OPEN ACCESS

Community seroprevalence of SARS-CoV-2 in children and adolescents in England, 2019–2021

Helen Ratcliffe ,[1] K S Tiley,[1] Nick Andrews,[2] Gayatri Amirthalingam,[3] I Vichos,[1] E Morey,[1] N L Douglas,[1] S Marinou,[1] Emma Plested,[1] Parvinder Aley,[1] Eva P Galiza,[4] Saul N Faust ,[5,6] S Hughes,[7] Clare S Murray ,[7,8] Marion Roderick,[9] Fiona Shackley,[10] Sam J Oddie ,[11] Tim Lees,[12] D P J Turner,[13] M Raman,[14] Stephen Owens ,[15,16] Paul Turner ,[17] H Cockerill,[18] J Lopez Bernal,[3] E Linley,[19] Ray Borrow,[19] Kevin Brown,[20] Mary Elizabeth Ramsay,[3] M Voysey,[1] Matthew D Snape[1]

► Additional supplemental material is published online only. To view, please visit the journal online (http://dx.doi.org/10.1136/archdischild-2022-324375).

For numbered affiliations see end of article.

Correspondence to
Dr Helen Ratcliffe, Paediatrics, University of Oxford, Oxford, UK; helen.ratcliffe@paediatrics.ox.ac.uk

Received 5 May 2022
Accepted 23 June 2022
Published Online First 20 July 2022

ABSTRACT

Objective To understand community seroprevalence of SARS-CoV-2 in children and adolescents. This is vital to understanding the susceptibility of this cohort to COVID-19 and to inform public health policy for disease control such as immunisation.

Design We conducted a community-based cross-sectional seroprevalence study in participants aged 0–18 years old recruiting from seven regions in England between October 2019 and June 2021 and collecting extensive demographic and symptom data. Serum samples were tested for antibodies against SARS-CoV-2 spike and nucleocapsid proteins using Roche assays processed at UK Health Security Agency laboratories. Prevalence estimates were calculated for six time periods and were standardised by age group, ethnicity and National Health Service region.

Results Post-first wave (June–August 2020), the (anti-spike IgG) adjusted seroprevalence was 5.2%, varying from 0.9% (participants 10–14 years old) to 9.5% (participants 5–9 years old). By April–June 2021, this had increased to 19.9%, varying from 13.9% (participants 0–4 years old) to 32.7% (participants 15–18 years old). Minority ethnic groups had higher risk of SARS-CoV-2 seropositivity than white participants (OR 1.4, 95% CI 1.0 to 2.0), after adjusting for sex, age, region, time period, deprivation and urban/rural geography. In children <10 years, there were no symptoms or symptom clusters that reliably predicted seropositivity. Overall, 48% of seropositive participants with complete questionnaire data recalled no symptoms between February 2020 and their study visit.

Conclusions Approximately one-third of participants aged 15–18 years old had evidence of antibodies against SARS-CoV-2 prior to the introduction of widespread vaccination. These data demonstrate that ethnic background is independently associated with risk of SARS-CoV-2 infection in children.

Trial registration number NCT04061382.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ Previous serostudies show children are frequently asymptomatic or have mild symptoms of COVID-19 infection.
⇒ Ancestral lineages A and B presented predominantly with gastrointestinal symptoms in the paediatric population.
⇒ Minority ethnic groups are at increased risk of seropositivity for SARS-CoV-2.

WHAT THIS STUDY ADDS

⇒ Community-based recruitment of participants aged 0–18 years old representative of seven National Health Service regions allowing generalisations to be made across England as a whole.
⇒ Approximately one-third of participants 15–18 years old had evidence of antibodies against SARS-CoV-2 prior to the introduction of widespread immunisation in June 2021.
⇒ In children <10 years, there were no symptoms or symptom clusters that reliably predicted seropositivity.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Seroprevalence studies provide estimates of the levels of immunity within the paediatric population, vital for modelling of disease susceptibility and immunisation planning in England.
⇒ This study creates a unique biobank from children and young adults aged 0–24 years with a comprehensive history of immunisation and demography for future research.

To cite: Ratcliffe H, Tiley KS, Andrews N, *et al*. *Arch Dis Child* 2023;**108**:123–130.

