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Risk factors for SARS-CoV-2 infection in primary and secondary school students and staff in England in the 2020/2021 school year: a longitudinal study

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ABSTRACT

Objectives: Investigate risk factors for SARS-CoV-2 infections in school students and staff.
Methods: In the 2020/2021 school year, we administered polymerase chain reaction, antibody tests, and questionnaires to a sample of primary and secondary school students and staff, with data linkage to COVID-19 surveillance. We fitted logistic regression models to identify the factors associated with infection.
Results: We included 6799 students and 5090 staff in the autumn and 11,952 students and 4569 staff in the spring/summer terms. Infections in students in autumn 2020 were related to the percentage of students eligible for free school meals. We found no statistical association between infection risk in primary and secondary schools and reported contact patterns between students and staff in either period in our study. Using public transports was associated with increased risk in autumn in students (adjusted odds ratio = 1.72; 95% confidence interval 1.31-2.25) and staff. One or more infections in the same household during either period was the strongest risk factor for infection in students and more so among staff.
Conclusion: Deprivation, community, and household factors were more strongly associated with infection than contacts patterns at school; this suggests that the additional school-based mitigation measures in England in 2020/2021 likely helped reduce transmission risk in schools.

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Background

Early in the COVID-19 pandemic, concerns that schools might contribute to sustaining or amplifying community transmission of SARS-CoV-2 led to widespread school closures [1]. This impacted education, well-being, and societal health [2,3]. Evidence now indicates that SARS-CoV-2 transmission does occur among and from children but can be reduced by preventive interventions in schools [4–6]. The overall role of schools in community spread is thought to be low-to-moderate, especially with mitigations in place; although, this may vary with virus variants [7–9]. The reopening of schools in many settings was accompanied by measures to minimize transmission, such as physical distancing, regular testing, improving ventilation, reducing social contact within/between classes, and mask-wearing [6,10]. These measures were complemented by the introduction of vaccination, widely offered to the adults in the UK from December 2020 [11].

Given the importance of the pandemic's impact on education provision, the potential role of school children in community transmission and ongoing evolution of virus variants, and potential impact of long-COVID on school populations, it is important to identify the risk factors for infection in schools to reduce transmission and minimize disruptions to education.

We conducted a large longitudinal study in students and staff from a sample of primary and secondary schools in England from November 2020 to July 2021 [12]. The national-level advice on school mitigation measures was provided by the Department for Education and was largely implemented by the schools in this study [13]. We examined school- and individual-level risk factors for incident SARS-CoV-2 infection, contrasting the two main periods of the academic year when schools were open to all students: autumn 2020 and midspring/summer 2021.

Methods

Design and setting

This study was nested in England's COVID-19 Schools Infection Study (SIS), run by the Office for National Statistics (ONS), the UK Health Security Agency (UKHSA, formerly Public Health England), and the London School of Hygiene and Tropical Medicine between November 2020 and July 2021 [12,14]. Briefly, SIS enrolled students and staff in 57 primary and 91 secondary schools across 15 local authorities (LAs) in England, selected using stratified multistage probabilistic sampling, including 10/30 LAs with the 20% highest case rates and 5/117 LAs with the 80% lowest community case rates at the start of the school year in September 2020. Six surveys were conducted with consenting participants at half-termly intervals [12] in autumn 2020 (round 1 [R1, November 2020] and R2 [December 2020]), spring 2021 (R3 [January 2021 during the lockdown, home testing only] and R4 [March 2021]), and summer 2021 term (R5 [May 2021] and R6 [June 2021]), respectively. Each survey included the collection of biological samples for laboratory testing and administration of online questionnaires. The infection rates in our cohort in relation to school closures over that year were similar to community infection patterns in England [15].

Participants and ethical considerations

We offered enrollment to all primary school staff and students plus all secondary school staff. The enrollment of secondary students was initially restricted to two randomly selected consecutive year groups, then extended to all-year groups from January 2021 [12]. The project received ethical clearance from London School of Hygiene and Tropical Medicine (22657) and UKHSA (NR0237).

Data sources, data collection, and variables

The trained nurses visiting schools collected nasal swabs from all participants (tested for SARS-CoV-2 by reverse transcriptase-polymerase chain reaction (PCR) at the Glasgow Lighthouse Labs), oral fluid from students, and finger-prick blood from staff for antibodies against SARS-CoV-2 nucleocapsid protein (antinucleocapsid [anti-N] antibodies, produced only after natural infection). Antibody tests were done by UKHSA using an in-house validated immunoglobulin G capture-based enzyme immunoassay for oral fluids [16], and Thriva testing service for blood (using the European Union-approved commercial Roche Cobas® Elecsys Anti-SARS-CoV-2 immunoassay).

Individual sociodemographic information was collected at enrollment. A second (additional) questionnaire after the biological samples were taken was used to collect information on general health, history of COVID-19 including symptoms, contacts in and out of school, travel, household composition, household history of COVID-19, and individual socioeconomic status (free school meal [FSM]; funded by the government for socioeconomically disadvantaged students) eligibility, family affluence survey (FAS-III [17]). The online questionnaires were self-completed by participants aged $\geq$16 years and by their parents/legal guardian (who were asked to obtain the support of their children to complete some questions, for example, on school contact patterns) for those aged $<$16 years. The questionnaires are available from ONS [14].

Linkage of individuals to UKHSA's Second-Generation Surveillance System (SGSS, collates national laboratory reports on infectious diseases) provided community SARS-CoV-2 infections ("confirmed COVID-19 case reports") and the National Immunisations Management System for staff-provided information on COVID-19 vaccine receipt. We considered any vaccination up to July 2021 and did not account for the interval between vaccination and infection because infection date cannot be inferred from antibody conversions. Anonymous linkage to SGSS using Unique Property Reference Numbers was also used to obtain information on laboratory-confirmed COVID-19 cases in the participants' households.

Linkage to the Department for Education's schools census data provided schools' characteristics: urban/rural location; LA maintained or not, government school inspection (Office for Standards in Education, Children's Services and Skills [OFSTED] rating); proportion of students eligible for FSM, as a measure of poverty; proportion of non-White ethnicity; and proportion of those speaking English as an additional language.

Outcomes

SARS-CoV-2 infections occurring during one of the study periods (autumn 2020 and midspring /summer 2021) were defined as (i) evidence of SARS-CoV-2 in the nasal swab PCR, (ii) laboratory-confirmed COVID-19 reported in the SGSS database, or (iii) antibody conversion from negative to positive between two testing rounds in autumn and separately in spring/summer.

The presence of SARS-CoV-2 antibodies at the start of the study (R1) was considered separately as a measure for infection before the school year 2020/2021. The median half-life of anti-N antibodies is estimated at about 20 weeks and samples were collected 8 weeks into the school year [18].

Statistical methods

We examined the risk factors for incident infection while schools were open in the autumn term 2020 (R1 and R2) compared with the spring and summer terms (R4, R5, and R6). The interval between R2 (December 2020) and R4 (March 2021) covers a period of national lockdown, with restrictions in attendance in schools, thus was excluded from this analysis, as were participants who were antibody-positive at the start of the study (R1) or when joining the study in R4.

Continuous variables were transformed into categorical variables. First, we described the characteristics of the population subsamples contributing to each analysis, then we calculated the proportion of infections overall and by covariates. The analyses were conducted separately for staff and students.

To estimate the odds ratios (ORs) and 95% confidence intervals (CIs) of the association between covariates and outcomes, we fitted mixed effect logistic regression models with a school-level random intercept and robust standard errors clustered at the LA level to account for the sampling design.

For each population group and study period (autumn vs spring/summer terms), we performed two sets of analyses. First, we examined school-level and individual covariates collected at study enrollment in all participants with valid laboratory results. We estimated the crude ORs and then adjusted OR (aOR) for age, sex, and LA-level initial transmission stratum.

For those with data from the second (additional) questionnaire, we carried out separate analyses focused on household, community, and school factors. ORs were adjusted for the same *a priori* variables in the first analyses, together with household Index of Multiple Deprivation and school level urban/rural location and OFSTED rating. More complex multivariable analyses were not conducted because of limited statistical power from relatively low infection rates in the study population.

P-values were obtained using adjusted Wald tests. The main analyses were restricted to participants with complete data for each outcome and all covariates in the adjusted model. The analyses were conducted using STATA 16.

Results

Participants and descriptive analyses

Overall, 14,842 students and 7743 staff participated in at least one study round during the school year 2020/2021 [11], of whom 6799 (46%) students and 5090 (66%) staff contributed data to the autumn term analyses, and 11,952 (81%) students and 4569 (59%) staff contributed data to the spring/summer term analyses (Table 1). The overall participation rate was 45.2% in primary and 30.0% in secondary school staff and 16.4% and 15.2% in primary and secondary school students [11]. The sociodemographic characteristics of students contributing data in the autumn term and the spring/summer terms were similar: most were from urban areas. The largest age group was 10-14 years, equally distributed by sex, and mostly White (84%). About 3.5% reported at least one COVID-19 case in their household during the study periods. Staff characteristics were similar between the two study periods, with a predominance of women (77%), White race (93%), and age under 55 years (85%); nearly 67% of the staff had received at least one vaccine dose by the end of the summer 2021 term.

