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

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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 each 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.

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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.[8]

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.[16–20]

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[21] 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.

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.[22–24]

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*.

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 1 Patients/Population, Intervention, comparison and Outcome for included studies

|	Patients/Population	Intervention/Exposure	Comparator	Outcome
Transmission of SARS-CoV-2 in school	School staff, any contacts of school staff	School, primary school, secondary school	School children, general population, present in the school (distance learning), school staff in different school forms or learning situations	Secondary attack rates as reported by authors of original papers, relative/infection risk, OR
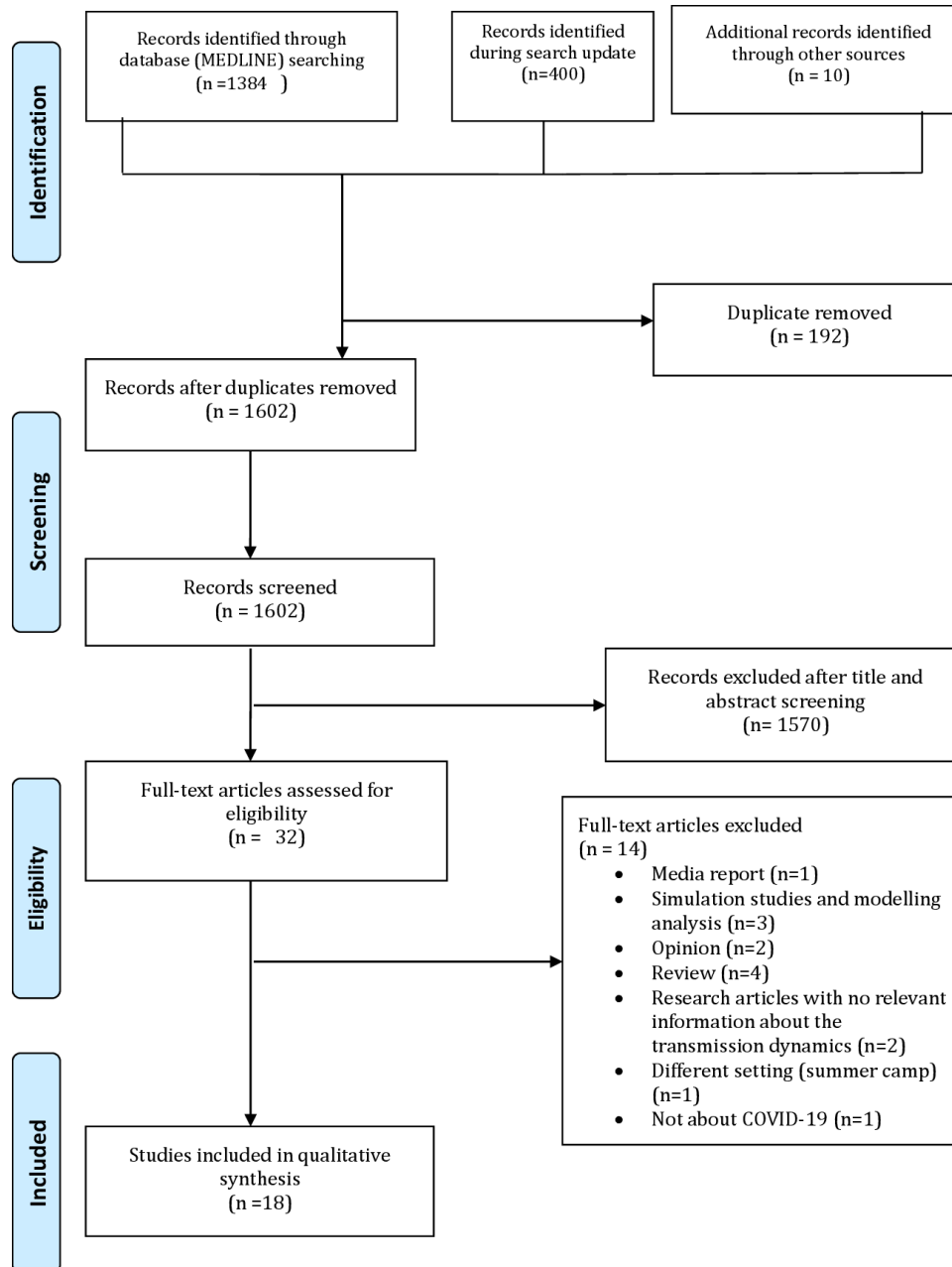
Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram.