INTRODUCTION

Seroprevalence studies evaluating population prevalence of SARS-CoV-2 antibodies have an important role in understanding the spread of and population vulnerability to SARS-CoV-2 infection. The majority have been performed in adults,[1 2] and those in children have predominantly tested samples obtained opportunistically in a clinical context or in school-based populations,[3–5] both of which bring potential biases.

In response to the COVID-19 pandemic, the Oxford Vaccine Group, in collaboration with UK Health Security Agency, modified an existing seroprevalence pilot study ('What's the STORY?') evaluating serum antibody concentrations against vaccine preventable diseases to determine anti-SARS-CoV-2

serum antibodies across England. This study was funded by the National Institute for Health Research.

Here we report SARS-CoV-2 sero-epidemiology in participants aged 0–18 years old in England prior to widespread immunisation in this population from samples collected from the end of 2019 through to mid-2021. In addition, we explore potential risk factors for COVID-19 seropositivity and the utility of symptom-based indicators of infection.

METHODS

Study design

This was a cross-sectional seroprevalence study recruiting participants from 13 sites distributed across all seven National Health Service (NHS) regions in England, conducted between October 2019 and June 2021. Eleven sites recruited participants aged 0–24 years (data for those aged 0–18 years old presented here) from postcode districts representative of their NHS region in terms of deprivation (defined by 2019 Index of Multiple Deprivation (IMD)[6]) and urban/rural ratio as identified by local knowledge (online supplemental table 1). IMD measures deprivation available at a Lower Super Output Area (LSOA, an area with an average population of 1500) level and based on seven domains of deprivation (income, employment, education, health, crime, barriers to housing and services and living environment).[6] Invitation letters were sent through Docmail (a UK General Data Protection Regulation compliant bulk mailing system) from extracts provided by either NHS Digital[7] or Child Health Information Systems (CHIS)[8] databases, in addition to social media campaigns. Two sites recruited participants aged 0–19 years old via social media campaigns and were not postcode restricted. Potential participants and their families were invited to visit the study website (https://whatsthestory.web.ox.ac.uk) for additional information and local teams' contact details

Due to emerging differences in COVID-19 infection in minority ethnic groups in adult studies,[1 9] an enhanced recruitment strategy for ethnic minority groups started in January 2021. Multiple strategies (targeted mail outs, social media, text messages from general practitioners (GPs), pharmacy advertising) were used.

Data collection

Participants or their parent/guardian recorded (electronically or on a paper form) responses to questions regarding the participant's demographics, as well as selected questions from the UK Census 2011 relating to accommodation and employment, and from the Family Affluence Scale iii (FASiii)[10] relating to socioeconomic status. These data were collected using the Research Electronic Data capture system, V.10.6.13. Responses to the individual-level UK Census[11] and FASiii questions[10] for those aged 0–15 years old (scored out of a total of 13[12]) were used to assess the appropriateness of the LSOA-level IMD and the Income Deprivation Affecting Children Index (IDACI, the proportion of children aged 0–15 years living in income-deprived families) scores for our study.

In response to the pandemic, from February 2020, questionnaires were adapted to ask if participants and/or their household had experienced any potential COVID-19 symptoms (fever, dry cough, shortness of breath, muscle aches, feeling tired, loss of appetite). This was further adapted in July 2020 to enable description of which symptoms participants and household contacts had experienced, self-reported results of relevant PCR or antibody testing. Those participants who were already enrolled were approached retrospectively to collect missing data from the updated questionnaire (online supplemental appendix 1). Receipt of a COVID-19 vaccine and vaccination date were recorded either at the visit from personal written documentation or afterwards from GP or CHIS records.