Excluded from the study were 6.8% students and 11.2% staff who were already positive for SARS-CoV-2 anti-N antibodies at start of the surveillance. After accounting for school and LA-level clustering, the proportions with new SARS-CoV-2 infections were, respectively, 3.42% (95% CI 2.88-4.07%) in students and 3.75% (95% CI 3.07-4.58%) in staff across the 5-week autumn term study period and 3.12% (95% CI 2.39-4.19%) in students and 2.47% (95% CI 1.79-3.40%) in staff across the 16-week spring/summer study period. About 40% of the infections in students and 31% in staff were detected using school nasal swab PCR in the autumn term, compared with roughly 10% in both groups in the spring/summer terms (when over 50% infections were detected through linkage to surveillance (Fig. 1).

School-level and soci-demographic risk factors for infection

At the school level, controlling for age, sex, and LA stratum of community rates at the start of the school year, the incident infection in the autumn term was associated with indicators of socioeconomic deprivation (*e.g.,* aOR 2.69; 95% CI 1.30-5.56) in schools with ≥30% vs <10% of students eligible for FSMs) in schools rated as inadequate/requiring improvement compared with outstanding schools (based on OFSTED ratings) and higher proportion of non-White ethnicity students (Table 2). There was also some evidence ($P = 0.05$) of about 50% lower risk in LA maintained schools than academies and free schools. There was no statistical association with other school-level factors, including community rates in the LA at the start of the school year and primary versus secondary schools. Conversely, by the summer term, the students in high-transmission areas at the start of the academic year had over twice the risk of infection compared with low transmission areas. The percentage of non-White students in the school was associated with the risk of infection (aOR 1.57; 95% CI 1.04-2.38 for highest tertile compared with lowest tertile), but there was no statistical association for other school-level factors in this study.

We found no association between the students' sociodemographic characteristics (including sex, ethnicity, Index of Multiple Deprivation score, and the risk of infection in both autumn and spring/summer periods; Table 3).

Among the staff, there was a higher infection risk in the autumn term for schools in urban locations (aOR 1.34; 95% CI 0.59-3.03 and aOR 2.18; 95% CI 0.93-5.13), respectively, for cities, towns, and conurbations compared with rural areas), albeit not significant; whereas in the spring/summer terms, the only risk factor was high community transmission at the start of the school year (aOR 2.54; 95% CI 1.35-4.78). No other school-level (Table 4) or individual sociodemographic characteristics (Table 5) were statistically associated with the risk of infection in either study periods in this study.

SARS-CoV-2 N-antibody-positivity in students in November 2020 was associated with urban location, higher proportion of FSM-eligible students and students speaking English as an additional language, older student's age, non-White ethnicity, and higher deprivation (details in Supplementary Tables 1 and 2). Similar patterns were found for the staff, except for age, where a lower risk was found in staff members who were older.

Household, community, and school risk factors

The second (additional) questionnaire was available for 63% (4254/6799) and 61% (7247/11952) of the student participants in the autumn and spring/summer terms; the corresponding figures for staff were 65% (3303/5090) and 74% (3388/4569). The characteristics of those completing the second questionnaire were broadly similar to all enrolled participants (Supplementary Tables 3 and 4).

Table 1
Characteristics of student and staff participants in the autumn 2020[a] and spring/summer 2021[b] school terms study periods.

Variables		Student / Autumn n (%) (N = 6799)	Students Spring/Summer n (%) (N = 11,952)	Staff / Autumn n (%) (N = 5090)	Staff Spring /Summer n (%) (N = 4569)
School rural/urban					
	Rural	737 (10.84)	841 (7.04)	368 (7.23)	289 (6.33)
	Urban city and town	3248 (47.77)	6807 (56.95)	2313 (45.44)	2187 (47.87)
	Urban conurbation	2814 (41.39)	4304 (36.01)	2409 (47.33)	2093 (45.81)
LA-level transmission at start of school year 2020/2021					
	Low	2517 (37.02)	4715 (39.45)	1861 (36.56)	1642 (35.94)
	High	4282 (62.98)	7237 (60.55)	3229 (63.44)	2927 (64.06)
School type					
	Primary	2503 (36.81)	3795 (31.75)	1156 (22.71)	1301 (28.47)
	Secondary	4296 (63.19)	8157 (68.25)	3934 (77.29)	3268 (71.53)
School establishment group[c]					
	Academy/Free	3288 (48.36)	6545 (54.76)	2731 (53.65)	2527 (55.31)
	LA maintained	3511 (51.64)	5407 (45.24)	2359 (46.35)	2042 (44.69)
School Office for Standards in Education, Children's Services and Skills rating					
	Outstanding/good	4968 (73.07)	8943 (74.82)	3382 (66.44)	3218 (70.43)
	Inadequate/requires improvement	947 (13.93)	1624 (13.59)	918 (18.04)	723 (15.82)
	Not yet available	884 (13.00)	1385 (11.59)	790 (15.52)	628 (13.74)
School % students eligible for free school meals band[d]					
	<10%	1776 (26.12)	3429 (28.69)	668 (13.12)	680 (14.88)
	10% - <30%	4110 (60.45)	6932 (58.00)	3290 (64.64)	2848 (62.33)
	>=30%	913 (13.43)	1591 (13.31)	1132 (22.24)	1041 (22.78)
School % non-white ethnicity students					
	<7.70%	2818 (41.45)	4103 (34.33)	1784 (35.05)	1496 (32.74)
	7.70-<29.06%	2518 (37.03)	5252 (43.94)	1614 (31.71)	1656 (36.24)
	>29.06%	1463 (21.52)	2597 (21.73)	1692 (33.24)	1417 (31.01)
School % students with English as additional language (tertile)					
	<4.23%	2513 (36.96)	4005 (33.51)	1444 (28.37)	1325 (29.00)
	4.23-<21.06%	3002 (44.15)	5960 (49.87)	2201 (43.24)	2006 (43.90)
	>21.06%	1284 (18.89)	1987 (16.62)	1445 (28.39)	1238 (27.10)
School size (tertiles)					
	Small <202 students	1375 (20.22)	2980 (24.93)	1133 (22.26)	1064 (23.29)
	Medium 202 - <338 students	2366 (34.80)	4174 (34.92)	1878 (36.90)	1690 (36.99)
	Large 338 - 1732 students	3058 (44.98)	4798 (40.14)	2079 (40.84)	1815 (39.72)
School student to teacher ratio					
	<20	4321 (63.55)	8233 (68.88)	3879 (76.21)	3276 (71.70)
	20 - <51	2063 (30.34)	2897 (24.24)	936 (18.39)	993 (21.73)
	Data not available	415 (6.10)	822 (6.88)	275 (5.40)	300 (6.57)
Educational key stages (students) / age group (staff)					
	KS 1 (5 to 7 years)	1094 (16.09)	1507 (12.61)	-	-
	KS 2 (8 to 11 years)	1410 (20.74)	2287 (19.13)	-	-
	KS 3 (12 to 14 years)	3026 (44.51)	6032 (50.47)	-	-
	KS 4 (15 and 16 years)	586 (8.62)	1421 (11.89)	-	-
	KS 5 (17 and 18 years)	683 (10.05)	705 (5.90)	-	-
	<35 years	-	-	1571 (30.86)	1381 (30.23)
	35-44 years	-	-	1493 (29.33)	1331 (29.13)
	45-54 years	-	-	1264 (24.83)	1178 (25.78)
	55+ years	-	-	762 (14.97)	679 (14.86)
Gender					
	Male	3370 (49.57)	5965 (49.91)	1160 (22.79)	968 (21.19)
	Female	3429 (50.43)	5987 (50.09)	3930 (77.21)	3601 (78.81)
Ethnicity					
	White	5698 (83.81)	10178 (85.16)	4724 (92.81)	4269 (93.43)
	Non-white (minority)	1101 (16.19)	1774 (14.84)	366 (7.19)	300 (6.57)
Index of multiple deprivation 2019 quintiles					
	Least deprived	1333 (19.61)	2448 (20.48)	1080 (21.22)	981 (21.47)
	4	1315 (19.34)	2296 (19.21)	1098 (21.57)	996 (21.80)
	3	1104 (16.24)	1915 (16.02)	947 (18.61)	799 (17.49)
	2	1423 (20.93)	2472 (20.68)	1056 (20.75)	955 (20.90)
	Most deprived	1624 (23.89)	2821 (23.60)	909 (17.86)	838 (18.34)
Household size					
	1-2 persons	440 (6.47)	795 (6.65)	1975 (38.80)	1771 (38.76)
	3-5 persons	5566 (81.86)	9764 (81.69)	2910 (57.17)	2626 (57.47)
	6+ persons	793 (11.66)	1393 (11.65)	205 (4.03)	172 (3.76)

