 35 42\) Of the remaining seven studies, six reported attack rates of 0%–13% following outbreaks among students and attack rates of 0%–16.6% following outbreaks among school staff.\(^{29} 30 32 36-40\) One of the studies reports 100 secondary cases in staff and 22 in students related to one outbreak.\(^{36}\)

Secondary attack rates among pupils were 0.14%,\(^{39} 0.3%, 0.81%\) and 3.8%.\(^{40}\) The latter study further differentiated between 6.6% in secondary schools and 0.38% in primary schools with no secondary transmission in preschools.\(^{40}\) The secondary attack rate of pupils to staff was 1% in one study.\(^{38}\)

Regarding transmission among school staff, values of 1.29%,\(^{38} 3.5%\) and 4.4%\(^{30}\) and 16.6%\(^{32}\) were reported. Two studies showed no transmission among staff.\(^{39} 40\)

### Risk of infection in seroprevalence studies

Four studies\(^ {25} 28 37\) describe the detection of antibodies in school contexts in Germany, France and the USA. The detail information is provided in online supplemental table 3.

In Germany, analysis of 13 schools in Saxony showed past infection in 0.2% of teaching staff and 0.7% of students, with an average of 0.6%.\(^{25}\) In comparison, seroprevalence in northern France was 25.9% on average, with 28.75% in teaching staff and 12.8% in students.\(^{25}\) In the USA, 14 days after a school index case, 1.66% of students and 0% of teachers tested positive for antibodies.\(^{26}\)

### Stratification of studies according to risk of infection after index case during data collection period

In order to better classify these heterogeneous results, study results were differentiated by two aspects: first, into three categories according to the prevalence of infection at the time of data collection and second, according to the prevailing measures in schools at that time (table 3). The detailed information about stratification of studies according to infection dynamics and NPIs during data collection period is provided in online supplemental table 4.

Three studies conducted while the incidence of infection was low found no secondary cases following index cases.\(^{27} 35 42\) Five studies conducted while the incidence of infection was in the medium range, reported that 0%–4.4% of school staff and 0%–6.5% of students developed secondary infections following index cases.\(^{29} 30 36 38 40\) Two studies conducted while population infection incidence was reported that up to 16% of school staff developed infections following index cases, and up to 15% of students.\(^{32} 39\)

### Comparison of the risk of infection of teachers and other population groups

Two studies\(^ {31} 33\) describe the risk of infection in Sweden. Here, during a period of high infection incidence, secondary schools were closed and pupils were taught in distance, while primary schools remained open and face-to-face teaching continued. The relative risk (RR) and 95% CI for teachers in open primary schools was 1.1 (0.9 to 1.3), whereas RR and 95% CI for teachers in closed schools was 0.7 (0.5 to 1).\(^ {31}\)