Measurement of serum antibodies

Blood samples were analysed for SARS-CoV-2-specific antibody responses using the Roche Elecsys Anti-SARS-CoV-2 serological assays for the detection of anti-SARS-CoV-2 IgG spike protein (RocheS) and nucleocapsid (RocheN) antibodies in serum/plasma samples using electrochemiluminescent immunoassays.[13 14] Both assays report high sensitivity and specificity (online supplemental table 2).[13 14]

Statistical analysis

Seroprevalence

The unweighted observed prevalence for RocheS and RocheN separately was calculated as n+/N for children aged 0–18 years, where n+ was the number of individuals who tested positive, and N was the total number of individuals tested with an available result. Unweighted prevalence was calculated for each of six time periods (figure 1),[15 16] overall, by age group (0–4 years, 5–9 years, 10–14 years, 15–18 years) and by region. Prevalence estimates for each time period were standardised by age group, ethnicity and NHS region using the STATA stdize command. Population estimates of demographic variables were determined from NewETHPOP-Evaluation, Revision and Extension of Ethnic Population Projections.[17]

Risk factors

Age group, sex, NHS region, time period, ethnicity (grouped as white and minority ethnic groups), IMD or Income Deprivation Affecting Children Index (IDACI) deprivation quintile (for comparison) and urban/rural classifications were analysed in univariate and multivariable logistic regression models. A separate model tested the presence of a healthcare worker in the family as a risk factor.

Symptoms

Symptoms associated with seropositivity were explored for participants aged 0–9 years old and 10–18 years old separately to optimise statistical power while allowing discrimination of differences between participants attending early-years and primary school educational settings compared with secondary school and higher education. A backwards stepwise regression approach was applied whereby variables with the highest p value were sequentially excluded and model Akaike Information Criterion (AIC) values were compared until a model with the lowest AIC value had been reached. Sex, a non-significant variable, was included to show it did not influence the model. Highly correlated symptoms were grouped, for example, gastrointestinal symptoms included diarrhoea, vomiting and abdominal pain.

Participants reported to be vaccinated before their visit were excluded from all analyses. Analyses were carried out in Stata V.17.[18]

RESULTS

The study recruited 2963 participants 0–24 years between October 2019 and June 2021, 2542 of whom were aged 0–18 years. Of these, 2540 were COVID-19 vaccine naïve prior to their visit. RocheS and RocheN results were available for 2477 of 2540 (98%) and 2475 of 2540 (97%) participants,