(*continued on next page*)

Table 1 (*continued*)

Variables		Student / Autumn n (%) (N = 6799)	Students Spring/Summer n (%) (N = 11,952)	Staff / Autumn n (%) (N = 5090)	Staff Spring /Summer n (%) (N = 4569)
Household composition					
	Only adults ≥16 years	513 (7.55)	699 (5.85)	2717 (53.38)	2454 (53.71)
	One child <16 years	1919 (28.22)	3576 (29.92)	992 (19.49)	932 (20.40)
	Multiple children	4367 (64.23)	7677 (64.23)	1381 (27.13)	1183 (25.89)
Person per bedroom					
	≤1	1533 (22.55)	2832 (23.69)	1908 (37.49)	1716 (37.56)
	>1-2	4743 (69.76)	8195 (68.57)	3038 (59.69)	2728 (59.71)
	>2	523 (7.69)	925 (7.74)	144 (2.83)	125 (2.74)
Job group (staff only)					
	Senior leader	-	-	421 (8.27)	384 (8.40)
	Middle leader	-	-	907 (17.82)	738 (16.15)
	Teacher	-	-	1731 (34.01)	1453 (31.80)
	Teaching Assistant / Special Education	-	-	707 (13.89)	727 (15.91)
	Admin / pastoral	-	-	728 (14.30)	728 (15.93)
	Cater/clean/maintenance	-	-	228 (4.48)	212 (4.64)
	Other	-	-	368 (7.23)	327 (7.16)
Year group with most contact (staff only)					
	None	-	-	2781 (54.64)	2584 (56.56)
	Year 2 and below	-	-	265 (5.21)	290 (6.35)
	Year 3 to 6	-	-	274 (5.38)	318 (6.96)
	Year 7 to 9	-	-	655 (12.87)	502 (10.99)
	Year 10 & 11	-	-	861 (16.92)	677 (14.82)
	Year 12 & 13	-	-	254 (4.99)	198 (4.33)
Vaccination between rounds 4 and 6[e]					
	unvaccinated	-	-	-	1502 (32.87)
	≥ 1 vaccine dose	-	-	-	3067 (67.13)

[a] Autumn 2020 term: R1 (November 03-19, 2020) and R2 (December 02-10, 2020).
[b] Spring and Summer 2021 terms: R4 (R2 March 15-31, 2021), R5 (May 05-21, 2021), and R6 (June 14- July 06, 2021).
[c] Academies and free schools are directly funded by the government, thus have more control over how they are run, whereas LA maintained schools are funded via their local authority.
[d] Funded by the government for socioeconomically disadvantaged students.
[e] Vaccination program started in England in December 2020 after study R2. KS, key stage; LA, local authority.

The strongest factor associated with incident infection in both students and staff in the autumn term was the presence of laboratory-confirmed COVID-19 cases in their household during that term (aOR 3.02; 95% CI 1.51-6.04 and aOR 23.7; 95% CI 15.1-37.2), respectively, in students with one or two or more cases in their household compared with none; Fig. 2). The association was stronger among the staff (aOR 15.3; 95% CI 9.1-25.7 and aOR 124.2; 95% CI 42.1-366.4; Fig. 3). Similar patterns persisted in the spring/summer terms in the staff and over three times stronger in students compared with the autumn term. We found no statistical association with household members working in education, transport, retail or hospitality sectors, or in health care in students and staff during all study periods. We also found no statistical association between individual socioeconomic indicators (FSM eligibility and FAS-III) and infection in students.

In the autumn term, there was some evidence of lower risk in students and staff who reported visiting other households respectively (aOR 0.73; 95% CI 0.51-1.04 and aOR 0.63; 95% CI 0.41-0.98), and higher risk in students and staff using public transport to commute to and from school compared to walking respectively (aOR 1.72; 95% CI 1.31-2.25 and aOR 5.94; 95% CI 1.31-26.91), but these associations were not found in the spring/summer terms in this study. In both periods, we found no statistical associations between infection and going to a restaurant or history of travel abroad after March 2020; although, the latter was associated with staff antibody-positivity at the start of school year (aOR 1.57; 95% CI 1.23-2.01).

Within schools, we found no statistical association between infections in the staff and contact with students or other staff in either autumn or spring/summer terms. There was also no association found between infection and contacts between students in this study, including within their class, with adjacent year groups, or with other students reported as close contacts, and student infections (full results in Supplementary Tables 5 and 6). There was also no statistical association between student infections and contact with staff in the autumn term but some evidence of lower risk in students with more staff contacts in the spring/summer term (aOR 0.72; 95% CI 0.55-0.95).

Discussion

SIS is one of the largest cohorts of school students and staff in England, in which COVID-19 infections were actively monitored throughout the 2020/2021 academic year to assess SARS-CoV-2 transmission within schools and risk factors for transmission. The infection risk in the autumn term was similar in students and staff but lower in staff than students in the spring/summer term. In autumn 2020 there was evidence of an association between SARS-CoV-2 infection and school-level indicators of deprivation but not in the spring/summer terms. We found no statistical difference between urban and rural schools nor primary and secondary schools in this study. Consistent with a respiratory mode of transmission, the strongest factor associated with infection was laboratory-confirmed SARS-CoV-2 infection in the household. SARS-CoV-2 infection in the staff and students was also associated with using public transport to commute to school in the autumn term but not in the spring/summer terms. There was no statistical association in this study with presence of a health care worker in the household nor with the type or frequency of school contacts.

The lack of observed association with individual contact patterns in school is consistent with the hypothesis that within-school transmission was relatively low in our study sample during a pe-

Table 2
Association between school-level characteristics and risk of incident COVID-19 infection in a sample of primary and secondary students in the Autumn 2020 and Spring/Summer 2021 school terms.