The chance for primary school teachers to become infected with SARS-CoV-2 was about twice as high as that of secondary school teachers in distance, with the OR and 95% CI of 2.01 (1.52 to 2.67). Partners of primary school teachers and parents of primary school students also had an increased chance of becoming infected, OR 1.3 (1 to 1.68) and OR 1.15 (1.03 to 1.27), when compared with secondary.
<table>
<thead>
<tr>
<th>Source</th>
<th>Author</th>
<th>Region</th>
<th>Main issue</th>
<th>Type of study</th>
<th>Population</th>
<th>Population contacts</th>
<th>Setting</th>
<th>Comparator</th>
<th>Date collection period</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lancet Child and Adolescent Health</td>
<td>Macartney et al. [9]</td>
<td>Australia</td>
<td>Transmission of SARS-CoV-2 among children and staff in schools and early childhood education and care (ECEC) settings</td>
<td>Perspective cohort study</td>
<td>Total=1475 27 primary infections (12 children and 15 adults) and 1448 contacts</td>
<td>NA</td>
<td>1448 schools and 10 ECEC in New South Wales Australia 633 had nucleic acid or antibody testing or both</td>
<td>Students</td>
<td>25 January–1 May 2020</td>
<td>Attack rate</td>
</tr>
<tr>
<td>Euro Surveillance</td>
<td>Stein-Zamir et al. [12]</td>
<td>Israel</td>
<td>COVID-19 outbreak in school in Israel. The school hosts grades 7-12</td>
<td>Observational</td>
<td>Total=1314 2 primary infections among students. 1161 student contacts and 151 staff in the school</td>
<td>151</td>
<td>1312 SARS-CoV-2 outbreak in school in Israel after school reopening</td>
<td>Students</td>
<td>May–June 2020</td>
<td>Attack rate</td>
</tr>
<tr>
<td>Euro Surveillance</td>
<td>Larosa et al. [30]</td>
<td>Italy</td>
<td>Secondary transmission of COVID-19 cases in school and preschool setting in northern Italy</td>
<td>Observational</td>
<td>Total=1248 48 index cases (43 students and 5 teachers) and 1200 contacts of primary cases</td>
<td>209</td>
<td>1200 Total 36 schools and preschools in northern Italy</td>
<td>Students of different school levels</td>
<td>1 September–15 October 2020</td>
<td>Attack rate</td>
</tr>
<tr>
<td>Frontiers of Public Health</td>
<td>Hernandez et al. [19]</td>
<td>Panama</td>
<td>Secondary transmission of school staff</td>
<td>Case report</td>
<td>Total=202 2 primary cases (1 teacher and 1 director) Approx. 200 contacts in school Household contacts of primary cases</td>
<td>NA</td>
<td>200 School in Panama</td>
<td>Students</td>
<td>February–March 2020</td>
<td>Secondary attack rate, attack rate</td>
</tr>
<tr>
<td>Euro Surveillance</td>
<td>Heavey et al. [36]</td>
<td>Ireland</td>
<td>Secondary transmission in school setting</td>
<td>Observational</td>
<td>Total in school=1031 Total including other setting=1161 (6 cases=3 paediatric and 3 adult)</td>
<td>NA</td>
<td>School in Ireland</td>
<td>NA</td>
<td>12 March 2020</td>
<td>Secondary attack rate, attack rate</td>
</tr>
<tr>
<td>Clinical Infectious Diseases</td>
<td>Yung et al. [34]</td>
<td>Singapore</td>
<td>Secondary transmission in school setting</td>
<td>Observational</td>
<td>Total=122 (3 primary cases (1 student from secondary school, 1 student from preschool and 1 adult staff from other preschool)</td>
<td>NA</td>
<td>119 3 different schools in Singapore</td>
<td>NA</td>
<td>February–March 2020</td>
<td>Secondary transmission, attack rate</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>Source</th>
<th>Author</th>
<th>Region</th>
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<th>Population contacts</th>
<th>Setting</th>
<th>Comparator</th>
<th>Date collection period</th>
<th>Outcome</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clinical Infectious Diseases</td>
<td>Danis et al[27]</td>
<td>France</td>
<td>Tertiary transmission of SARS-CoV-2 in school setting</td>
<td>Observational</td>
<td>113</td>
<td>112</td>
<td>3 different schools and 1 ski club in the French Alps</td>