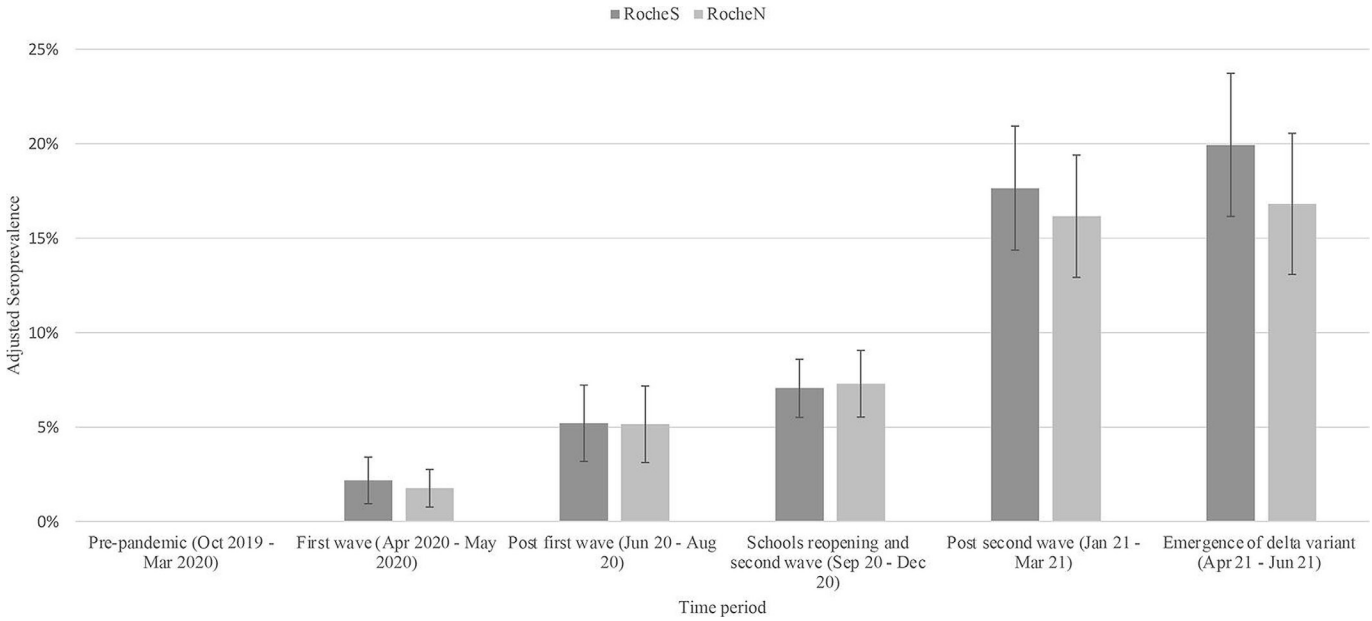


Figure 1 Overall SARS-CoV-2 seroprevalence (RocheS (anti-SARS-CoV-2 IgG spike protein antibodies) and RocheN (anti-SARS-CoV-2 IgG nucleocapsid antibodies)) by time period October 2019–June 2021 in England, adjusted for age, National Health Service region and ethnicity. Error bars indicate 95% CI. (1) First national lockdown came into force (26 March 2020). Schools closed with only children of key workers attending school.[15] (2) Phased reopening of schools (1 June 2020). Pupils aged 5, 6 and 11 years returned to school. 16- and 18-year-olds were allowed to attend in limited times.[15] (3) Variant of concern – B.1.1.7 (Alpha) first detected in the UK and sequenced in September 2020.[16] (4) Second national lockdown came into force (5th November 2020). Schools closed with only children of key workers attending school[16] (5) Second national lockdown came to an end (2 December 2020)[15] (6) Variant of concern B.1.351 (Beta) variant first detected in South Africa and was first sequenced in December 2020.[16] (7) Third national lockdown came into force (6 January 2021). Schools closed with only children of key workers attending school.[15] (8) Variant of concern – P.1 (Gamma) first detected in Japan in travellers from Brazil in January 2021 and was first detected in the UK in February 2021.[16] (9) Primary and secondary schools reopen in England (8 March 2021).[15] (10) Variant of concern B.1.617.2 (Delta) variant first detected in India were first detected in the United Kingdom in mid-April 2021.[16] All legal limits on social contact removed (21 June 2021).[15]

respectively. Of those with ethnicity specified, 17% were non-white ethnic groups (online supplemental tables 3 and 4).

The proportion of children aged 0–15 years in each IMD and IDACI quintile was similar (within 1.5%) for the study overall, and within 10% of their local IMD quintile across the majority of regions with the exception of the North West (<1% in least deprived IMD quintile vs 21% in least deprived IDACI quintile) and South East. Nevertheless, >8% of children aged 0–15 years in the North West had individual-level FASiii scores >11 (where 13 is most affluent) (online supplemental table 5). Responses to selected UK Census questions for children aged 0–15 years were generally in agreement with IMD and IDACI quintiles. but did not clearly differentiate between the scoring systems.

In total, 628 of 2477 (25%) were children of healthcare workers.

Comparison of assays

Of the 2472 participants with results for both assays, 218 (9%) were both positive, and 2215 (90%) both negative with 40 (1%) having discordant results (online supplemental figure 1). The majority (35 of 40, 88%) of discordant results were RocheS positive and RocheN negative. Here we report RocheS results (online supplemental materials include RocheN results).

Seroprevalence

Overall seroprevalence, adjusted for age, ethnicity and NHS region, increased over time (figure 1 and online supplemental table 6) from 0 in October 2019–March 2020 to 20% (95% CI 16% to 24%) in April 2021–June 2021. For all age groups, seroprevalence remained relatively stable (10% or below) until September–December 2020, where those aged 15–18 years old increased to 23%, followed by an increase in all age groups from January 2021 onwards. By April–June 2021, the adjusted seroprevalence was 20%, varying from 14% in children aged 0–4 years old to 33% in those aged 15–18 years old (figure 2 and online supplemental table 7).

In June–August 2020, the highest age and ethnicity-adjusted seroprevalence was recorded in London (34%, 95% CI 19% to 49%). In April–June 2021, the highest seroprevalence was in the North West (52%, 95% CI 33% to 71%) (figure 3 and online supplemental table 8).

