SARS-CoV-2 infections in children following the re-opening of schools and the impact of national lockdown during Autumn 2020: prospective, national observational cohort surveillance, England

Anna A Mensah MSc,[1] Mary Sinnathamby MPH,[2] Asad Zaidi MSc,[2] Laura Coughlan MSc,[1] Sharif A Ismail MBBS,[1] Mary E Ramsay FFPH,[1] Vanessa Saliba MD,[1] Shamez N Ladhani PhD.[1,3]

[1] Immunisation and Countermeasures Division, Public Health England, London, UK

[2] COVID-19 Epi Cell, Public health England, London, UK

[3] Paediatric Infectious Diseases Research Group (PIDRG), St George's University of London, London, UK

CORRESPONDING AUTHOR

Dr Shamez Ladhani, Immunisation and Countermeasures Division, National Infection Service

Public Health England Colindale, London NW9 5EQ, UK. Email: shamez.ladhani@phe.gov.uk

sharif.ismail@phe.gov.uk

Abstract

Background

The reopening of schools during the COVID-19 pandemic has raised concern for the safety of staff and students, their families and the wider community. We monitored SARS-CoV-2 infection rates in school-aged children and compared them with adult infection rates before and after schools reopened in England.

Methods

Public Health England receives daily electronic reports of all SARS-CoV-2 tests nationally. SARS-CoV-2 infection rates by school year from July to November 2020 were analysed, including the effect of a week-long half-term school break in October and national month-long lockdown whilst keeping schools open in November 2020

Findings

SARS-CoV-2 infections rates were low during early summer but started increasing in mid-August, initially in young adults followed by secondary and then primary school-aged children prior to schools reopening in September 2020. Cases in school-aged children lagged behind and followed adult trends after schools reopened, with a strong age gradient in weekly infection rates. There was a strong ($P<0.001$) correlation in regional infection rates between adults and secondary (R^2=0.96-0.98), primary (R^2=0.93-0.94) and preschool-aged (R^2=0.62-0.85) children. The half-term break had a small and transient effect on infection rates in school-aged children, but there was a sharp decline in adult cases followed a week later by a decline in student cases after national lockdown in November 2020.

Interpretation

In school-aged children, SARS-CoV-2 infections followed the same trajectory as adult cases and only declined after national lockdown was implemented whilst keeping schools open. Maintaining low community infection rates is critical for keeping schools open during the pandemic.

Funding: PHE

Research in Context

Evidence Before this study

We searched PubMed with the terms “COVID-19” or “SARS-CoV-2” with “school”, “education”, “nursery” or “student” to identify publications relating to SARS-CoV-2 infections in educational settings since the start of the COVID-19 pandemic in December 2019. Most publications were reviews and opinion pieces on the impact of school closures on disease transmission and child health. Outbreak investigations early in the pandemic reported very low rates of SARS-CoV-2 infection in staff or students in educational settings. Countries that kept their educational settings open, mainly preschools and primary schools, and those that partially reopened their schools after implementing national lockdowns also reported very low rates of SARS-CoV-2 infections or outbreaks in their educational settings. Secondary schools were more likely to experience a higher number of infections and outbreaks than primary schools or preschools.

Added Value of This Study

We used national surveillance data in England to monitor trends in weekly SARS-CoV-2 infection rates and test positivity rates by age and English region during the school summer holidays and during the school Autumn term when educational settings reopened for all school years. Weekly SARS-CoV-2 infection rates in school-aged children lagged over time behind but correlated closely with adult infection rates nationally and regionally, both before and after the reopening of schools during the Autumn term. The half-term school break had a small and transient impact on weekly infection rates in school-aged children, but the combination of local restriction tiers from 12 October 2020 and national lockdown imposed in November 2020, whilst keeping schools open, was associated with rapid declines in weekly infection rates in adults first and then in school-aged children a week later.

Implications of all the Available Evidence

SARS-CoV-2 infection rates in school-aged children are influenced by adult infection rates in the community, emphasising the importance of maintaining low community infection rates to allow schools to remain open during the current pandemic.

Introduction

The rapid spread of the SARS-CoV-2, the virus responsible for COVID-19, led many countries to impose strict national lockdowns which, in most countries, included school closures, even though children appeared to have been relatively spared by the COVID-19 pandemic.[1] At that time, children were responsible for only 1-3% of confirmed COVID-19 cases but their role in community infection and transmission of SARS-CoV-2 was not known.[2,3] School closures, however, not only disrupts the education of students, but also affects their physical, mental and social development and wellbeing, restricts access to health visiting, social care and school-based vaccinations, all of which disproportionately impact children from disadvantaged and vulnerable backgrounds, thus exacerbating inequalities.[3,4]

In England, the first imported COVID-19 cases were identified in late January 2020 and cases started increasing rapidly from March 2020, leading to school closures on 20 March and wider national lockdown on 23 March 2020. Cases eventually plateaued in mid-April 2020 and started declining gradually until the end of May 2020, allowing for phased easing of the national lockdown.[5] From 01 June 2020, preschool children and some primary school years returned to school, followed by some secondary school years from 15 June 2020, albeit with strict infection control and physical distancing measures in place, including small class sizes organised into self-contained bubbles that did not interact with each other.[6] Enhanced national surveillance identified very few cases or outbreaks in students or staff attending school during the summer mini-term.[7]

These findings, together with experiences of other countries that had kept their schools open throughout the pandemic and those that reopened schools as part of easing of their lockdown,[1] led to the full reopening of all school years in the UK during the Autumn term.[6] Unlike the previous summer mini-term, however, community infection rates were higher across England when the schools reopened in September 2020,[5] and, while extensive national guidelines were issued for educational settings,[6] the large number of children attending school provided unprecedented challenges, particularly in relation to maintaining adequate physical distancing within the educational environment.

Additionally, the full reopening of schools was likely to significantly increase the number of contacts students had both within and outside educational settings. We analysed age-specific regional and national trends of confirmed SARS-CoV-2 infections in England from the start of the summer holidays in July 2020 through to the reopening of schools in September 2020 in order to better understand risks and trends in SARS-coV-2 infection in school-aged children compared to adults. We also assessed the impact of the school half-term break in October 2020 and the national lockdown

whilst keeping the schools open during November 2020 on SARS-CoV-2 infection rates in children and adults.

Methods

Public Health England (PHE) conducts SARS-CoV-2 surveillance in England. PHE receives daily electronic notifications of SARS-CoV-2 tests through different routes called 'Pillars'.[8] In Pillar 1, SARS-CoV-2 RT-PCR tests are undertaken on respiratory swabs by PHE laboratories and National Health Service (NHS) hospitals for those with a clinical need and for health and care workers. Pillar 2, includes results of Lateral Flow and SARS-CoV-2 RT-PCR tests performed in the community, which can be requested by anyone with symptoms consistent with COVID-19 (fever, new onset cough or loss of smell or taste) a. The data are collated electronically in the Second Generation Surveillance System (SGSS) and includes name, sex, date of birth, place and date of testing and the test results.