<td>Teachers, students</td>
<td>February 2020</td>
<td>Tertiary transmission</td>
</tr>
<tr>
<td>National Centre for Immunisation Research and Surveillance, NSW, Australia</td>
<td>NCIRS[26]</td>
<td>Australia</td>
<td>Secondary transmission in different school settings</td>
<td>Observational</td>
<td>Total=527</td>
<td>521</td>
<td>6 different educational settings (5 schools and 1 ECEC)</td>
<td>Students</td>
<td>10 April – 3 July 2020</td>
<td>Secondary transmission, attack rate</td>
</tr>
<tr>
<td>National Centre for Immunisation Research and Surveillance, NSW, Australia</td>
<td>NCIRS[28]</td>
<td>Australia</td>
<td>Secondary transmission in different school settings</td>
<td>Observational</td>
<td>Total=3857</td>
<td>3824</td>
<td>39 different educational settings (28 schools and 6 ECEC)</td>
<td>Students</td>
<td>4 July – 25 September 2020</td>
<td>Secondary transmission, attack rate</td>
</tr>
<tr>
<td>Lancet Infectious Diseases</td>
<td>Ismail et al[36]</td>
<td>UK</td>
<td>Estimating the rate of SARS-CoV-2 infection and outbreaks among staff and students in educational settings during the summer half-term (June–July 2020) in England</td>
<td>Prospective cross-sectional analysis</td>
<td>Students and staff in school of England</td>
<td>NA</td>
<td>NA</td>
<td>Schools in England</td>
<td>Students</td>
<td>June/July 2020</td>
</tr>
<tr>
<td>Morbidity and Mortality Weekly Report</td>
<td>Falk et al[38]</td>
<td>USA</td>
<td>Secondary transmission in the school setting</td>
<td>Observational</td>
<td>Total=5530</td>
<td>5346</td>
<td>17 different schools settings; 8 elementary schools (k-6) and 9 secondary schools with grade 7-12 in Wisconsin, USA</td>
<td>Student</td>
<td>31 August–29 November 2020</td>
<td>Secondary transmission and attack rate</td>
</tr>
<tr>
<td>Source</td>
<td>Author</td>
<td>Region</td>
<td>Main issue</td>
<td>Type of study</td>
<td>Population</td>
<td>Population staff</td>
<td>Population contacts</td>
<td>Setting</td>
<td>Comparator</td>
<td>Date collection period</td>
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<tr>
<td><strong>Infection risk in teachers</strong></td>
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<tr>
<td>Public Health Agency Sweden</td>
<td>Karki et al.</td>
<td>Sweden</td>
<td>Risk of SARS-CoV-2 infection in teachers in Sweden</td>
<td>Observational report</td>
<td>364,760 (age 44–53) Teachers working in different school in Sweden</td>
<td>NA</td>
<td>NA</td>
<td>Different school settings in Sweden</td>
<td>Teachers of different school levels</td>
<td>March–May 2020</td>
</tr>
<tr>
<td>medRxiv</td>
<td>Vlachos et al.</td>
<td>Sweden</td>
<td>Risk of SARS-CoV-2 infection in parents, high school teachers, lower secondary school teacher and their partners were assessed after the partial school closure</td>
<td>Retrospective data analysis</td>
<td>NA</td>
<td>NA</td>
<td>Upper secondary and lower secondary schools of Sweden</td>
<td>Teachers of different school levels and their partners. Parents of children attending different schools</td>
<td>15 June 2020</td>
<td>OR</td>
</tr>
<tr>
<td><strong>Seroprevalence studies</strong></td>
<td></td>
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</tr>
<tr>
<td>Emerging Infectious Diseases</td>
<td>Brown et al.</td>
<td>USA</td>
<td>Teacher to student transmission</td>
<td>Cross-sectional (seroprevalence survey)</td>
<td>Total=121 infected teacher and 120 student contacts</td>
<td>NA</td>
<td>120</td>
<td>Students</td>
<td>Blood sample collection date: 13 March 2020</td>
<td>Secondary infection</td>
</tr>
<tr>
<td>medRxiv</td>
<td>Armann et al.</td>
<td>Germany</td>
<td>Seroprevalence study in teachers and students</td>
<td>Cross-sectional (seroprevalence study)</td>
<td>2045 participants (1538 students and 507 teachers)</td>
<td>507</td>
<td>NA</td>
<td>Students</td>
<td>Blood sample collection 25 May and 30 June 2020</td>
<td>Seroprevalence</td>
</tr>
</tbody>
</table>