	Autumn term[a]					Spring / Summer terms[a]				
Variables	d/n (%)	Crude OR[b] (95% CI)	*P*-value	aOR[c]	*P*-value	d/n (%)	Crude OR[b] (95% CI)	*P*-value	aOR[c]	*P*-value
School rural/urban			**0.87**		**0.93**			**0.12**		**0.67**
Rural	25 / 737 (3.39)	REF		REF		16 / 841 (1.90)	REF		REF	
Urban city and town	102 / 3248 (3.14)	0.96 (0.54, 1.70)		0.92 (0.55, 1.56)		216 / 6807 (3.17)	1.69 (0.73, 3.91)		1.36 (0.66, 2.81)	
Urban conurbation	98 / 2814 (3.48)	1.09 (0.63, 1.87)		1.01 (0.62, 1.66)		180 / 4304 (4.18)	2.26 (1.05, 4.91)		1.28 (0.60, 2.70)	
LA-level transmission at start of school year 2020/2021			**0.67**		**0.58**			**<0.01**		**<0.01**
Low	78 / 2517 (3.10)	REF		REF		85 / 4715 (1.80)	REF		REF	
High	147 / 4282 (3.43)	1.10 (0.68, 1.78)		1.13 (0.71, 1.80)		327 / 7237 (4.52)	2.52 (1.59, 3.98)		2.56 (1.63, 4.04)	
School type			**0.57**		**0.31**			**0.02**		**0.30**
Primary	79 / 2503 (3.16)	REF		REF		108 / 3795 (2.85)	REF		REF	
Secondary	146 / 4296 (3.40)	1.13 (0.73, 1.74)		1.61 (0.61, 4.26)		304 / 8157 (3.73)	1.38 (1.07, 1.79)		1.24 (0.80, 1.93)	
School establishment group			**0.11**		**0.05**			**0.69**		**0.67**
Academy/free	134 / 3288 (4.08)	REF		REF		215 / 6545 (3.28)	REF		REF	
LA maintained	91 / 3511 (2.59)	0.59 (0.30, 1.14)		0.53 (0.27, 1.01)		197 / 5407 (3.64)	1.08 (0.71, 1.65)		1.05 (0.84, 1.31)	
School Office for Standards in Education, Children's Services and Skills rating			**<0.01**		**<0.01**			**0.71**		**0.65**
Outstanding/good	126 / 4968 (2.54)	REF		REF		291 / 8943 (3.25)	REF		REF	
Inadequate/requires improvement	42 / 947 (4.44)	1.79 (1.35, 2.36)		1.81 (1.39, 2.37)		64 / 1624 (3.94)	1.24 (0.68, 2.29)		1.27 (0.71, 2.28)	
Not yet available	57 / 884 (6.45)	2.70 (1.69, 4.31)		2.66 (1.63, 4.35)		57 / 1385 (4.12)	1.09 (0.72, 1.66)		0.95 (0.70, 1.28)	
School % students eligible for free school meals band			**0.02**		**0.03**			**0.75**		**0.84**
<10%	43 / 1776 (2.42)	REF		REF		124 / 3429 (3.62)	REF		REF	
10% - <30%	125 / 4110 (3.04)	1.28 (0.82, 2.00)		1.27 (0.81, 2.01)		225 / 6932 (3.25)	0.89 (0.58, 1.35)		0.92 (0.67, 1.24)	
>=30%	57 / 913 (6.24)	2.68 (1.35, 5.29)		2.69 (1.30, 5.56)		63 / 1591 (3.96)	1.00 (0.53, 1.88)		0.90 (0.57, 1.44)	
School % non-white ethnicity students (tertile)			**0.09**		**0.08**			**0.35**		**0.05**
<7.70%	78 / 2818 (2.77)	REF		REF		128 / 4103 (3.12)	REF		REF	
7.70-<29.06%	74 / 2518 (2.94)	1.00 (0.56, 1.80)		0.98 (0.54, 1.76)		156 / 5252 (2.97)	0.95 (0.71, 1.26)		0.96 (0.73, 1.26)	
>29.06%	73 / 1463 (4.99)	1.70 (0.98, 2.95)		1.67 (0.97, 2.85)		128 / 2597 (4.93)	1.55 (0.82, 2.96)		1.57 (1.04, 2.38)	
School % students with English as Additional Language (tertile)			**0.16**		**0.12**			**0.70**		**0.21**
<4.23%	73 / 2513 (2.90)	REF		REF		132 / 4005 (3.30)	REF		REF	
4.23-<21.06%	92 / 3002 (3.06)	0.99 (0.66, 1.50)		0.99 (0.66, 1.49)		194 / 5960 (3.26)	1.09 (0.81, 1.46)		1.04 (0.77, 1.39)	
>21.06%	60 / 1284 (4.67)	1.55 (0.90, 2.68)		1.59 (0.90, 2.81)		86 / 1987 (4.33)	1.34 (0.65, 2.77)		1.52 (0.89, 2.57)	
School size			**0.68**		**0.61**			**0.46**		**0.36**
Small	52 / 1375 (3.78)	REF		REF		108 / 2980 (3.62)	REF		REF	
Medium	74 / 2366 (3.13)	0.80 (0.46, 1.39)		0.78 (0.42, 1.45)		126 / 4174 (3.02)	0.86 (0.62, 1.20)		0.92 (0.70, 1.22)	
Large	99 / 3058 (3.24)	0.88 (0.54, 1.43)		0.81 (0.50, 1.31)		178 / 4798 (3.71)	1.14 (0.76, 1.70)		1.20 (0.87, 1.66)	
School student teacher ratio			**0.14**		**0.10**			**0.05**		**0.64**
<20	146 / 4321 (3.38)	REF		REF		296 / 8233 (3.60)	REF		REF	
20 - <51	53 / 2063 (2.57)	0.68 (0.37, 1.25)		0.62 (0.35, 1.08)		84 / 2897 (2.90)	0.74 (0.59, 0.93)		0.86 (0.59, 1.26)	
Data not available	26 / 415 (6.27)	1.90 (0.83, 4.35)		1.86 (0.84, 4.13)		32 / 822 (3.89)	0.92 (0.51, 1.65)		0.90 (0.61, 1.34)	

[a] Total 225 cases in the autumn 2020 and 412 in the spring/summer terms (including respectively 74 [33%] and 95 [23%] diagnosed via antibody conversion only).
[b] Mixed effect model with random intercept at school-level and robust standard errors clustered at the local authority level.
[c] Controlled for age, gender and LA-level COVID-19 community rates at the start of the school year 2020/2021.aOR, adjusted OR; CI, confidence interval; LA, local authority; OR, odds ratio; REF, reference.

Table 3
Association between sociodemographic characteristics and risk of COVID-19 infection in primary and secondary students in the Autumn 2020 and Spring/Summer 2021 terms.

		Autumn term[a]					Spring / Summer terms[a]				
Variables		d/n (%)	Crude OR[b] (95% CI)	*P*-value	aOR[c]	*P*-value	d/n (%)	Crude OR[b] (95% CI)	*P*-value	aOR[c]	*P*-value
Gender				**0.81**		**0.76**			**0.58**		**0.55**
	Male	112 / 3370 (3.32)	REF		REF		202 / 5965 (3.39)	REF		REF	
	Female	113 / 3429 (3.30)	0.96 (0.71, 1.32)		0.96 (0.70, 1.30)		210 / 5987 (3.51)	0.96 (0.82, 1.13)		0.96 (0.81, 1.12)	
Ethnicity				**0.54**		**0.54**			**0.46**		**0.21**
	White	180 / 5698 (3.16)	REF		REF		338 / 10178 (3.32)	REF		REF	
	Non-white (minority)	45 / 1101 (4.09)	1.15 (0.71, 1.86)		1.16 (0.71, 1.89)		74 / 1774 (4.17)	1.14 (0.79, 1.63)		1.20 (0.89, 1.63)	
Educational key stage (age group)				**0.20**		**0.24**			**0.01**		**0.72**
	KS 1 (5 to 7 yrs)	35 / 1094 (3.20)	REF		REF		38 / 1507 (2.52)	REF		REF	
	KS 2 (8 to 11 years)	44 / 1410 (3.12)	0.88 (0.46, 1.69)		1.00 (0.51, 1.99)		70 / 2287 (3.06)	1.24 (0.84, 1.84)		1.18 (0.76, 1.83)	
	KS 3 (12 to 14 years)	89 / 3026 (2.94)	0.93 (0.46, 1.88)		1.54 (0.42, 5.64)		225 / 6032 (3.73)	1.56 (1.22, 2.00)		1.47 (0.85, 2.54)	
	KS 4 (15 - 16 years)	22 / 586 (3.75)	1.17 (0.70, 1.94)		1.98 (0.65, 6.04)		51 / 1421 (3.59)	1.49 (1.07, 2.08)		1.35 (0.83, 2.18)	
	KS 5 (17 - 18 years)	35 / 683 (5.12)	1.50 (0.75, 2.98)		2.79 (0.71, 10.96)		28 / 705 (3.97)	1.88 (0.86, 4.07)		1.70 (0.79, 3.68)	
Index of multiple deprivation 2019 (quintile)				**0.29**		**0.30**			**0.26**		**0.30**
	Least deprived	42 / 1333 (3.15)	REF		REF		93 / 2448 (3.80)	REF		REF	
	4	37 / 1315 (2.81)	0.89 (0.54, 1.47)		0.89 (0.54, 1.48)		70 / 2296 (3.05)	0.75 (0.60, 0.94)		0.76 (0.61, 0.95)	
	3	33 / 1104 (2.99)	0.90 (0.52, 1.56)		0.90 (0.53, 1.56)		60 / 1915 (3.13)	0.80 (0.60, 1.08)		0.83 (0.64, 1.08)	
	2	39 / 1423 (2.74)	0.80 (0.52, 1.23)		0.81 (0.52, 1.25)		83 / 2472 (3.36)	0.82 (0.56, 1.18)		0.83 (0.62, 1.12)	
	Most deprived	74 / 1624 (4.56)	1.24 (0.78, 1.95)		1.24 (0.80, 1.92)		106 / 2821 (3.76)	0.76 (0.44, 1.32)		0.75 (0.44, 1.28)	
Household size				**0.19**		**0.21**			**0.85**		**0.84**
	1-2 persons	19 / 440 (4.32)	REF		REF		30 / 795 (3.77)	REF		REF	
	3-5 persons	188 / 5566 (3.38)	0.80 (0.46, 1.39)		0.80 (0.46, 1.41)		330 / 9764 (3.38)	0.89 (0.57, 1.38)		0.90 (0.59, 1.38)	
	6+ persons	18 / 793 (2.27)	0.51 (0.25, 1.07)		0.52 (0.25, 1.10)		52 / 1393 (3.73)	0.94 (0.64, 1.38)		0.97 (0.68, 1.40)	
Household composition				**0.75**		**0.83**			**0.50**		**0.47**
	Only adults ≥16 years	23 / 513 (4.48)	REF		REF		28 / 699 (4.01)	REF		REF	
	One child <16 years	61 / 1919 (3.18)	0.82 (0.48, 1.41)		0.90 (0.49, 1.62)		117 / 3576 (3.27)	0.81 (0.52, 1.28)		0.84 (0.54, 1.28)	
	Multiple children	141 / 4367 (3.23)	0.87 (0.53, 1.41)		0.96 (0.58, 1.60)		267 / 7677 (3.48)	0.89 (0.55, 1.45)		0.94 (0.63, 1.39)	
People per bedroom				**0.09**		**0.11**			**0.80**		**0.85**
	<=1	61 / 1533 (3.98)	REF		REF		100 / 2832 (3.53)	REF		REF	
	>1-2	154 / 4743 (3.25)	0.81 (0.58, 1.12)		0.81 (0.59, 1.12)		276 / 8195 (3.37)	0.95 (0.80, 1.13)		0.97 (0.82, 1.15)	
	>2	10 / 523 (1.91)	0.44 (0.22, 0.89)		0.44 (0.22, 0.92)		36 / 925 (3.89)	1.01 (0.58, 1.76)		1.07 (0.64, 1.78)	

[a] Total 225 cases in the autumn 2020 and 412 in the spring/summer terms (including respectively 74 [33%] and 95 [23%] diagnosed via antibody conversion only).
[b] Mixed effect model with random intercept at school-level and robust standard errors clustered at the local authority level.
[c] Controlled for age, gender and LA-level COVID-19 community rates at the start of the school year 2020/2021.aOR, adjusted OR; CI, confidence interval; KS, key stage; LA, local authority; OR, odds ratio; REF, reference.