Presence of symptoms in seropositive participants

Overall, 48% (95% CI 42% to 55%) of seropositive participants reported no symptoms (figure 4 and online supplemental figure 2). Fever was reported in 29% of seropositive participants, and in a univariate analysis was predictive of SARS-CoV-2 positivity in those aged 10–18 years old only (online supplemental figure 3). No solicited symptoms were individually predictive of seropositivity in children aged 0–9 years old.

Backwards stepwise regression demonstrated fever and loss of taste and smell were significant in the older cohort (10–18 years). No symptom clusters were predictive in children 0–9 years old, and fever was of borderline significance in predicting seropositivity (online supplemental table 9).

Risk factor analysis

The risk of a RocheS seropositive result on a univariate analysis was stable across children 0–14 years old with an increased risk

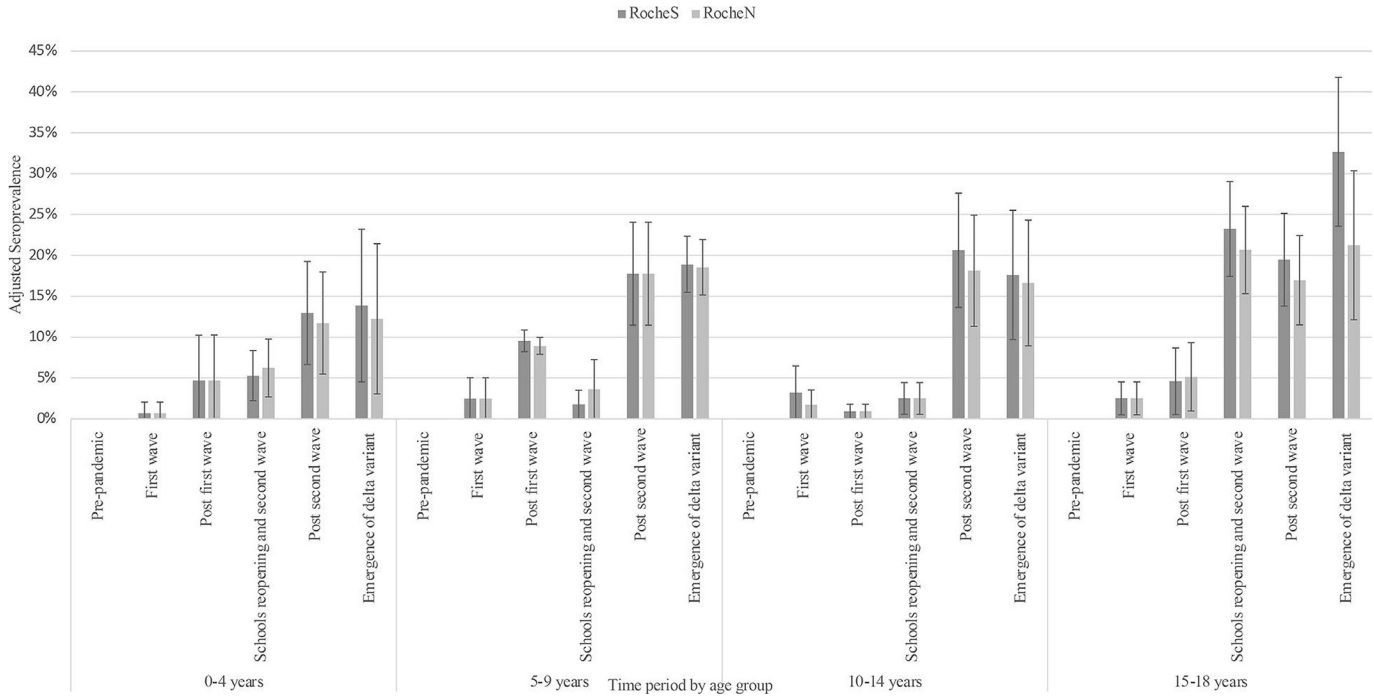
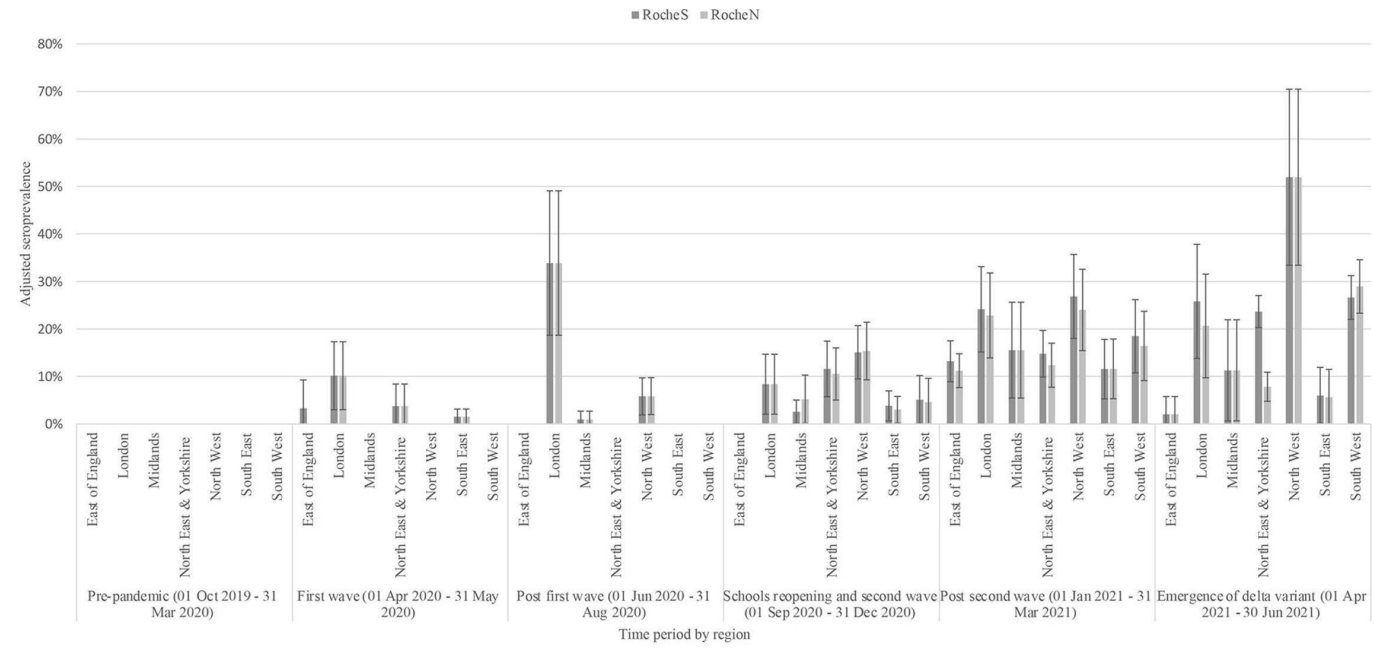