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]

The studies were originated in Australia,[30 35 38] France,[27 28] Germany,[25] Ireland,[42] Israel,[32] Italy,[40] Panama,[29] Singapore,[34] Sweden,[31 33] the UK,[36] Scotland[41] and the USA.[26 37 39] Among them three were reports published by the Public Health Agency of Sweden[31] and by the National Centre for Immunization Research and Surveillance, New South Wales, Australia.[35 38] Five were published in preprint[25 28 33 37 41] 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,[27 29 30 32 34–36 38–40 42] seroprevalence of SARS-CoV-2 IgG[25 26 28 37] or infection risk[31 33 41] among teachers and students. The characteristics of included studies are tabularised in table 2.

Quality assessment

Among the included studies, six have a low risk of bias, ten studies have a medium risk of bias, one has an unclear risk of and one has a high risk of bias. Reasons for assigning medium risk of bias were: not all contacts were tested in contact tracing studies and some of the studies used only case notification data from nationwide surveillance database. This increases the possibility of missing asymptomatic cases and cases that were not reported. The reason for assigning unclear risk of bias was that the occupation code was missing for 25% of the confirmed cases. It was unclear how the study group dealt with this issue. The reason for assigning high risk of bias to one of the studies was selective reporting of results, low participation rate and use of questionnaires to assess symptoms. This increases the possibility of recall and misclassification bias. The overall risk of bias assessments for included studies are tabularised (online supplemental table 1).

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 38–40] 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%,[30] 0.81%[38] 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.[30]

Regarding transmission among school staff, values of 1.29%,[38] 3.5%[29] 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 26 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.[28] In the USA, 14 days after a school index case, 1.66% of students and 0% of teachers tested positive for antibodies.[26] In the Midwest of the USA, 1.7% of teaching staff had a history of infection.[37]

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 13% 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]

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 2 Characteristics of included studies

Source	Author	Region	Main issue	Type of study	Population	Population staff	Population contacts	Setting	Comparator	Date collection period	Outcome
Attack rate/secondary infections in school											
Lancet Child and Adolescent Health	Macartney et al[30]	Australia	Transmission of SARS-CoV-2 among children and staff in schools and early childhood education and care (ECEC) settings	Perspective cohort study	Total=1475 27 primary infections (12 children and 15 adults) and 1448 contacts	NA	1448	15 schools and 10 ECEC in New South Wales Australia 633 had nucleic acid or antibody testing or both	Students	25 January–1 May 2020	Attack rate
Euro Surveillance	Stein-Zamir et al[32]	Israel	COVID-19 outbreak in school in Israel. The school hosts grades 7–12	Observational	Total=1314 2 primary infections among students. 1161 student contacts and 151 staff in the school	151	1312	SARS-CoV-2 outbreak in school in Israel after school reopening	Students	May–June 2020	Attack rate
Euro Surveillance	Larosa et al[40]	Italy	Secondary transmission of COVID-19 cases in school and preschool setting in northern Italy	Observational	Total=1248 48 index cases (43 students and 5 teachers) and 1200 contacts of primary cases	209	1200	Total 36 schools and preschools in northern Italy	Students of different school levels	1 September–15 October 2020	Attack rate
Frontiers of Public Health	Hernandez et al[29]	Panama	Secondary transmission of school staff	Case report	Total=202 2 primary cases (1 teacher and 1 director) Approx. 200 contacts in school Household contacts of primary cases	NA	200	School in Panama	Students	February–March 2020	Secondary attack rate, attack rate
Euro Surveillance	Heavey et al[42]	Ireland	Secondary transmission in school setting	Observational	**Total in school=1031** Total including other setting=1161 (6 cases=3 paediatric and 3 adult)	NA	**In school =1031** (1155 contacts including other settings)	School in Ireland	NA	12 March 2020	Secondary attack rate, attack rate
Clinical Infectious Diseases	Yung et al[34]	Singapore	Secondary transmission in school setting	Observational	Total=122 (3 primary cases (1 student from secondary school, 1 student from preschool and 1 adult staff from other preschool)	NA	119 (8+34+77)	3 different schools in Singapore	NA	February–March 2020	Secondary transmission, attack rate