Timelines

SARS-CoV-2 RT-PCR tests performed in England between 13 July 2020 (start of the summer school holidays) and 29 November 2020 were included in the analysis. This period included the start of the Autumn term which, for most schools was during the week beginning 30 August 2020, although some schools reopened a week later. The week-long half-term break started on 26 October 2020 for most schools, although half-term began a week early in some schools and others had a two-week half-term break.

Because of increasing numbers of cases across different regions in England, a local tier system of restrictions was announced on 12 October 2020,[9] with Tier 1 representing medium alert, Tier 2 high alert and Tier 3 very high alert.[10] Many parts of northern England and the Midlands were placed in Tier 3 restrictions at that time. Schools remained open in all tiers. With cases continuing to increase nationally, however, a national lockdown was imposed from 05 November 2020 to 02 December 2020, whilst keeping schools open.

Data analysis

SARS-CoV-2 tests performed in school-aged children were categorised by corresponding school year, whereby the children' born between 01 September and 31 August of the following calendar year were assigned to their respective school years, including nursery [2-3 year-olds], pre-school years [3-4 year-olds], reception [4-5 year-olds], primary school years 1 [5-6 year-olds] to 6 [10-11 year-olds], and secondary school year 7 [11-12 year-olds] to year 13 [17-18 year-olds]. The school years were

then categorised into three educational settings: preschools (nursery and preschool years), primary schools (reception, years 1 to 6) and secondary schools (years 7 to 13). In England, children are educated in secondary schools until school year 11 (15-16 year-olds) and can then opt for higher education in school or college, apprenticeships or traineeship, as well as being employed, self-employed or volunteering for 20 hours or more a week. For this analysis, they were grouped as a single cohort in either school year 12 (16-17 year-olds) or year 13 (17-18 year-olds).

SARS-CoV-2 infection rates in school-aged children were compared to two adult age-groups: all adults (16-64 year-olds representing working-age adults) and young adults (18-29 year-olds, the age group with the earliest, most rapid and highest increase in SARS-CoV-2 infection rates during the second pandemic wave).[5] Weekly SARS-CoV-2 infections were obtained using positive cases reported from Monday to Sunday for each week and positivity rates were calculated by dividing the number of positive cases with total number of tests performed in a single week. Mid-year estimates using 2019/2020 census data from the Office for National Statistic (www.statistics.gov) were used as denominators for age and the nine PHE regions.[11] Infection rate ratios (IRRs) were used to compare weekly infection rates between age-groups, educational settings and regions, using the group with the lowest weekly infection rate as baseline.

Confidence intervals were calculated using the following equations:

Standard Error (SE), (LnIR)=$\sqrt{(\frac{1}{e1}+\frac{1}{e2})}$

where e1 and e2 are the number of events in those population and

95% Confidence Interval (95% CI) = exp(LnIR ± 1.96*SE(LnIR)

Linear regression was used to assess correlation between weekly infection rates in the educational cohorts and adults (18-64 year-olds) in individual English regions. Correlation was assessed for the week of 27 July 2020 when SARS-Cov-2 infection rates were very low and 12 October 2020, when weekly infection rates were very high. Daily growth rates and doubling times were calculated using statistical software R with the "*i2extras*" package and included positive cases from the last four weeks before 31 August 2020 and before 19 October 2020

Role of the funding source:

This surveillance was internally funded by PHE and did not receive any specific grant funding from agencies in the public, commercial or not-for-profit sectors. All authors had access to the data; the

first and final authors verified the data and had final responsibility for the decision to submit for publication.

Ethical approval:

PHE has legal permission, provided by Regulation 3 of The Health Service (Control of Patient Information) Regulations 2002, to process patient confidential information for national surveillance of communicable diseases and as such, individual patient consent is not required.

Results

Infection Rate during the Summer Holidays

In England, the weekly incidence of confirmed SARS- CoV-2 infections during the summer holidays (13 July to 30 August 2020) was low across all age-groups. There was a consistent trend of increasing SARS-CoV-2 infection rates with increasing age, from preschool-aged children to young adults (18-29 year-olds) (**Fig 1a**). During the four weeks prior to the start of the school Autumn term (week beginning 31 August 2020), the daily growth rate of SARS-CoV2 infection rates was relatively stable in preschool-aged and primary school-aged children, but was increasing slowly in secondary school-aged children (daily growth rate, r= 0.00947; 95% CI: 0.00439 to 0.0146) (**Supplement Table S1**). In young adults, cases had been increasing since 13 July 2020 and accelerated after 03 August 2020 (**Figure 1b**).

Infection rates after schools reopening

During the week prior to schools reopening (24-30 August 2020), there was an upward inflection in weekly SARS-CoV-2 infection rates in both secondary and primary school-aged children but not in preschool children. In young adults, weekly infection rates remained higher than the three educational cohorts throughout the surveillance period, with a more rapid increase observed after 14 September 2020, peaking during the week of 05 October 2020 when infection rates in young adults were 12.98 times higher than in preschool children (95%CI, 11.80-14.27) and then plateauing (**Figure 1 and Supplement table S2**). During the week beginning 19 October 2020, just before the school half-term holidays, SARS-CoV-2 infection rates were increasing most rapidly in preschool-aged children, with a doubling time of 18.2 (95%CI, 15-22.3) days compared to 20.4 (18.8-22.2) days in primary school-aged and 30.1 (28.0-32.5) days in secondary school-aged children (**Supplement Table S1**).

Age-specific incidence

Throughout the autumn half-term, SARS-CoV-2 infection rates remained highest in young adults, followed by secondary, primary and preschool-aged children (**Figure 2**), as evidenced by the weekly trends in IRR between these cohorts (**Supplement Table S2**). During the week of 13 July 2020, the relative weekly SARS-CoV-2 infection rates compared to preschool-aged children were 1.14 (95% CI, 0.90-1.43) for primary school-aged children, 1.62 (95% CI, 1.29-2.02) for secondary school-aged children and 1.69 (95% CI, 1.36-2.10) for young adults. These relative infection rates increased to 1.86 (95% CI, 1.71-2.02), 5.06 (95%CI 4.66-5.49) and 8.43 (95% CI, 7.77-9.13), respectively, during the week of 19 October 2020 (**Supplement Table S2**). The same trends were also observed in the weekly SARS-CoV-2 positivity rates for the three educational settings, which increased throughout the autumn half-term and peaked during the half-term week beginning 26 October 2020, when positivity rates were 4.35% in preschool-aged children, 9.43% in primary school aged children and 18.9% in secondary school-aged children (**Figure 3**). This compares with 0.73%, 1.11% and 2.08% during the week prior to schools reopening from August 31, 2020. A consistent age gradient in weekly infection rates was observed for the educational cohorts throughout the autumn half-term, apart from school year 11 having higher weekly infection rates than school year 12 since the start of the Autumn half-term (**Figure 2**).

Regional Infection Rates

The national trends in SARS-CoV2 infection rates school-aged children and adults were also observed across the nine English regions albeit, although peak infection rates were varied in the different region. A strong and statistically significant ($P<0.001$) correlation was observed between weekly SARS-CoV-2 infection rates in adults and the three educational cohorts, both during a week of low (27 July 2020) and high (19 October 2020) national incidence, with the strongest correlation observed for secondary school-aged children (**Figure 5**). During the week of 19 October 2020, for every additional 100 cases per 100,000 young adults in the community, there were an additional 71 cases per 100,000 in secondary school-aged children, 26 per 100,000 in primary school-aged children and 14 per 100,000 in preschool-aged children.