Table 4
Association between school-level characteristics and risk of COVID-19 infection in primary and secondary staff in the Autumn 2020 and Spring/Summer 2021 terms

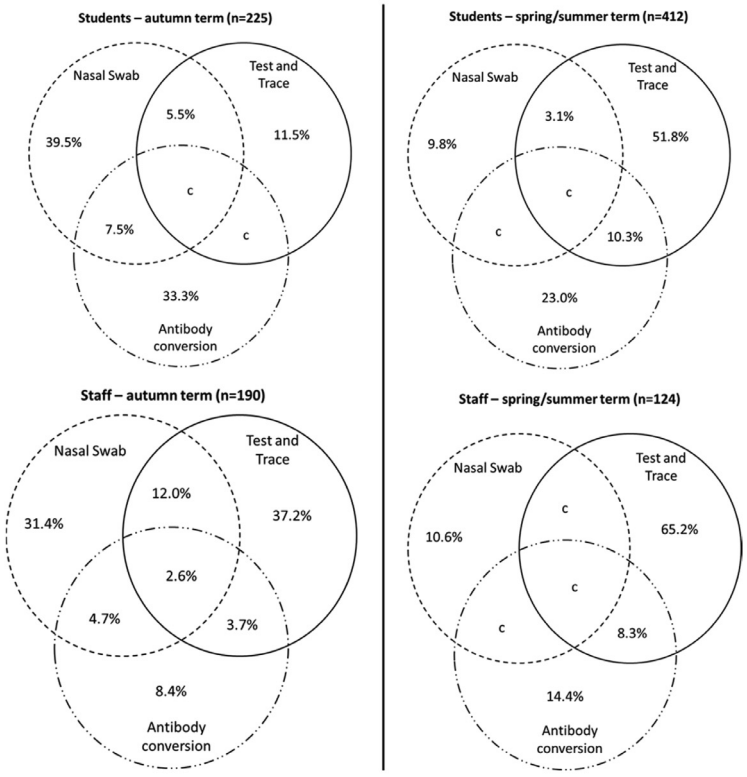
Variables	Autumn term[a]					Spring / Summer terms[a]				
	d/n (%)	Crude OR[b] (95% CI)	*P*-value	aOR[c]	*P*-value	d/n (%)	Crude OR[b] (95% CI)	*P*-value	aOR[c]	*P*-value
School rural/urban			**0.03**		**<0.01**			**0.02**		**0.64**
Rural	10 / 368 (2.72)	REF		REF		4 / 289 (1.38)	REF		REF	
Urban city and town	65 / 2313 (2.81)	1.32 (0.57, 3.07)		1.34 (0.59, 3.03)		53 / 2187 (2.42)	1.79 (1.11, 2.90)		1.42 (0.65, 3.11)	
Urban conurbation	115 / 2409 (4.77)	2.04 (0.77, 5.41)		2.18 (0.93, 5.13)		67 / 2093 (3.20)	2.41 (1.27, 4.59)		1.46 (0.59, 3.64)	
LA-level transmission at start of school year 2020/2021			**0.71**		**0.70**			**<0.01**		**<0.01**
Low	64 / 1861 (3.44)	REF		REF		23 / 1642 (1.40)	REF		REF	
High	126 / 3229 (3.90)	1.10 (0.66, 1.82)		1.10 (0.66, 1.83)		101 / 2927 (3.45)	2.52 (1.35, 4.72)		2.54 (1.35, 4.78)	
School type			**0.19**		**0.21**			**0.18**		**0.17**
Primary	32 / 1156 (2.77)	REF		REF		43 / 1301 (3.31)	REF		REF	
Secondary	158 / 3934 (4.02)	1.53 (0.80, 2.92)		1.51 (0.77, 2.95)		81 / 3268 (2.48)	0.77 (0.51, 1.15)		0.77 (0.52, 1.13)	
School establishment group			**0.39**		**0.43**			**0.31**		**0.40**
Academy/Free	109 / 2731 (3.99)	REF		REF		60 / 2527 (2.37)	REF		REF	
LA maintained	81 / 2359 (3.43)	0.79 (0.45, 1.39)		0.80 (0.45, 1.43)		64 / 2042 (3.13)	1.32 (0.75, 2.35)		1.22 (0.74, 2.02)	
School Office for Standards in Education, Children's Services and Skills rating			**0.80**		**0.86**			**0.99**		**0.91**
Outstanding/good	127 / 3382 (3.76)	REF		REF		87 / 3218 (2.70)	REF		REF	
Inadequate/requires improvement	33 / 918 (3.59)	0.99 (0.58, 1.68)		1.00 (0.59, 1.70)		20 / 723 (2.77)	1.05 (0.57, 1.94)		1.07 (0.57, 2.03)	
Not yet available	30 / 790 (3.80)	1.14 (0.70, 1.85)		1.12 (0.69, 1.80)		17 / 628 (2.71)	1.01 (0.43, 2.34)		0.86 (0.36, 2.06)	
School % students eligible for Free Sshool Meal band			**0.74**		**0.75**			**0.08**		**0.10**
<10%	19 / 668 (2.84)	REF		REF		11 / 680 (1.62)	REF		REF	
10% - <30%	124 / 3290 (3.77)	1.26 (0.66, 2.41)		1.28 (0.67, 2.44)		77 / 2848 (2.70)	1.64 (0.96, 2.79)		1.72 (1.02, 2.91)	
≥30%	47 / 1132 (4.15)	1.27 (0.66, 2.44)		1.24 (0.64, 2.44)		36 / 1041 (3.46)	2.21 (1.14, 4.30)		1.89 (0.99, 3.62)	
School % non-white ethnicity students (tertile)			**0.24**		**0.28**			**0.47**		**0.44**
<7.70%	55 / 1784 (3.08)	REF		REF		32 / 1496 (2.14)	REF		REF	
7.70-<29.06%	60 / 1614 (3.72)	1.43 (0.82, 2.50)		1.42 (0.82, 2.46)		42 / 1656 (2.54)	1.17 (0.59, 2.32)		1.22 (0.60, 2.47)	
>29.06%	75 / 1692 (4.43)	1.63 (0.92, 2.90)		1.62 (0.88, 2.98)		50 / 1417 (3.53)	1.59 (0.74, 3.44)		1.59 (0.76, 3.32)	
School % students with English as additional language (tertile)			**0.79**		**0.78**			**0.34**		**0.41**
<4.23%	59 / 1444 (4.09)	REF		REF		26 / 1325 (1.96)	REF		REF	
4.23-<21.06%	73 / 2201 (3.32)	0.91 (0.48, 1.70)		0.90 (0.48, 1.68)		57 / 2006 (2.84)	1.48 (0.78, 2.79)		1.54 (0.73, 3.26)	
>21.06%	58 / 1445 (4.01)	1.10 (0.66, 1.81)		1.10 (0.62, 1.95)		41 / 1238 (3.31)	1.62 (0.74, 3.57)		1.75 (0.72, 4.27)	
School size			**0.46**		**0.48**			**0.86**		**0.94**
Small	35 / 1133 (3.09)	REF		REF		30 / 1064 (2.82)	REF		REF	
Medium	83 / 1878 (4.42)	1.53 (0.67, 3.46)		1.53 (0.67, 3.51)		48 / 1690 (2.84)	0.99 (0.55, 1.78)		1.01 (0.59, 1.75)	
Large	72 / 2079 (3.46)	1.19 (0.52, 2.71)		1.20 (0.53, 2.70)		46 / 1815 (2.53)	0.87 (0.51, 1.48)		0.92 (0.56, 1.51)	
School student to teacher ratio			**0.83**		**0.89**			**0.91**		**0.90**
<20	149 / 3879 (3.84)	REF		REF		86 / 3276 (2.63)	REF		REF	
20 - <51	31 / 936 (3.31)	0.85 (0.42, 1.75)		0.87 (0.42, 1.82)		29 / 993 (2.92)	1.09 (0.63, 1.87)		1.12 (0.67, 1.88)	
Data not available	10 / 275 (3.64)	1.05 (0.64, 1.73)		1.03 (0.62, 1.73)		9 / 300 (3.00)	1.11 (0.43, 2.88)		0.94 (0.36, 2.46)	

[a] Total 190 cases in the autumn 2020 and 124 in the spring/summer terms (including respectively 16 [8%] and 18 [14%] diagnosed via antibody conversion only).
[b] Mixed effect model with random intercept at school-level and robust standard errors clustered at the local authority level.
[c] Controlled for age, gender and LA-level COVID-19 community rates at the start of the school year 2020/2021)aOR, adjusted OR; CI, confidence interval; LA, local authority; OR, odds ratio; REF, reference.