*Table 2 Continued*
schools cohorts. The comparison of infection risks and attack rates of school staff with other population groups is presented in table 4.

A study from Scotland compares the risk of infection as well as the risk of hospitalisation of teachers during a period of high infection incidence with school closures and a period of lower infection incidence and open schools with both hospital staff and the general population. The risk of infection as well as the risk of hospitalisation of teachers during school closures is about half that of the general population (RR 0.5). Following school openings, the risk of infection increased threefold and is higher than that of the general population (RR 1.42) and the risk of hospitalisation doubles and is similar to that of the general population (RR 0.97).

**DISCUSSION**

On stratification of heterogeneous results in this review of infection risk and secondary attack rates of SARS-CoV-2 infection in school staff, we show that during a low incidence of infection at the time of data collection, attack rates are rather low and similar among teachers and students compared with medium and high incidence of infection. During a medium incidence and mortality rate of SARS-CoV-2 at the time of data collection, secondary attack rates in school were higher and higher for teachers than among students (0% –6.6%). In settings with high infection dynamics during data collection (incidence >25/7 days/100 000, deaths per day >5/million population) intervals, the risk of infection following outbreaks in schools is usually higher among teachers than among students (up to 16%), and the risk of infection via seroprevalence studies is up to 28%.

Infectious students tend to infect other students rather than teachers. The student to staff transmission rate is low, that is, 0%, compared with staff to student transmission, which was 1% in the same setting. This is in line with several studies suggesting low secondary transmission from students to teachers in different countries. Infectious teachers tend to infect other teachers rather than students. This is supported by a study from Australia and other transmission studies. The study summarises that in the school setting the transmission risk is higher among adults and infectious children are less likely to infect teachers.

In setting with high population infection incidence during data collection, the risk of infection was higher among teachers in face-to-face classes compared with teachers in distance classes (RR 1.1–2.0 risk of infection) and the risk of infection as well as the risk of hospitalisation increased among teachers during school openings compared with school closings (one study, RR=3 for infection risk and one study, RR=2, for hospitalisation risk).

Compared with the general population, the risk of infection and hospitalisation was lower for teachers during school closures than for the general population (RR=0.5 in one study) and increased (RR=1.42) after
Table 3  Studies on the risk of new infections after index case in schools (attack rate) and the risk of infection based on seroprevalence in students and teachers

<table>
<thead>
<tr>
<th>Infection risk of students</th>
<th>Attack rate students</th>
<th>Infection risk teachers</th>
<th>Attack rate teachers</th>
<th>Infection risk students</th>
<th>Attack rate students</th>
<th>Infection risk teachers</th>
<th>Attack rate teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low infection incidence at the time of data collection</td>
<td>No studies</td>
<td>No infections after initial infection (1 study)</td>
<td>No studies</td>
<td>No infections after initial infection (1 study)</td>
<td>No studies</td>
<td>No infections after initial infection (2 studies)</td>
<td>No infections after initial infection (2 studies)</td>
</tr>
<tr>
<td>Case peak 0–10</td>
<td>No studies</td>
<td>0%–6.5%, higher in secondary school (5 studies)</td>
<td>No studies</td>
<td>0%–4.4%, higher among school staff than pupils (5 studies)</td>
<td>0.7%–1.7% (seroprevalence, 2 studies)</td>
<td>No studies</td>
<td>0%–0.2% (seroprevalence, 2 studies)</td>
</tr>
<tr>
<td>Death peak &lt;5</td>
<td>No studies</td>
<td>0.1%–13% (2 studies)</td>
<td>No studies</td>
<td>0%–16.6% (2 studies)</td>
<td>12.8% (1 study)</td>
<td>No studies</td>
<td>1.7%–28% (2 studies)</td>
</tr>
<tr>
<td>Medium incidence infections at the time of data collection</td>
<td>No studies</td>
<td>0%–6.5%, higher in secondary school (5 studies)</td>
<td>No studies</td>
<td>0%–4.4%, higher among school staff than pupils (5 studies)</td>
<td>0.7%–1.7% (seroprevalence, 2 studies)</td>
<td>No studies</td>
<td>0%–0.2% (seroprevalence, 2 studies)</td>
</tr>
<tr>
<td>Case peak 10–150</td>
<td>No studies</td>
<td>0%–6.5%, higher in secondary school (5 studies)</td>
<td>No studies</td>
<td>0%–4.4%, higher among school staff than pupils (5 studies)</td>
<td>0.7%–1.7% (seroprevalence, 2 studies)</td>
<td>No studies</td>
<td>0%–0.2% (seroprevalence, 2 studies)</td>
</tr>
<tr>
<td>Death peak &lt;5</td>
<td>No studies</td>
<td>0.1%–13% (2 studies)</td>
<td>No studies</td>
<td>0%–16.6% (2 studies)</td>
<td>12.8% (1 study)</td>
<td>No studies</td>
<td>1.7%–28% (2 studies)</td>
</tr>
<tr>
<td>High incidence of infection at the time of data collection</td>
<td>No studies</td>
<td>0.1%–13% (2 studies)</td>
<td>No studies</td>
<td>0%–16.6% (2 studies)</td>
<td>12.8% (1 study)</td>
<td>No studies</td>
<td>1.7%–28% (2 studies)</td>
</tr>
<tr>
<td>Case peak &gt;150</td>
<td>No studies</td>
<td>0.1%–13% (2 studies)</td>
<td>No studies</td>
<td>0%–16.6% (2 studies)</td>
<td>12.8% (1 study)</td>
<td>No studies</td>
<td>1.7%–28% (2 studies)</td>
</tr>
<tr>
<td>Death peak &gt;5</td>
<td>No studies</td>
<td>0.1%–13% (2 studies)</td>
<td>No studies</td>
<td>0%–16.6% (2 studies)</td>
<td>12.8% (1 study)</td>
<td>No studies</td>
<td>1.7%–28% (2 studies)</td>
</tr>
</tbody>
</table>