Continued

Table 2 Continued

Source	Author	Region	Main issue	Type of study	Population	Population staff	Population contacts	Setting	Comparator	Date collection period	Outcome
Clinical Infectious Diseases	Danis et al[27]	France	Tertiary transmission of SARS-CoV-2 in school setting	Observational	113 (1 secondary cases and 112 school contacts)	NA	112	3 different schools and 1 ski club in the French Alps	Teachers, students	February 2020	Tertiary transmission
National Centre for Immunisation Research and Surveillance, NSW, Australia	NCIRS[35]	Australia	Secondary transmission in different school settings	Observational	Total=527 6 primary cases (4 students and two staffs) and 521 close contacts from 6 different educational settings (5 schools and 1 ECEC)	62	521	six different schools (5 schools and 1 ECEC) in NSW; Australia. The primary cases were found in the school setting and contact tracing was done and diagnostic test were performed in close contacts	Students	10 April –3 July 2020	Secondary transmission, attack rate
National Centre for Immunisation Research and Surveillance, NSW, Australia	NCIRS[38]	Australia	Secondary transmission in different school settings	Observational	Total=3857 39 primary cases (32 students and 7 staff) and 3824 close contacts in 34 different educational settings (28 schools and 6 ECEC)	385	3824	39 primary cases were found in 34 different educational settings (28 schools and 5 ECEC) in NSW Australia	Students	4 July–25 September 2020	Secondary transmission, attack rate
Lancet Infectious Diseases	Ismail et al[36]	UK	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	Prospective cross-sectional analysis	Students and staff in school of England	NA	NA	Schools in England	Students	June/July 2020	Secondary transmission
Morbidity and Mortality Weekly Report	Falk et al[39]	USA	Secondary transmission in the school setting	Observational	Total=5530 184 primary cases with 5346 close contacts in 17 different educational settings in Wisconsin, USA (4876 students and 654 staff in face-to-face learning)	654	5346	17 different schools settings; 8 elementary schools (k-6) and 9 secondary schools with grade 7–12 in Wisconsin, USA	Student	31 August–29 November 2020	Secondary transmission and attack rate

Continued

Table 2 Continued

Source	Author	Region	Main issue	Type of study	Population	Population staff	Population contacts	Setting	Comparator	Date collection period	Outcome
Infection risk in teachers											
Public Health Agency Sweden	Public Health Agency Sweden[31]	Sweden	Risk of SARS-CoV-2 infection in teachers in Sweden	Observational report	364 760 (age 44–53) Teachers working in different school in Sweden	NA	NA	Different school settings in Sweden	Teachers of different school levels	March–May 2020	Relative risk
medRvix	Vlachos *et al*[33]	Sweden	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	Retrospective data analysis	Upper secondary and lower secondary school teachers, their partners and students' parents from Sweden	NA	NA	Upper secondary and lower secondary schools of Sweden	Teachers of different school levels and their partners. Parents of children attending different schools	15 June 2020	OR
medRvix	Lynda *et al*[41]	Scotland	Risk of COVID-19 and risk of hospitalisation with COVID-19 among teachers compared with healthcare workers and general population of working age	Case–control study	Total study population N=871 568 N teachers=18479 N healthcare workers=35461	18479	NA	Teachers and healthcare workers in Scotland	Healthcare workers, household members of healthcare workers and teachers	March 2020–January 2021	Risk rate
Seroprevalence studies											
Emerging Infectious Diseases	Brown *et al*[26]	USA	Teacher to student transmission	Cross-sectional (seroprevalence survey)	Total=121 1 infected teacher and 120 student contacts	NA	120	School in the USA. All students were instructed to quarantine. 21 students participated in serological survey 14 days after quarantine	Students	Blood sample collection date: 13 March 2020	Secondary infection
medRvix	Armann *et al*[25]	Germany	Seroprevalence study in teachers and students	Cross sectional (seroprevalence study)	2045 participants (1538 students and 507 teachers)	507	NA	13 different secondary schools in Saxony, Germany	Students	Blood sample collection 25 May and 30 June 2020	Seroprevalence