Table 5
Association between sociodemographic characteristics and risk of COVID-19 infection in primary and secondary staff in the Autumn 2020 and Spring/Summer 2021 terms.

Variables	Autumn term[a]					Spring / Summer terms[a]				
	d/n (%)	Crude OR[b] (95% CI)	*P*-value	aOR[c]	*P*-value	d/n (%)	Crude OR[b] (95% CI)	*P*-value	aOR[c]	*P*-value
Age group (years)			**0.74**		**0.74**			**0.23**		**0.16**
<35 years	66 / 1571 (4.20)	REF		REF		41 / 1381 (2.97)	REF		REF	
35-44 years	49 / 1493 (3.28)	0.78 (0.49, 1.26)		0.79 (0.49, 1.26)		31 / 1331 (2.33)	0.78 (0.43, 1.44)		0.78 (0.42, 1.44)	
45-54 years	49 / 1264 (3.88)	0.92 (0.58, 1.48)		0.94 (0.59, 1.48)		38 / 1178 (3.23)	1.08 (0.65, 1.81)		1.11 (0.65, 1.90)	
55+ years	26 / 762 (3.41)	0.78 (0.42, 1.45)		0.79 (0.42, 1.47)		14 / 679 (2.06)	0.67 (0.34, 1.31)		0.67 (0.35, 1.31)	
Gender			**0.38**		**0.40**			**0.63**		**0.64**
Male	48 / 1160 (4.14)	REF		REF		29 / 968 (3.00)	REF		REF	
Female	142 / 3930 (3.61)	0.87 (0.62, 1.21)		0.87 (0.63, 1.22)		95 / 3601 (2.64)	0.88 (0.51, 1.53)		0.88 (0.51, 1.53)	
Ethnicity			**0.64**		**0.63**			**0.99**		**0.98**
White	178 / 4724 (3.77)	REF		REF		116 / 4269 (2.72)	REF		REF	
Non-white (minority)	12 / 366 (3.28)	0.82 (0.33, 2.03)		0.81 (0.33, 2.02)		8 / 300 (2.67)	1.01 (0.47, 2.17)		1.01 (0.49, 2.09)	
Index of multiple deprivation 2019 quintiles			**0.30**		**0.28**			**0.35**		**0.33**
Least deprived	42 / 1080 (3.89)	REF		REF		19 / 981 (1.94)	REF		REF	
4	34 / 1098 (3.10)	0.77 (0.42, 1.43)		0.77 (0.42, 1.41)		33 / 996 (3.31)	1.71 (0.89, 3.27)		1.68 (0.87, 3.24)	
3	43 / 947 (4.54)	1.13 (0.71, 1.80)		1.12 (0.70, 1.80)		24 / 799 (3.00)	1.55 (0.87, 2.76)		1.54 (0.87, 2.75)	
2	39 / 1056 (3.69)	0.93 (0.58, 1.49)		0.92 (0.58, 1.46)		25 / 955 (2.62)	1.33 (0.93, 1.92)		1.33 (0.93, 1.89)	
Most deprived	32 / 909 (3.52)	0.82 (0.48, 1.39)		0.81 (0.47, 1.38)		23 / 838 (2.74)	1.31 (0.56, 3.03)		1.23 (0.52, 2.89)	
Household size			**0.83**		**0.79**			**0.32**		**0.28**
1-2 persons	72 / 1975 (3.65)	REF		REF		45 / 1771 (2.54)	REF		REF	
3-5 persons	109 / 2910 (3.75)	1.05 (0.71, 1.55)		1.09 (0.71, 1.66)		70 / 2626 (2.67)	1.08 (0.80, 1.46)		1.11 (0.78, 1.60)	
6+ persons	9 / 205 (4.39)	1.23 (0.54, 2.82)		1.26 (0.53, 2.98)		9 / 172 (5.23)	2.21 (0.77, 6.29)		2.34 (0.81, 6.72)	
Household composition			**0.45**		**0.35**			**0.79**		**0.69**
Only adults ≥16 years	94 / 2717 (3.46)	REF		REF		63 / 2454 (2.57)	REF		REF	
One child <16 years	39 / 992 (3.93)	1.18 (0.80, 1.75)		1.26 (0.81, 1.95)		27 / 932 (2.90)	1.13 (0.70, 1.82)		1.18 (0.67, 2.10)	
Multiple children	57 / 1381 (4.13)	1.22 (0.86, 1.74)		1.38 (0.85, 2.24)		34 / 1183 (2.87)	1.13 (0.72, 1.76)		1.24 (0.72, 2.14)	
Person per bedroom			**0.84**		**0.85**			**0.16**		**0.15**
≤1	72 / 1908 (3.77)	REF		REF		46 / 1716 (2.68)	REF		REF	
>1-2	111 / 3038 (3.65)	1.01 (0.72, 1.41)		1.01 (0.72, 1.43)		70 / 2728 (2.57)	0.98 (0.74, 1.29)		0.98 (0.72, 1.34)	
>2	7 / 144 (4.86)	1.38 (0.38, 4.96)		1.39 (0.39, 4.96)		8 / 125 (6.40)	2.63 (0.98, 7.05)		2.65 (1.00, 6.99)	
Job group (staff only)			**0.43**		**0.21**			**0.16**		**0.25**
Senior leader	17 / 421 (4.04)	REF		REF		11 / 384 (2.86)	REF		REF	
Middle leader	36 / 907 (3.97)	1.00 (0.51, 1.95)		1.01 (0.50, 2.04)		26 / 738 (3.52)	1.26 (0.65, 2.45)		1.27 (0.67, 2.43)	
Teacher	79 / 1731 (4.56)	1.21 (0.70, 2.09)		1.20 (0.68, 2.12)		34 / 1453 (2.34)	0.80 (0.35, 1.83)		0.80 (0.37, 1.73)	
TA / Special Ed	24 / 707 (3.39)	0.89 (0.48, 1.68)		0.89 (0.48, 1.64)		27 / 727 (3.71)	1.30 (0.70, 2.39)		1.41 (0.75, 2.66)	
Admin / Pastoral	19 / 728 (2.61)	0.66 (0.28, 1.57)		0.66 (0.28, 1.55)		17 / 728 (2.34)	0.82 (0.38, 1.75)		0.92 (0.42, 2.02)	
	6 / 228 (2.63)	0.74 (0.24, 2.23)		0.71 (0.23, 2.18)		c / 212 (c)	0.15 (0.02, 1.07)		0.16 (0.02, 1.14)	
Catering/Cleaning/Maintenance										
Other	9 / 368 (2.45)	0.60 (0.22, 1.65)		0.59 (0.21, 1.70)		8 / 327 (2.45)	0.90 (0.37, 2.18)		0.98 (0.40, 2.38)	
Year group with most contact			**0.31**		**0.27**			**0.64**		**0.65**
None	97 / 2781 (3.49)	REF		REF		59 / 2584 (2.28)	REF		REF	
Year 2 and below	10 / 265 (3.77)	1.17 (0.52, 2.60)		1.18 (0.52, 2.67)		12 / 290 (4.14)	1.80 (0.73, 4.44)		1.85 (0.75, 4.59)	
Year 3 to 6	5 / 274 (1.82)	0.52 (0.22, 1.23)		0.52 (0.21, 1.28)		12 / 318 (3.77)	1.57 (0.85, 2.91)		1.53 (0.83, 2.83)	
Year 7 to 9	32 / 655 (4.89)	1.39 (0.93, 2.07)		1.35 (0.92, 1.98)		20 / 502 (3.98)	1.82 (0.80, 4.18)		1.77 (0.78, 4.03)	
Year 10 & 11	35 / 861 (4.07)	1.11 (0.69, 1.80)		1.10 (0.66, 1.82)		17 / 677 (2.51)	1.11 (0.62, 2.01)		1.10 (0.61, 1.98)	
Year 12 & 13	11 / 254 (4.33)	1.13 (0.55, 2.30)		1.13 (0.55, 2.31)		4 / 198 (2.02)	0.89 (0.33, 2.38)		0.91 (0.38, 2.21)	
COVID-19 vaccination[d]								**0.11**		**0.09**
Unvaccinated	-	-		-		49 / 1502 (3.26)	REF			
Vaccinated (≥1 dose)	-	-		-		75 / 3067 (2.45)	0.74 (0.51, 1.08)		0.71 (0.47, 1.07)	

[a] Total 190 cases in the autumn 2020 and 124 in the spring/summer terms (including respectively 16 [8%] and 18 [14%] diagnosed via antibody conversion only).
[b] Mixed effect model with random intercept at school-level and robust standard errors clustered at the local authority level.
[c] Controlled for age, gender and LA-level COVID-19 community rates at the start of the school year 2020/2021.
[d] receipt of at least one dose of any COVID-19 vaccine at any point in the study period, but does not account for interval between vaccination and infection.aOR, adjusted OR; CI, confidence interval; LA, local authority; OR, odds ratio; REF, reference.