Low incidence of infection: per 1 million population: peak number of daily cases less than 10/day, peak number of deaths <1/day.

Medium incidence of infection: per 1 million population: peak number of daily cases below 150/day, peak number of deaths <5/day.

High incidence of infection: per 1 million population: peak number of daily case over 150/day, peak number of deaths >5/day.
re-opening compared with the general population, while hospitalisation risk was not increased (RR=0.97) concordantly.41 Thus, continuous presence of teaching staff in schools compared with intervals of or teachers in distance learning increases the risk of infection and also hospitalisation.

This highlights the importance of transmission control measures such as contact tracing and fast quarantine orders. On detection of a single or few infections in schools, quarantine and testing strategies can help to prevent larger outbreaks.46 During large outbreaks transmission directions are less defined and attack rates are much higher.32

However, the dependence on local arrangements and testing strategies of the evidence presented is critical. For example, if only symptomatic cases are tested or only reported cases are evaluated, this can lead to high numbers of unreported asymptomatically infected or untested infected people. This distorts the comparison between teachers and pupils, as children experience a mild clinical course and fewer symptoms hence increasing the chance of being untested or not reported.

Similarly, seroprevalence studies reveal a heterogeneous picture with low evidence of infection incidence in the example of schools in Saxony, Germany during a data collection period with medium infection dynamics. However, the formation of antibodies is dependent on the intensity of the infection and immune response and can thus be underestimated, especially for children. Besides, it is difficult to reconstruct whether all detected infections occurred in the school environment.

**Limitation of the review**

There are limitations to this review. First, we did not conduct quantitative meta-analysis since the heterogeneity among included studies make them less comparable and hence meta-analysis was not right choice in this situation. Second, the included studies did not explicitly mentioned whether they tested only symptomatic or reported cases or both symptomatic and asymptomatic cases. Testing mainly symptomatic cases might skew results towards higher infection risks in school staff as adults typically have a higher proportion symptomatic infections.47 Third, we were not able to capture the endemicity and virulence of recent SARS-CoV-2 variant that is, alpha, beta and delta variant, as data gathered here refers to time periods in which these were not yet identified. Fourth, we exclude preprints or reports published only on homepages or institutional websites.

**CONCLUSION**

Despite of heterogeneity in the included studies, two conclusions can be drawn from this review. First, documenting local infection dynamics and implemented NPIs during data collection periods is crucial to understanding transmission dynamics in schools. Not all studies report these consistently. During periods of low incidence in the local population and schools with NPIs in place the risk to school staff is not necessarily higher than that of the general population and not comparable to the risk related to other high-risk professions such as healthcare staff. Studies reporting periods of high incidence are scarce but do show higher risk to school staff in these situations during periods where schools are not closed or NPIs are only partly in place. This may be due to the higher number and proximity of daily contacts in open schools compared with a general population under NPI public health measures.