Impact of school closure during half-term and the second national lockdown

SARS-CoV-2 infection rates dipped during the half-term school break during the week of 26 October 2020 and was associated with fewer tests performed for all three educational cohorts, although positivity rates were highest during this week. The re-opening of schools after the half-term was associated with a continuing increase in SARS-CoV-2 infection rates across all educational settings

and at the same rate as the weeks prior to the school half-term holiday (**Figure 1**). Trends in SARS-CoV2 infection rates remained unchanged in adults.

Following national lockdown in November 2020, cases in adults plateaued and then fell rapidly within two weeks. Similar trends were observed across all three educational settings but with a lag of one week after the adults, such that, for the first time in England, adult infection rates fell below secondary school-aged children (**Figure 1**). Concomitant reductions in SARS-CoV-2 tests and positivity rates were observed after the half-term holiday, although positivity rates in primary and secondary school-aged children did increase in the last week of November 2020 (**Figure 3**). The national trends are reflected in the regions with SARS-CoV-2 infection rates >300/100,000, where large declines were observed in young adults followed by similar declines in secondary school-aged children and the same trends with smaller declines in primary schools-aged and preschool-aged children (**Figure 4**). In the East of England and in the London region, SARS-CoV-2 infection rates remained low (<300/100,000) throughout the second wave and, whilst the national lockdown in November was also associated with a decline in adult SARS-CoV-2 infection rates the declines were more moderate. In these two regions, infection rates plateaued in preschool and primary school-aged children but continued to increase throughout in secondary school-aged children throughout the month of November.

Discussion

In England, SARS-CoV-2 infection rates were very low during early summer 2020, but started to increase from August 2020, initially in young adults, followed by secondary and primary school-aged children, with little change in preschool-aged children. These increases started before schools reopened but continued to increase in children across all school years until the Autumn half-term nine weeks later. SARS-CoV-2 infections rates increased with age across the three educational settings and consistently followed the same gradient but always lagging behind trends in young adults. There was a strong correlation in regional weekly infection rates between adults and school-aged children across all three educational settings, during periods of both low and high community incidence. The half-term school break was associated with a small and temporary decline in infection rates, which then went up again at the same rate as soon as children returned to school after the half-term break. The national lockdown in November 2020 which allowed children and young people to continue attending all educational settings, however, was associated with rapid declines in SARS-CoV-2 infection rates, initially in young adults followed by children across all school year groups a

week later. These same trends were most noticeable in English regions with moderate-to-high infection rates prior to lockdown

In the UK and elsewhere, the decision to reopen all schools has been contentious with much debate among scientists, epidemiologists, educationalists, parents, politicians and policymakers.[1 4] Whilst the consequences of prolonged school closures on children's physical, mental, emotional and social health cannot be refuted, there remain concerns about children transmitting the virus to school staff and to household members, including elderly relatives. Even if very few children became infected with SARS-CoV-2, the large numbers of children returning to school significantly increases opportunities for such transmissions to occur. With all school years returning to school during the Autumn term, an important question that needs answering urgently is whether children acquire SARS-CoV-2 within or outside the school premises. So far, investigations focusing on individual outbreaks in educational settings generally reported low rates of transmission among pupils and staff.[7,12,13] Some countries had kept their preschools and primary schools open during their lockdown and did not see any increase in cases among children or in the wider community.[1] There have, however, been large outbreaks reported in secondary schools, possibly because older children appear to be more able to get infected and transmit the virus and have different behavioural contact pattern with each other and with those around them than younger children.[14-16]

During the summer mini-term in England, the reopening of preschools and some primary school years, albeit with strict physical distancing and infection control measures,[6] was associated with very few cases or outbreaks, with more than half the outbreaks affecting staff only.[7] Similar experiences were reported following partial reopening of schools after lockdown in Germany, Netherlands and other European countries during summer 2020.[17,18]

During the autumn term, the full reopening of schools in England was associated with a week-by-week increase in SARS-CoV-2 infection rates until the half-term holidays almost two months later. We observed a strong age effect, with SARS-CoV-2 infection rates increasing with each school year-group, except in school year 12 (higher education/college) which was lower than in year 11 (final year of secondary school). We speculate that the students in the final year of secondary schools are likely to have a wider network of contacts compared to those in the year 12 age-group, who may be starting higher education in a different school, attending college or beginning an apprenticeship elsewhere.

It has been proposed that the decision to reopen schools should be based on indicators of low community infection rates (e.g. incidence or test positivity rates) and the ability of schools to implement safe physical distancing and infection control measures.[1,19] In England, with the easing of

the first national lockdown, SARS-CoV-2 infection rates started to rise from August 2020, especially in young adults and, whilst directionality of infection cannot be inferred, the increase in cases among school-aged children occurred after the adults and before schools re-opened. Moreover, trends in all school years and across all three educational settings consistently lagged behind yet followed the trajectory of infection in young adults, both upwards towards the peak and downwards after national lockdown in November 2020. We also found a strong correlation in weekly infection rates between adults and the three educational cohorts during periods of both low and high community infection rates. The correlation was strongest for secondary school-aged children and less so for preschool-aged children, which is plausible because secondary school-aged students are only just younger than the young adults and likely to have similar social contacts and behaviours as young adults.

Interestingly, the half-term break only served to pause the rapidly increasing infection rates, with cases continuing to increase along the same trajectory after the half-term holidays. The small decline in infection rates during the half-term week was associated with fewer SARS-CoV-2 tests performed in children during the holidays. In contrast, the implementation of a second national lockdown whilst keeping schools open from 05 November 2020 was associated with large declines in adult infection rates nationally and across most English regions, especially those experiencing the highest infection rates. It is likely that the 3-tier system, where regions with the highest infection rates were placed into Tier 3 (very high alert) from 12 October 2020, also helped control the spread of the virus and could explain the rapid decline in infection rates as soon as national lockdown was announced in regions with high infection rates.[10] By the end of November 2020, infection rates in secondary school-aged children were higher than in young adults across all English regions. Given that childhood infections have closely followed adult trends in areas with large declines in adult infections, it is likely that rates in children will eventually find an equilibrium below that of adult infection rates as national lockdown for adults eases from 02 December 2020. In London, the continuing increase in infection rates among secondary school-aged children will need to be monitored closely in the coming weeks. Large-scale rapid-result coronavirus tests will be available for use in schools for staff and students from January 2021 with the aim of identifying and isolating symptomatic and asymptomatic staff and, therefore, reduce virus introduction and transmission in schools.[20]

Strengths and Limitations

The strength of this analysis lies in the near real-time availability of national and regional surveillance data during a period when widespread testing was available. There are, however, some

important limitations. Our data only included cases that presented to a national testing centre because they had COVID-19 symptoms. We, therefore, cannot comment on asymptomatic infections, that are likely to play an important role in SARS-CoV-2 transmission both within educational settings and in the wider community.[21] A recent school infection survey (SIS) involving 105 primary and secondary schools across England found that asymptomatic SARS-CoV-2 infections were rare but equally prevalent in students (1.24%) and staff (1.29%), suggesting that students attending school were as likely to have symptomatic infection as the staff.[22] We also analysed data according to the age of the children and their corresponding school year, but without knowledge of whether they were attending school, so we cannot comment on whether they acquired the infection inside or outside school. We also do not have information on the reason for testing, potential source of infection or illness severity. Finally, we cannot evaluate the impact of the nationally-recommended infection control measures on SARS-CoV-2 transmission in educational settings.