(c = results suppressed due to low numbers to prevent statistical disclosure) (Test and Trace data are laboratory-confirmed COVID-19 case reported to the Second-Generation Surveillance System)

Figure 1. Data source for infection cases in students and staff in the autumn 2020 and spring/summer 2021 school terms. c = results suppressed due to low numbers to prevent statistical disclosure (Test and Trace data are laboratory-confirmed COVID-19 case reported to the Second-Generation Surveillance System).

riod of widely implemented school-based mitigation measures, including isolation of cases and contacts at home [8]. Notwithstanding our findings, some school-related outbreaks did occur in England [19], as in other countries [20]. Likewise, our findings are in contrast with school-aged cohort studies in different settings [21,22]. The infection rates were similar in students and staff in the autumn term, consistent with broadly comparable risks; despite the limited evidence in this study, this does not support the hypothesis of children infecting staff because of higher infection rates.

The low infection rates in this cohort in the spring/summer terms and lower prevalence in staff than students may reflect lower community rates in that period, but perhaps are also partly due to the deployment of new mitigation measures when schools reopened after the second national lockdown in March 2021, including adult COVID-19 vaccination and mass testing for secondary schools students using rapid antigen tests [8]. The head teachers and staff surveyed in schools indicated that most of the nationally recommended measures were implemented [10,13]. Modeling work also suggests benefits from the mass lateral flow testing program in reducing within-school transmission [23].

The association between infection and school-level deprivation indicators in the autumn term may partly reflect that some schools cover more deprived populations [24], with deprivation associated with higher infection numbers in the community. The lack of statistical associations between infection and deprivation indicators in the spring/summer terms in this study may be explained by the community-wide mitigation measures, including the national lockdown, adult vaccinations, and mass testing and isolation.

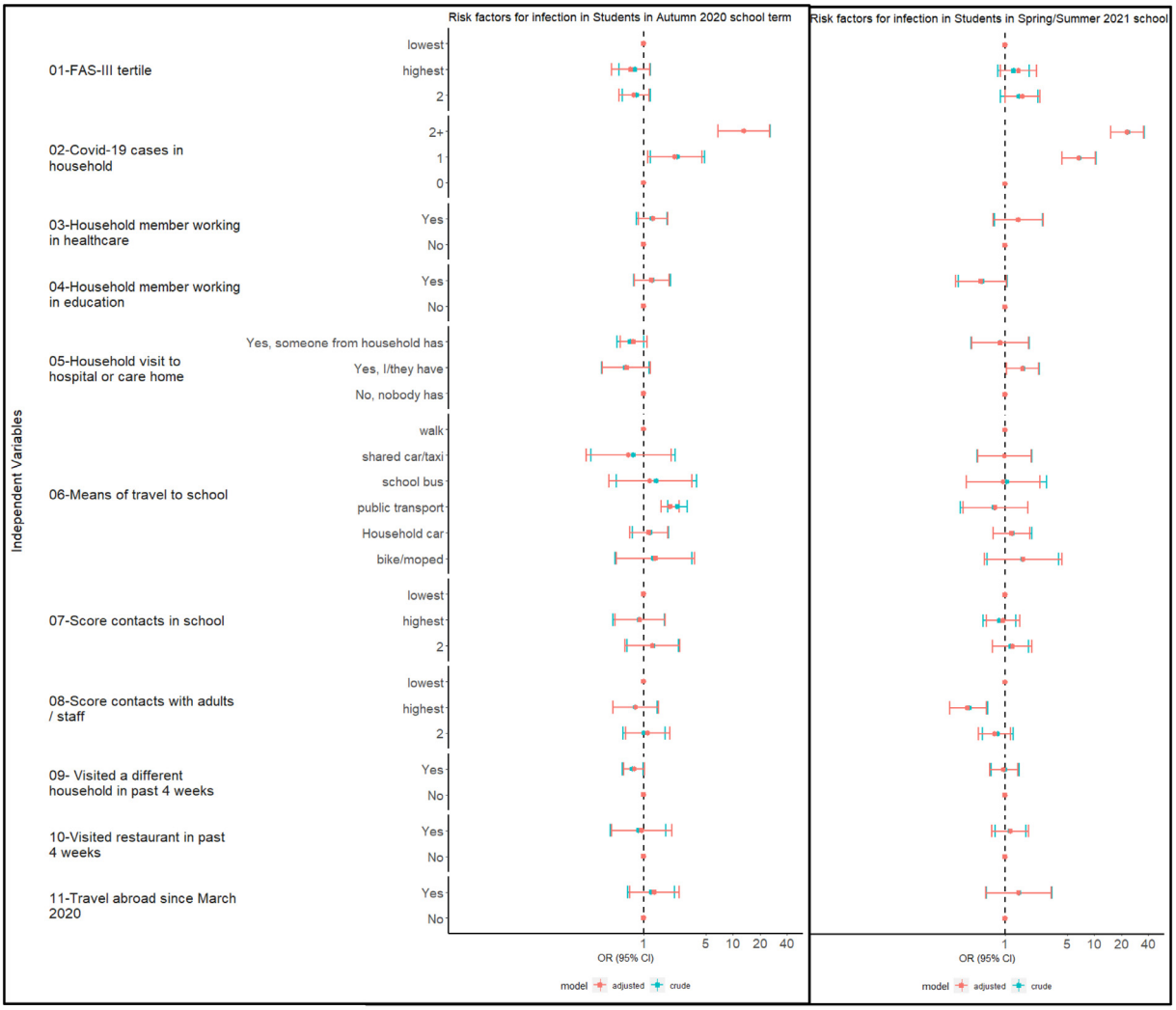
The strong association found between household cases and infection during school terms is consistent with previous analyses in England that showed strong household clustering [25–27]. The increased association between household cases and risk of infection in students in the spring/summer terms could reflect the higher infectiousness of the SARS-CoV-2 Delta variant emerging over that study period [25]. Investigation of the direction of transmission within households, thus whether open schools amplify community transmission, is beyond the scope of this study and will be examined separately.

A curious finding was the lower infection risk associated with visiting another household during the autumn term, which may be reverse causality, with people at lower risk or with access to regular testing more able or likely to visit other households at a time when stay-at-home recommendations were in place [28].

Non-White ethnicity was associated with higher antibody prevalence at the start of the study, consistent with a higher risk in minority ethnic groups during the pandemic's first wave [29]. However, we did not find any statistical association between ethnicity and infection in this study; although, the number of non-White ethnicity participants was small.