Second, implementing screening and testing in schools is essential. In most of the included studies children seem less susceptible to SARS-CoV-2 infection. Students are less likely to transmit the virus to their peers or to teachers in the school setting. A large meta-analysis of prevalence studies3 and school outbreak studies48

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**Table 4** Comparison of infection risks and attack rates of school staff with other population groups

<table>
<thead>
<tr>
<th>Infection dynamics</th>
<th>Schools open with/without non-pharmaceutical interventions</th>
<th>School (partially closed)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Comparison students/teachers</td>
<td>Comparison teachers/teachers</td>
</tr>
<tr>
<td>low</td>
<td>Attack rates: Similar, no RR calculable (1 study)</td>
<td>No studies</td>
</tr>
<tr>
<td>Case peak 0–10</td>
<td>No studies</td>
<td>No studies</td>
</tr>
<tr>
<td>Death peak &lt;1</td>
<td>No studies</td>
<td>No studies</td>
</tr>
<tr>
<td>Medium</td>
<td>Attack rate: Higher in teachers (RR 1.6–4.4, 3 studies)</td>
<td>No studies</td>
</tr>
<tr>
<td>Case peak 10–150</td>
<td>No studies</td>
<td>No studies</td>
</tr>
<tr>
<td>Death peak 0.5–5</td>
<td>Same (1 study)</td>
<td>No studies</td>
</tr>
<tr>
<td>High</td>
<td>Attack rate: Higher in teachers (RR 1.2–1 study)</td>
<td>No studies</td>
</tr>
<tr>
<td>Case peak 90–1000</td>
<td>Lower in teachers (RR N, 1 study)</td>
<td>No studies</td>
</tr>
<tr>
<td>Death peak 5–20</td>
<td>Same (1 study)</td>
<td>No studies</td>
</tr>
</tbody>
</table>

RR, relative risk.
supports this finding. However, these findings are biased by test strategies. If only symptomatic persons are tested and children show less symptoms, the number of positive cases in children is underestimated. Mass screenings of asymptomatic populations decrease the transmission of SARS-CoV-2. Mass testing after index cases and frequent testing of asymptomatic students and staff was shown to reduce transmission in schools, although not specifically the infection risk of staff. Mass testing and serial contact tracing and testing coupled with isolation and physical distancing can reduce the transmission SARS-CoV-2 in schools.

**IMPLICATIONS**

In Germany, schools were reopened in February 2021 despite rising population incidences (predominantly due to increased endemicity of the variant B1.1.7, now accounting for over 70% of cases in Germany). A rise in cases among school-aged children is already reported by the Robert Koch Institute and the national average incidence exceeds 100 cases/100 000/7 days. Applying the conclusions to this scenario, we expect an increasing risk to school staff and students as social contacts in open schools will outnumber out-of-school contacts in a high community NPI and infection environment. Whereas the political discourse focuses primarily on the contribution of school cases to the overall infection dynamics, the reverse dependence of the infection risks in schools on community incidences and the associated health risk to staff and students is less discussed. Presumably, the school population is misleadingly thought of as young students (only) and thus considered to be less at risk of adverse outcomes. As we have demonstrated, the staff population has to be somewhat separated from the student population in terms of infection and transmission risks. Consequently, the risk to teachers and household contacts of students and staff should be considered more prominently in the balancing political decision around school openings and closures.

With that in mind, we recommend that legislators implement well-designed mass testing and serial contact tracing and testing strategies, also including asymptomatic individuals, to minimise the risk of school outbreaks during high infection dynamics.

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**Contributors**

BL had the idea for the review and initiated the work. SJK and AJ performed the search, screening, study selection and data extraction. SJK and AJ wrote the first draft of the manuscript. BL and TH contributed in writing. All authors critically revised and discussed the manuscript and approved submission of the final version. SJK and AJ contributed equally to this paper and shared the first authorship. BL and SJK act as a guarantor.

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None declared.

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**Data availability statement**

Data sharing not applicable as no datasets generated and/or analysed for this study. No data are available. Not Applicable. In this systematic review no datasets were generated and analysed.

**Supplemental material**

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