Conclusions

Nevertheless, our data show that, in England, childhood cases closely followed adult infection rates and, although the half-term break had little impact, national lockdown whilst keeping schools open was associated with large declines in SARS-CoV-2 infection rates, first in adults and the in children a week later. The strong regional correlation between adult and childhood infection rates highlights the important of maintaining low community infection rates to allow schools to remain open safely through the pandemic. SARS-CoV-2 infections in school-aged children reflect a combination of within-school and community transmission; therefore, local and national restrictions should not only drive down community infection and transmission but also reduce the risk of virus introduction into educational settings, thus potentially reducing transmission inside schools too.

Contributors

AAM: methodology; formal analysis; investigation; data curation; writing the original draft; writing – review and editing; visualisation

MS, AZ, LC: data curation; writing- review and editing

SAI: methodology, writing – review and editing

VS, MER and SNL: conceptualisation; methodology; supervision; writing – review and editing

Declaration of interests:

We declare no conflicts of interest.

Data sharing

Applications for relevant anonymised data should be submitted to the Public Health England Office for Data Release: https://www.gov.uk/government/publications/accessing-public-health-england-data/about-the-phe-odr-and-accessing-data.

References

References

1. Levinson M, Cevik M, Lipsitch M. Reopening Primary Schools during the Pandemic. N Engl J Med 2020; 383:981-985.

2. Munro APS, Faust SN. COVID-19 in children: current evidence and key questions. Curr Opin Infect Dis 2020;33:540-7.

3. Snape MD, Viner RM. COVID-19 in children and young people. Science 2020;370:286-8.

4. Viner RM, Bonell C, Drake L, et al. Reopening schools during the COVID-19 pandemic: governments must balance the uncertainty and risks of reopening schools against the clear harms associated with prolonged closure. Arch Dis Child 2020; Aug 3;archdischild-2020-319963. doi: 10.1136/archdischild-2020-319963. Online ahead of print.

5. Public Health England (PHE). Weekly Coronavirus Disease 2019 (COVID-19) Surveillance Report: Summary of COVID-19 surveillance systems. 2020. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/880925/COVID19_Epidemiological_Summary_w17.pdf. Accessed 13 December 2020.

6. Department for Education (DfE). Guidance for full opening: schools. 27 July 2020. Available at: https://www.gov.uk/government/publications/actions-for-schools-during-the-coronavirus-outbreak/guidance-for-full-opening-schools. Accessed: 05 August 2020

7. Ismail S, Saliba V, Lopez-Bernal J, Ramsay M, Ladhani S. SARS-CoV-2 infection and transmission in educational settings: cross-sectional analysis of clusters and outbreaks in England. Lancet Infect Dis 2020; Published **Online** December 8, 2020**:** https://doi.org/10.1016/S1473-3099(20)30882-3.

8. Zhang Y, Ma ZF. Impact of the COVID-19 Pandemic on Mental Health and Quality of Life among Local Residents in Liaoning Province, China: A Cross-Sectional Study. Int J Environ Res Public Health 2020;17.

9. Prime Minister's Office. Prime Minister announces new local COVID Alert Levels, 12 October 2020. 2020. Available at https://www.gov.uk/government/news/prime-minister-announces-new-local-covid-alert-levels. Accessed: 13 December 2020.

10. Department of Health and Social Care (DHSC). Local restriction tiers: what you need to know 2020. Available at: https://www.gov.uk/guidance/local-restriction-tiers-what-you-need-to-know. Accessed: 13 December 2020.

11. Office for National Statistics (ONS). Dataset: population projections for regions - Table 1. 14 October 2020. Available at:

https://www.ons.gov.uk/peoplepopulationandcommunity/populationandmigration/populationprojections/datasets/regionsinenglandtable1. Accessed: 13 December 2020.

12. Viner RM, Russell SJ, Croker H, et al. School closure and management practices during coronavirus outbreaks including COVID-19: a rapid systematic review. Lancet Child Adolesc Health 2020;4:397-404.

13. Macartney K, Quinn HE, Pillsbury AJ, et al. Transmission of SARS-CoV-2 in Australian educational settings: a prospective cohort study. Lancet Child Adolesc Health 2020;4:807-16.

14. Stein-Zamir C, Abramson N, Shoob H, et al. A large COVID-19 outbreak in a high school 10 days after schools' reopening, Israel, May 2020. Euro Surveill 2020; 25(29): 2001352.

15. Fontanet A, Tondeur L, Madec Y et al. Cluster of COVID-19 in northern France: A retrospective closed cohort study. MedRxiv 23 April 2020; https://doi.org/10.1101/2020.04.18.20071134.

16. Fontanet A, Grant R, Tondeur L, et al. SARS-CoV-2 infection in primary schools in northern France: A retrospective cohort study in an area of high transmission MexRxIV 29 June 2020; https://doi.org/10.1101/2020.06.25.20140178.

17. Otte Im Kampe E, Lehfeld AS, Buda S, Buchholz U, Haas W. Surveillance of COVID-19 school outbreaks, Germany, March to August 2020. Euro Surveill 2020; 25(38):pii=2001645. https://doi.org/10.2807/1560-7917.ES.2020.25.38.2001645.

18. Couzin-Frankel J, Vogel G, Weiland M. Not open and shut. Science 2020;369:241-5.

19. Center for Disease Control and Prevention (CDC). Indicators for Dynamic School Decision-Making, Updated September 15, 2020 2020. Available at: https://www.cdc.gov/coronavirus/2019-ncov/community/schools-childcare/indicators.html#thresholds. Accessed: 13 December 2020.

20. Guidance: Coronavirus (COVID-19) asymptomatic testing in schools and colleges (15 december 2020). Available at: https://www.gov.uk/government/publications/coronavirus-covid-19-asymptomatic-testing-in-schools-and-colleges/coronavirus-covid-19-asymptomatic-testing-in-schools-and-colleges. Accessed: 18 December 2020.

21. Buitrago-Garcia D, Egli-Gany D, Counotte MJ, et al. Occurrence and transmission potential of asymptomatic and presymptomatic SARS-CoV-2 infections: A living systematic review and meta-analysis. PLoS Med 2020;17:e1003346.

22. COVID-19 Schools Infection Survey Round 1, England: November 2020 (17 December 2020). Available at: https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/bulletins/covid19schoolsinfectionsurveyround1england/november2020. Accessed: 22 December 2020.