Figure 2 SARS-CoV-2 seroprevalence (RocheS (anti-SARS-CoV-2 IgG spike protein antibodies) and RocheN (anti-SARS-CoV-2 IgG nucleocapsid antibodies)) by age group and time period October 2019–June 2021 in England, adjusted for National Health Service region and ethnicity. Error bars indicate 95% CI.

in those 15–18 years old (OR 1.5, 95% CI 1.0 to 2.1, p=0.08), and increase persisting in the multivariable analysis (OR between 1.4 and 1.5, p≤0.05) (table 1 and online supplemental table 10). The North West and London NHS regions showed a higher seropositivity compared with South East (baseline). A higher proportion of children were seropositive living in urban areas than rural areas. Children in minority ethnic groups showed a significantly higher risk in the multivariable analyses compared with their white counterparts (OR 1.4, p=0·04). On univariate analysis, a significant trend towards higher risk of seropositivity in the areas with higher deprivation was seen, however, this was not statistically significant in the multivariable analysis when using either



Enhanced recruitment for minority ethnic groups started in Jan 2021.
Data showed differing results between RocheS and RocheN in the North-East and Yorkshire (April-June 2021). After comparing the raw data between groups without finding significant differences the most likely explanation is a chance variation within these data

Figure 3 SARS-CoV-2 seroprevalence (RocheS (anti-SARS-CoV-2 IgG spike protein antibodies) and RocheN (anti-SARS-CoV-2 IgG nucleocapsid antibodies)) by region and time period October 2019–June 2021 in England, adjusted for age and ethnicity. Error bars indicate 95% CI.