Strengths and limitations

The strengths of SIS included its relatively large sample size and broad geographic coverage in challenging circumstances [12]. However, the response rates were lower than expected, especially in students, varying from 12-18% per round [12,15]; although, this was similar to other large COVID-19 surveys [30]. Among those who agreed to participate, there may be some selection bias to-



crude odds ratio and 95% confidence interval from mixed effect model with random intercept at school-level and robust standard errors clustered at the local authority level

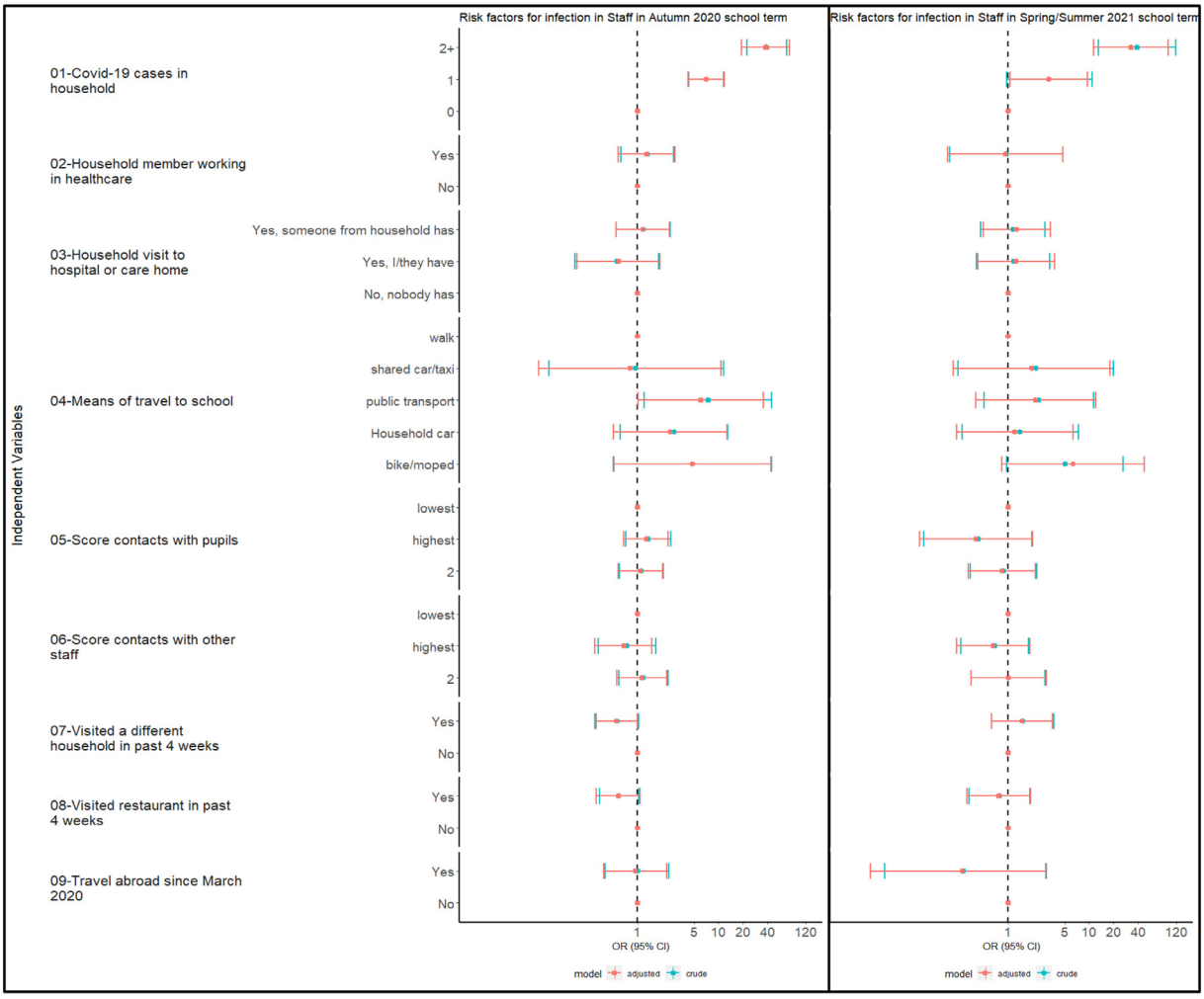
adjusted odds ratio controlled for age, gender, LA-level covid-19 community rates at the start of the school year 2020/2021, school's urban/rural location, Ofsted rating, and IMD

Figure 2. Forest plot with OR and 95% CI for the association between selected household, community and school risk factors and COVID-19 infection in primary and secondary students in the Autumn 2020 and Spring/Summer 2021 school terms. Crude OR and 95% CI from mixed effect model with random intercept at school-level and robust standard errors clustered at the LA-level. aOR controlled for age, gender, LA-level COVID-19 community rates at the start of the school year 2020/2021, school's urban/rural location, Office for Standards in Education, Children's Services and Skills rating, and Index of Multiple Deprivation. aOR, adjusted OR; CI, confidence interval; FAS-III, family affluence survey-III; LA, local authority; OR, odds ratio.

ward those students or staff believing themselves at a higher risk and looking for confirmation. In addition, because of the large numbers, participant recruitment was carried out by online email requests, which was the main form of communication used by schools; the resulting digital divide is well recognized, especially the lack of suitable equipment in poor households [31]. Attempts were made initially and throughout the year to gain participation through letters and posters in schools; questionnaires were also designed to be compatible with handheld mobile devices.

Detailed data on individual factors were collected in the longer second questionnaire after enrollment to minimize nonresponse for biological testing at recruitment. The response rate was reasonable but reduced the sample size available. This, together with the shorter period, led to smaller numbers in the autumn 2020 term. For instance, although we collected information on facemask usage during commute and within schools, the small sample size and limited variability reduced our ability to investigate their association with infection risk. The smaller sample size may have also affected our study's statistical power to detect some associations. Some measurement error may also have been introduced where parents answered for younger students. Residual confounding is also possible, for example, from rapidly changing community transmission rates or household members' vaccination. These could have biased results, but given the lack of strong confounders in our analysis, any bias would likely be minimal. Also note that with the relatively low infection numbers in our participants, we did not attempt to separate the net effect of each exposure in a single multivariable regression model that simultaneously included all variables.

Another consideration when interpreting our findings is that this was a rapidly evolving pandemic; for example, the study spans



crude odds ratio and 95% confidence interval from mixed effect model with random intercept at school-level and robust standard errors clustered at the local authority level

adjusted odds ratio controlled for age, gender, LA-level covid-19 community rates at the start of the school year 2020/2021, school's urban/rural location, Ofsted rating, and IMD

Figure 3. Forest plot with OR and 95% CI for the association between selected household, community and school risk factors and COVID-19 infection in primary and secondary staff in the Autumn 2020 and Spring/Summer 2021 school terms. Crude OR and 95% CI from mixed effect model with random intercept at school-level and robust standard errors clustered at the LA-level. aOR controlled for age, gender, LA-level COVID-19 community rates at the start of the school year 2020/2021, school's urban/rural location, Office for Standards in Education, Children's Services and Skills rating, and Index of Multiple Deprivation. aOR, adjusted OR; CI, confidence interval; FAS-III, family affluence survey-III; LA, local authority; OR, odds ratio.

the emergence and spread of the Alpha (autumn), then Delta (summer) variants, alongside the phased introduction of vaccines for adults. By March 2022, however, there was high vaccine uptake with boosters in adults and the dominant virus was the Omicron variant, which is more infectious and was associated with school outbreaks and peaks in student and staff absences.

We used multiple sources to ascertain infections in this study, including linkage to the SGSS to identify infections not otherwise detected by the study testing regimen, which increased the study's statistical power. It is possible there was some bias in the identification of cases in SGSS, especially asymptomatic and mild cases during the autumn term when rapid antigen testing was not widely available, but the impact on the findings appears minimal because the results were broadly similar, albeit with lower precision, when restricted to infection from the study testing regimen (data not presented).

Conclusion

Our analysis aimed to examine the factors affecting risk of SARS-CoV-2 infection in school settings and populations. Despite its limitations, our analyses provide further insights that various indicators of deprivation were associated with infections, especially in the autumn 2020 term when schools reopened at the time the second wave was beginning. Household infections were also noted as important factors associated with incident infections in the 2020/2021 school year, a common feature given the ease of transmission of an airborne infection. However, we did not observe a statistical association with social contact patterns in schools or other school-based factors in this study. This suggests that in addition to adult vaccination, rapid testing and isolation where available have been key in reducing community burden, and that school-based mitigation measures, such as social distanc-

ing, improved ventilation, and isolation of cases and close contacts, likely contributed to reduce the transmission risk in schools.

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Ethical approval

The Public Health England (now part of the UK Health Security Agency) Research Support and Governance Office (NR0237) and the London School of Hygiene & Tropical Medicine Ethics Review Committee (ref: 22657).

Author contributions

JH, SML, SNL, CB, PM, PJ, NS, and PND were responsible for conceptualization and study design and methodology. JH, SNL, SML, and PJ obtained funding. PND, KEH, WEO, SC, JS, JP, GI, AJ, CB, NS, PM, JH, SML, and SNL were involved in acquisition of data. PND and WEO performed the analysis and interpretation of data with support from SC and PM. PND, WEO, KEH, JS, GI, and AJ were responsible for data validation and verification. PND, WEO, and PM drafted the manuscript. All authors gave critical revision of the manuscript for important intellectual content and contributed to reviewing and editing of the manuscripts. All authors had access to the data. PND and PM had final responsibility to submit for publication.

Disclaimer

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Data Availability statement

Deidentified study data are available for access by accredited researcher in the ONS Secure Research Service for accredited research purposes under part 5, chapter 5 of the Digital Economy Act 2017. For further information about accreditation, contact Research.support@ons.gov.uk or visit the SRS website.

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Provenance and peer review

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Declaration of competing interest

The authors have no competing interests to declare.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijid.2022.12.030.

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