FIGURE LEGENDS

Figure 1. Weekly infection rates of confirmed COVID-19 cases per 100,000 population per age cohort, England

Figure 2. Weekly infection rates of confirmed COVID-19 cases per 100,000 population for each school cohort and adult age groups, England

Figure 3. Weekly COVID-19 test rates per 100,000 population and weekly COVID-19 positivity rates for preschool, primary and secondary school birth cohorts, England

Figure 4. Regional weekly infection rates of confirmed COVID-19 cases per 100,000 population for school cohorts and adult age groups, England

Figure 5. Correlation between weekly SARS-CoV-2 infection rates in adults (18-64 years old) and school cohorts across the nine different regions in England, along with linear regression, correlation coefficient and coefficient of determination R^2 for the week starting (A) 27 July 2020 (low community infection rates) and (B) 19 October 2020 (low community infection rates)

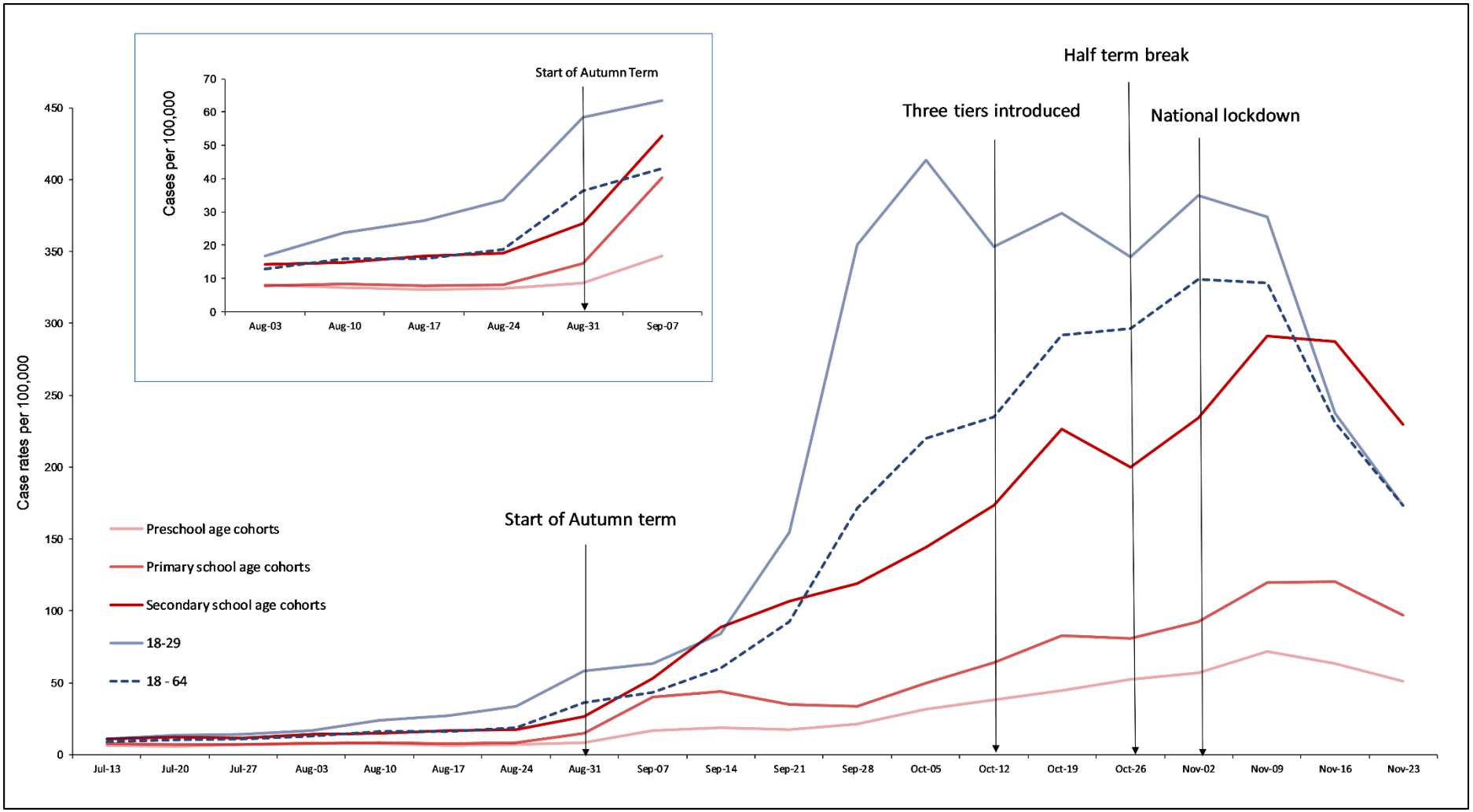


Figure 1. Weekly infection rates of confirmed COVID-19 cases per 100,000 population per age cohort, England