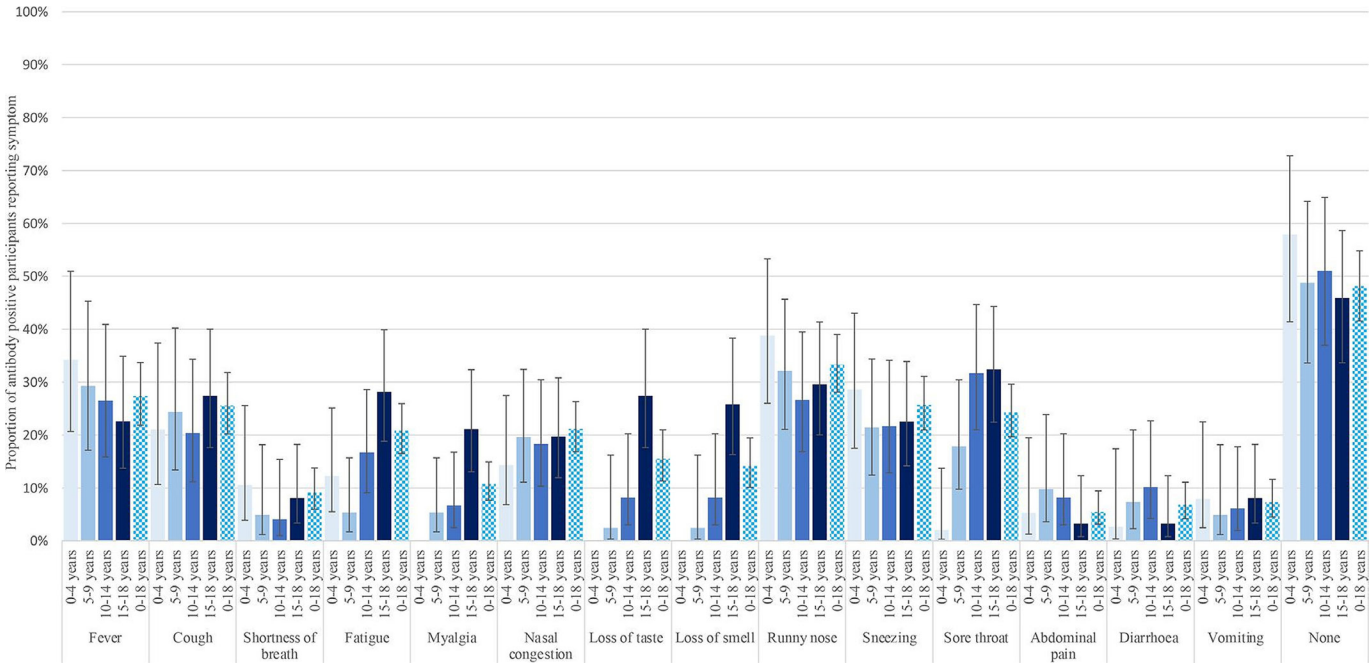


Figure 4 Summary of symptoms reported by participants seropositive on RocheS (anti-SARS-CoV-2 IgG spike protein antibodies) by age group.

IDACI and IMD. A healthcare worker in the family increased the risk of seropositivity (OR 1.6, 95% CI 1.2 to 2.2, p=0.001).

DISCUSSION

Here we report results of a community-based study recruiting a representative cohort of the paediatric population in England from the start of the SARS-CoV-2 pandemic, with extensive characterisation of demography and potential COVID-19 symptoms. This provides a unique assessment of the prevalence and risk factors for naturally acquired antibodies against the SARS-CoV-2 virus in children and adolescents prior to introduction of widescale immunisation. Notably, approximately one-third of participants aged 15–18 years old had antibodies against SARS-CoV-2 in April–June 2021, prior to immunisation or the further wave of infections in this age group that occurred in Autumn 2021.