Continued

Table 2 Continued

Source	Author	Region	Main issue	Type of study	Population	Population staff	Population contacts	Setting	Comparator	Date collection period	Outcome
medRvix	Lopez et al[37]	USA	Seroprevalence of anti-SARS-CoV-2 IgG antibodies in school staff in Midwestern USA	Population-based seroprevalence study	1261 eligible school staff	753 staff members participated in the survey	NA	18 years or older staff of Lake Central School Corporation located in suburban Indiana employed in academic year 2018/2019 or 2019/2020 and with record pf annual wellness check	General population	July 2020	Seroprevalence of antibody
medRvix	Fontanet et al[28]	France	Assessing infection attack rate using serological assays	Observational cohort (seroprevalence study)	661 (pupils, parents, siblings, including teachers and non-teaching staff)	661	NA	Secondary school and household in Oise department in Northern France	Students and general population	30 March–4 April 2020	Infection attack rate

schools cohorts.[33] 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).[41]

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%),[32] and the risk of infection via seroprevalence studies is up to 28%.[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.[30] This is in line with several studies suggesting low secondary transmission from students to teachers in different countries.[12 26] Infectious teachers tend to infect other teachers rather than students.[32 36] This is supported by a study from Australia[44] and other transmission studies.[29 30 45] The study summarises that in the school setting the transmission risk is higher among adults and infectious children are less likely to infect teachers.[44]

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)[31] 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).[41]

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

	Schools open with/without non-pharmaceutical interventions at the time of data collection				Schools partially or completely closed at the time of data collection			
	Infection risk of students	Attack rate students	Infection risk teachers	Attack rate teachers	Infection risk students	Attack rate students	Infection risk teachers	Attack rate teachers
Low infection incidence at the time of data collection Case peak 0–10 Death Peak <1	No studies	No infections after initial infection (1 study)	No studies	No infections after initial infection (1 study)	No studies	No infections after initial infection (2 studies)	No studies	No infections after initial infection (2 studies)
Medium incidence infections at the time of data collection Case peak 10–150 Death peak <5	No studies	0%–6.5%, higher in secondary school (5 studies)	No studies	0%–4.4%, higher among school staff than pupils (5 studies)	0.7%–1.7% (seroprevalence, 2 studies)	No studies	0%–0.2% (seroprevalence, 2 studies)	No studies
High incidence of infection at the time of data collection Case peak >150 Death peak >5	No studies	0.1%–13% (2 studies)	No studies	0%–16.6% (2 studies)	12.8% (1 study)	No studies	1.7%–28% (2 studies)	No studies

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.

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

Infection dynamics	Schools open with/without non-pharmaceutical interventions			School (partially) closed		
	Comparison students/teachers	Comparison teachers/teachers	Comparison teachers/ population	Comparison students/teachers	Comparison teachers/teachers	Comparison teachers/ population
low Case peak 0–10 Death peak <1	Attack rates: <u>Similar</u>, no RR calculable (1 study)	No studies	No studies	Attack rates: <u>Similar</u> (2 studies)	No studies	No studies
Medium Case peak 10–150 Death peak 0.5–5	Attack rate: **Higher** in teachers (RR 1.6–4.4, 3 studies) **Lower** in teachers (RR n.c., 2 studies) **Same** (1 study)	No studies	No studies	Infection risk: <u>Lower</u> in teachers (RR=0.3, 1 study)	No studies	No studies
High Case peak 90–1000 Death peak 5–20	Attack rate: **Higher** in teachers (RR 1.2 1 study) **Lower** in teachers (NR, 1 study)	No studies	Infection risk: After school opening higher (1.42, 1 study) Hospitalisation: After school opening similar (0.97, 1 study)	No studies	Infection risk: **Same to higher** in teachers in **presence** compared with distance (1.1.–2.0, 2 studies)	Infection risk: Before school opening lower (RR 0.5, 1 study) Hospitalisation: Before school opening lower (RR 0.5, 1 study)

RR, relative risk.

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 studies[3] and school outbreak studies[48]

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.[49] 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.[50] Mass testing and serial contact tracing and testing coupled with isolation and physical distancing can reduce the transmission SARS-CoV-2 in schools.[51 52]

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).[53] 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.[53] 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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