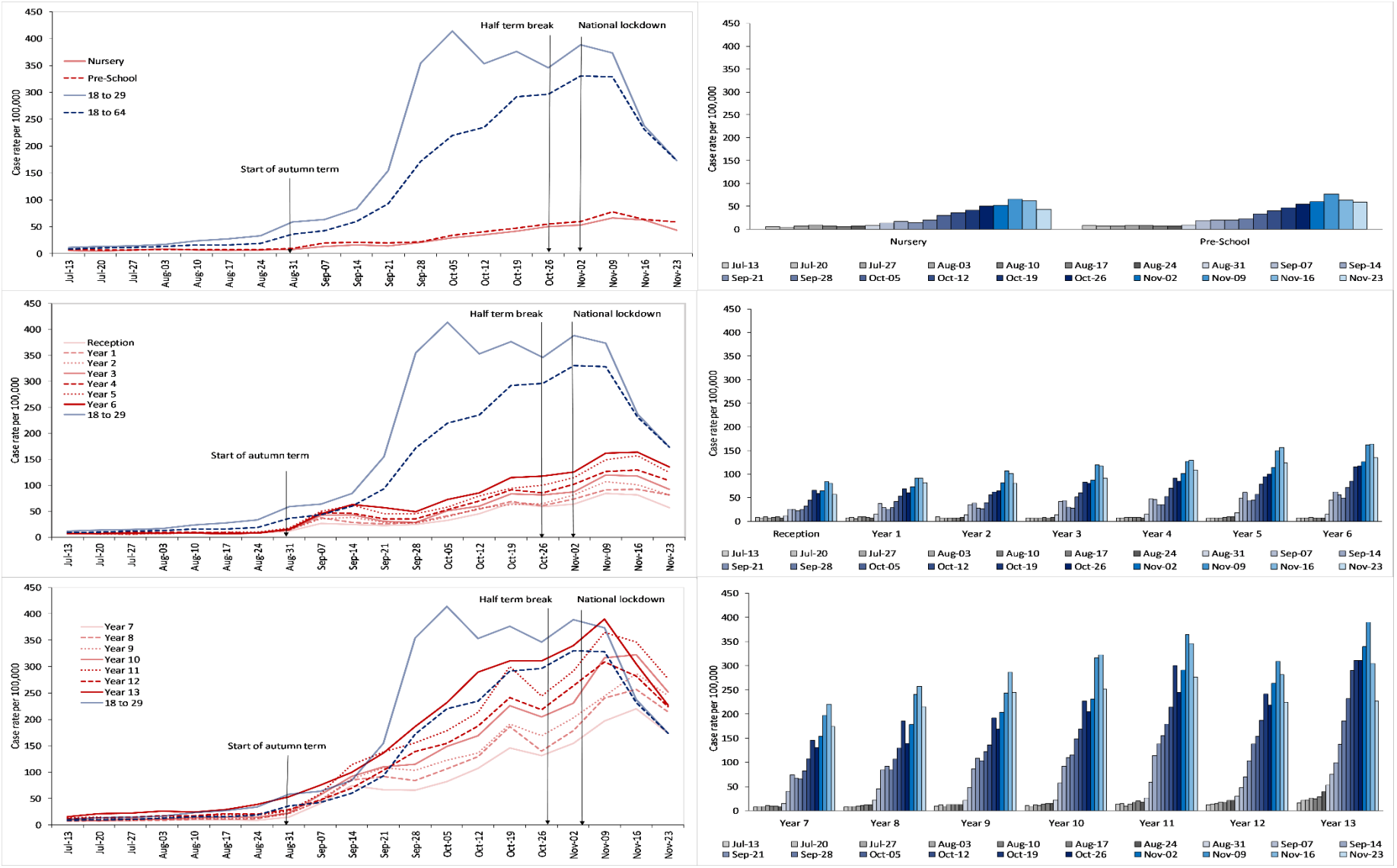


Figure 2. Weekly infection rates of confirmed COVID-19 cases per 100,000 population for each school cohort and adult age groups, England

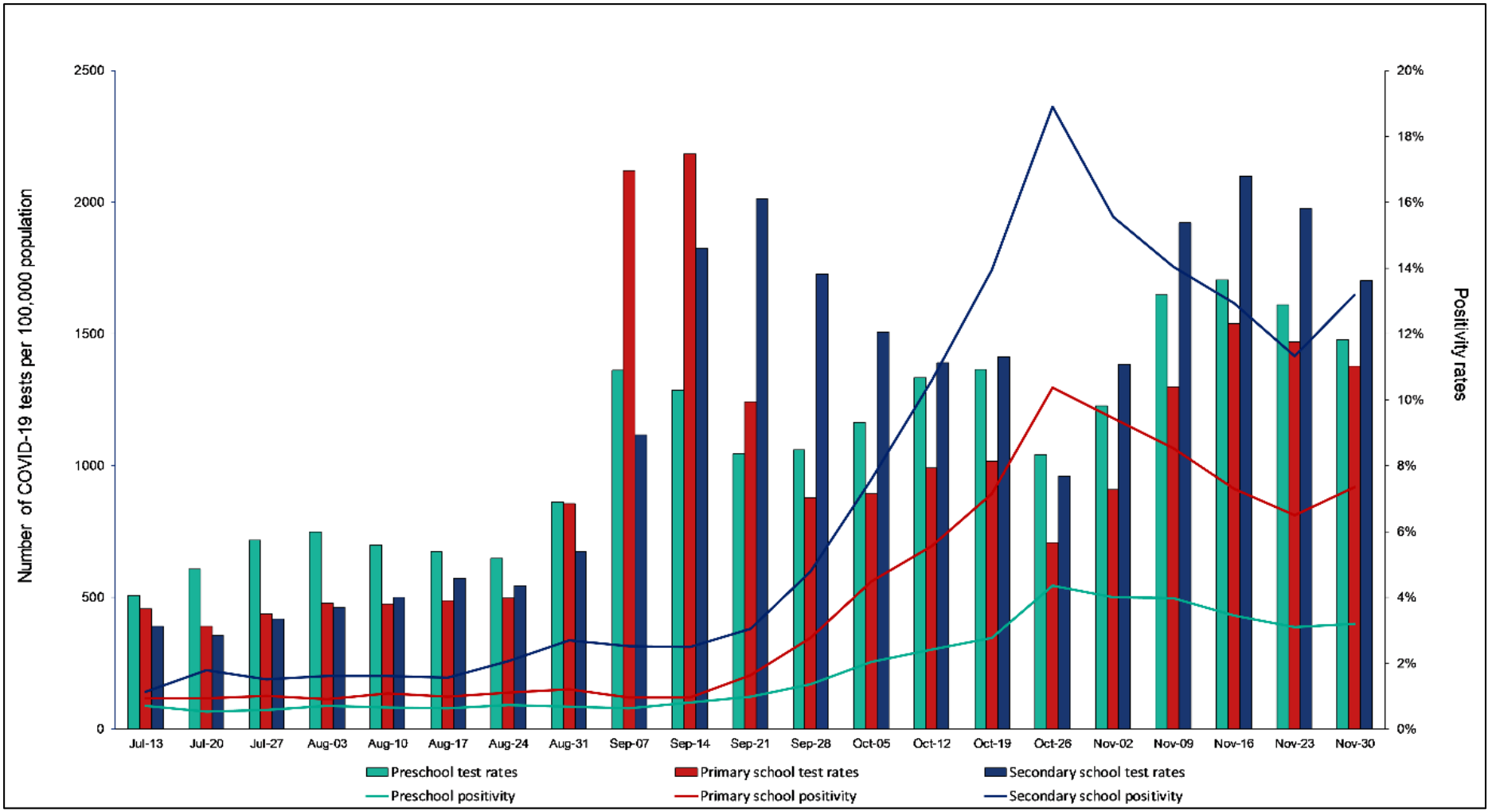


Figure 3. Weekly COVID-19 test rates per 100,000 population and weekly COVID-19 positivity rates for preschool, primary and secondary school birth cohorts, England

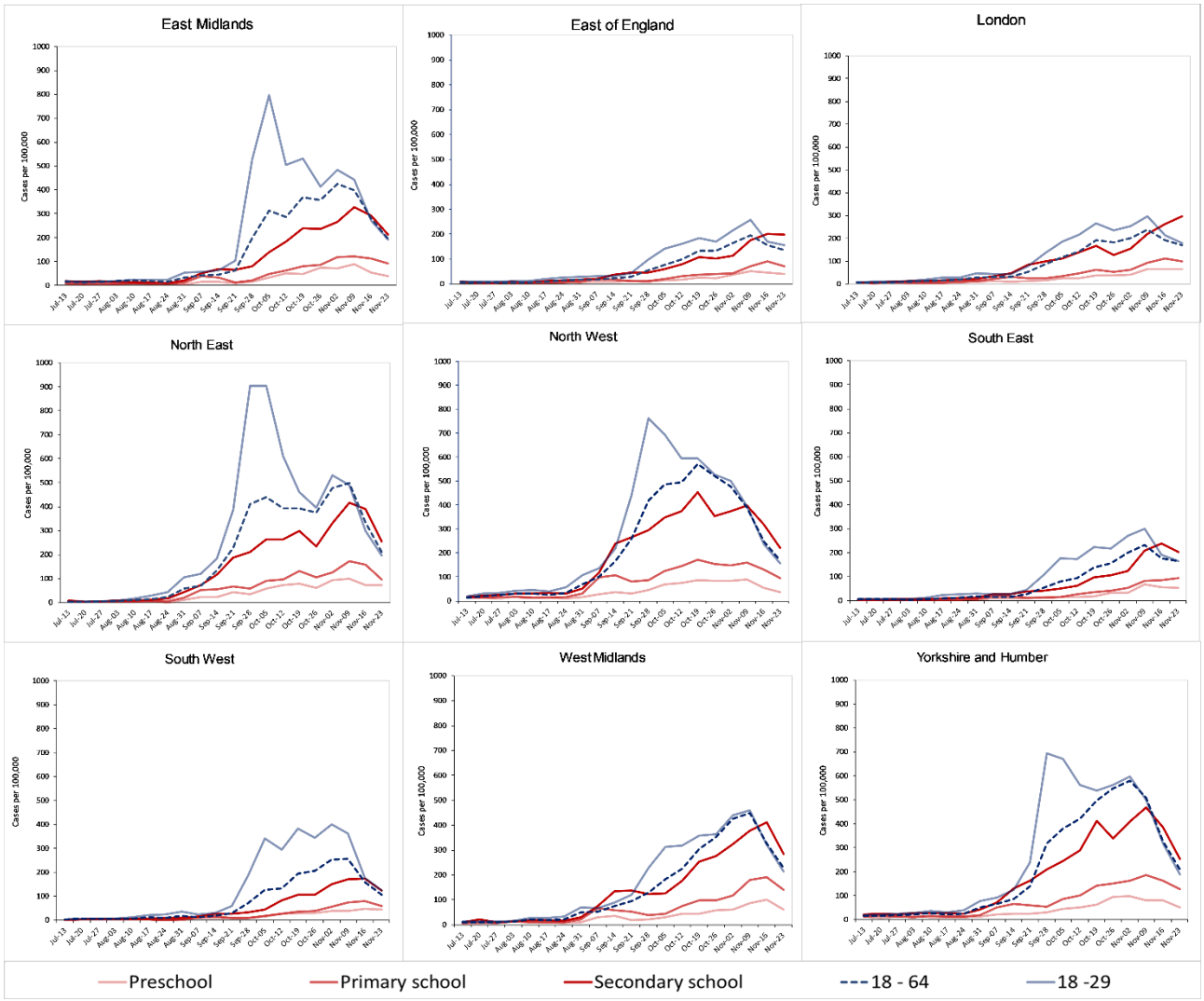
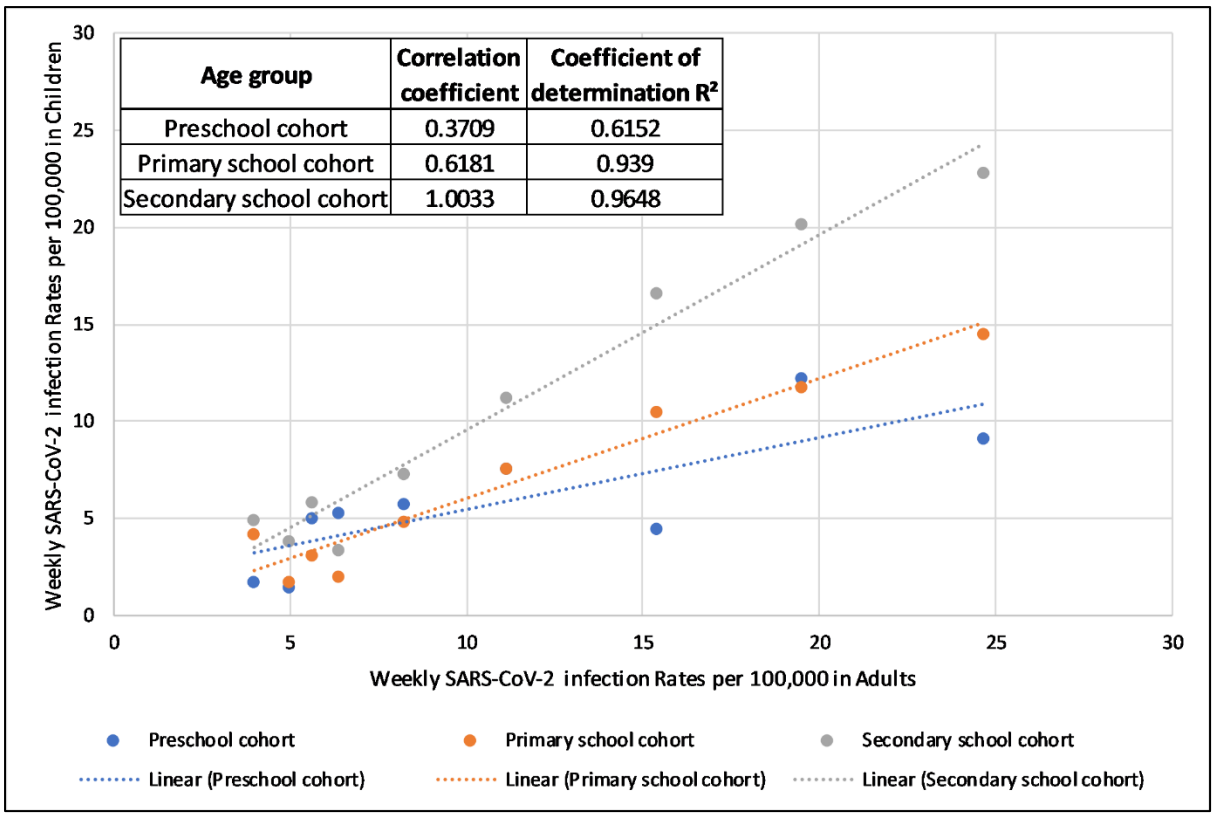


Figure 4. Regional weekly infection rates of confirmed COVID-19 cases per 100,00 population for school cohorts and adult age groups, England



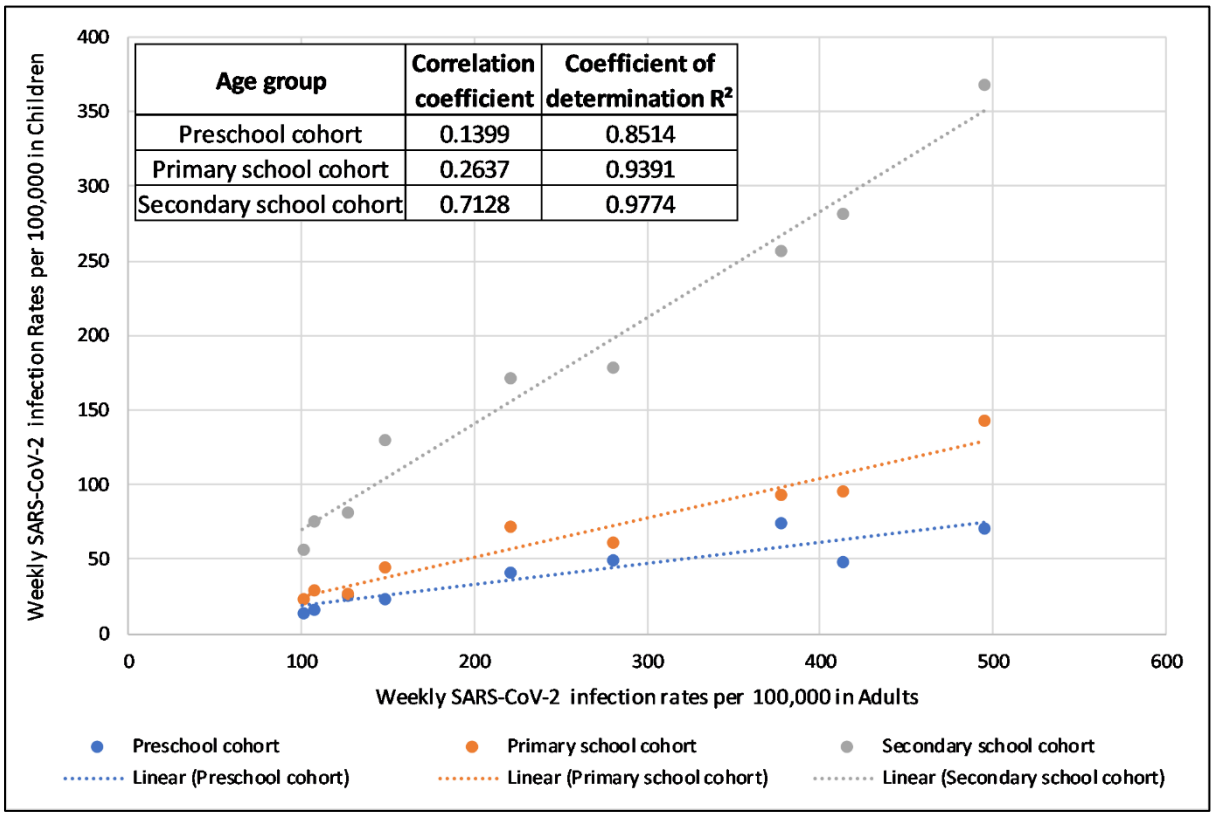


Figure 5. Correlation between weekly SARS-CoV-2 infection rates in adults (18-64 years old) and school cohorts across the nine different regions in England, along with linear regression, correlation coefficient and coefficient of determination R^2 for the week starting (A) 27 July 2020 (low community infection rates) and (B) 19 October 2020 (low community infection rates)

SUPPLEMENT DATA

Supplement Table S1. Growth rates and doubling times given for the nursery/preschool, primary and secondary school cohorts

Before the start of first term

School Setting	Daily growth rate r *	r lower	r upper	Time to growth or decay (days)	Time lower	Time upper
Preschool age cohorts	-0.0173	-0.0308	-0.00389	Halving in 40.1 days	22.5	178
Primary school age cohorts	0.000417	-0.00635	0.00718	NA	-	-
Secondary school age cohorts	0.00947	0.00439	0.0146	Doubling in 73.2 days	47.6	158

*Calculated for the last four weeks before start of term (03/082020 to 30/08/2020)

Before the end of half term

School Setting	Daily growth rate r*	r lower	r upper	Time to growth or decay (days)	Time lower	Time upper
Preschool age cohorts	0.0382	0.0311	0.0452	Doubling in 18.2 days	15.3	22.3
Primary school age cohorts	0.034	0.0312	0.0369	Doubling in 20.4 days	18.8	22.2
Secondary school age cohorts	0.023	0.0213	0.0247	Doubling in 30.1 days	28	32.5

* Calculated for the last four weeks before end of half term (21/09/2020 to 18/10/2020)

Supplemental Table S2: Weekly COVID-19 infection rate ratio for each school cohort and adult age groups using the nursery school birth cohort as baseline, England**.**

Week starting	Primary school age cohorts		Secondary school age cohorts		18-29 years old		18 - 64 years old	
	IR	95%CI	IR	95%CI	IR	95%CI	IR	95%CI
Jul-13	1.14	0.90 ; 1.43	1.62	1.29 ; 2.02	1.69	1.36 ; 2.10	1.33	1.078 ; 1.64
Jul-20	1.21	0.95 ; 1.54	2.05	1.62 ; 2.59	2.25	1.80 ; 2.83	1.72	1.38 ; 2.14
Jul-27	1.05	0.83 ; 1.32	1.73	1.38 ; 2.15	2.11	1.70 ; 2.60	1.65	1.34 ; 2.02
Aug-03	0.96	0.78 ; 1.18	1.74	1.42 ; 2.13	2.06	1.69 ; 2.49	1.57	1.30 ; 1.90
Aug-10	1.13	0.91 ; 1.40	2.02	1.64 ; 2.49	3.21	2.62 ; 3.92	2.15	1.76 ; 2.62
Aug-17	1.19	0.95 ; 1.50	2.51	2.01 ; 3.12	4.11	3.33 ; 5.08	2.41	1.96 ; 2.97
Aug-24	1.16	0.92 ; 1.44	2.48	2.01 ; 3.07	4.74	3.87 ; 5.08	2.64	2.16 ; 3.23
Aug-31	1.69	1.39 ; 2.05	3.07	2.54 ; 3.71	6.75	5.62 ; 8.11	4.19	3.49 ; 5.02
Sep-07	2.40	2.09 ; 2.76	3.14	2.74 ; 3.60	3.78	3.31 ; 4.31	2.56	2.25 ; 2.92
Sep-14	2.34	2.05 ; 2.67	4.74	4.18 ; 5.39	4.50	3.97 ; 5.10	3.23	2.85 ; 3.66
Sep-21	1.99	1.74 ; 2.28	6.16	5.40 ; 7.07	8.91	7.83 ; 10.13	5.33	4.69 ; 6.06
Sep-28	1.58	1.39 ; 1.79	5.56	4.94 ; 6.26	16.53	14.72 ; 18.56	7.99	7.12 ; 8.97
Oct-05	1.55	1.40 ; 1.72	4.53	4.11 ; 4.99	12.98	11.80 ; 14.27	6.90	6.28 ; 7.59
Oct-12	1.68	1.53 ; 1.85	4.56	4.17 ; 4.98	9.29	8.51 ; 10.13	6.18	5.66 ; 6.74
Oct-19	1.86	1.71 ; 2.02	5.06	4.66 ; 5.49	8.43	7.77 ; 9.13	6.53	6.03 ; 7.08
Oct-26	1.55	1.43 ; 1.67	3.81	3.53 ; 4.11	6.60	6.13 ; 7.11	5.65	5.25 ; 6.08
Nov-02	1.64	1.52 ; 1.77	4.14	3.85 ; 4.46	6.87	6.39 ; 7.38	5.84	5.44 ; 6.27
Nov-09	1.67	1.56 ; 1.79	4.05	3.79 ; 4.32	5.20	4.88 ; 5.54	4.57	4.29 ; 4.86
Nov-16	1.90	1.79 ; 2.04	4.54	4.24 ; 4.87	3.76	3.51 ; 4.03	3.66	3.42 ; 3.92
Nov-23	1.89	1.75 ; 2.05	4.48	4.15 ; 4.83	3.38	3.13 ; 3.65	3.38	3.14 ; 3.65

IR, incidence rate; CI, confidence interval

Supplement Figure S3: Weekly infection rates of confirmed COVID-19 cases per 100,000 population per age cohort, England