This study adds to the evidence base regarding paediatric SARS-CoV-2 seroprevalence, building on other studies in England and/or the UK, including SKIDS[4 5] (recruiting from educational settings) and COVID Warriors[3] (recruiting children of healthcare workers). Together these seroprevalence studies provide estimates of the levels of seropositivity within the paediatric population, vital for modelling of disease susceptibility and immunisation planning, complementing insights gained from repeat cross-sectional community infection surveys such as REACT-1[2] and the COVID-19 infection survey.[19]

When comparing studies at similar time points, differences in estimates emerge. In April–August 2020, overall rates of seropositivity in our data were approximately half those of COVID Warriors,[3] likely due to the elevated risk of seropositivity in household members of healthcare workers. In June 2021, our age-adjusted estimates were higher than the SKIDS Study, which reports 11.25% and 12.95% of primary and secondary school pupils being seropositive using oral fluid sampling,[20] compared with 18.9% and 32.7% in similar age groups in our study. This may reflect differences in sensitivity in antibody detection in saliva (75%) vs serum (95.5%).[14 21] Lastly, ONS (Office for National Statistics) data in summer 2021 showed a seroprevalence of 47% in participants aged 16–24 years old[19] compared with 32.7% in those aged 15–18 years old in our study, a variance potentially accounted for by higher infection rates observed in those aged 18–24 years old in the period,[22] along with the possibility of vaccine-induced immunity in this older age group.

More consistency is seen when comparing trends over time. The dramatic increase in seropositivity evident in September–December 2020 in participants 15–18 years old, followed by all younger age groups (including those 0–4 years old) in January 2021–March 2021 is consistent with antibody data from SKIDS showing an increase in infection rates in those aged 11–18 years old in September–December 2020.[5] A further increase in seropositivity in participants aged 15–18 years old in April–June 2021 corresponds to the emergence of the delta variant, and associated increase in adolescent (13–17 years old) infections demonstrated in REACT-1 antigen data in May–July 2021.[2] COVID-19 seroprevalence varied across regions, with an early (June–August 2020) increase in London, again consistent with COVID Warriors and REACT Studies,[3] while the striking increase in seropositivity rates in the North West from May to June 2021 is reflected in regional data from the COVID-19 infection survey.

Our data showed a greater than twofold increased risk for participants from a minority ethnic group compared with white participants, which remained elevated in the multivariable analysis (including adjustment for socioeconomic status). This is consistent with the increased risk of SARS-CoV-2 infection from minority ethnic groups reported in the adult and paediatric populations since the first peak of the pandemic in England. Ward *et al* showed a threefold increase in risk of being antibody positive in the adult black population in England.[1] This trend was also reported by Ladhani *et al* in primary school children in June 2020.[23] Our data were not powered to look at individual ethnic groups, nevertheless we show that belonging to a minority ethnic group is a significant risk factor in the paediatric population (independent of socioeconomic status and adult-type comorbidities). Of note is that this increased risk became of borderline significance

Table 1 Univariate and multivariable logistic regression models to establish risk of SARS-CoV-2 seropositivity on Roche Elecsys Anti-SARS-CoV-2 serological assays for the detection of anti-SARS-CoV-2 IgG spike protein antibodies (RocheS (anti-SARS-CoV-2 IgG spike protein antibodies)) in children aged 0–18 years

			Multivariable					
			IMD deprivation quintiles		IDACI*† deprivation quintiles		IMD and incl HCW†	
	Univariate		2287		2287		1886	
Number of participants in model	OR (95% CI)	LR test (p value)	OR (95% CI)	LR test‡ (p value)	OR (95% CI)	LR test (p value)	OR (95% CI)	LR test (p value)
Age group								
0–4 years	1.1 (0.7 to 1.6)	0.08	0.8 (0.5 to 1.2)	0.01	0.8 (0.5 to 1.2)	0.01	0.8 (0.5 to 1.2)	0.05
5–9 years	1.0 (0.7 to 1.4)		1.0 (0.6 to 1.4)		1.0 (0.6 to 1.4)		0.9 (0.6 to 1.4)	
10–14 years	1 (ref)		1 (ref)		1 (ref)		1 (ref)	
15–18 years	1.5 (1.0 to 2.1)		1.5 (1.1 to 2.2)		1.5 (1.1 to 2.2)		1.4 (1.0 to 2.2)	
Sex								
Female	1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Male	0.9 (0.7 to 1.2)	0.7	1.0 (0.8 to 1.3)	0.9	1.0 (0.8 to 1.3)	1.0	1.0 (0.7 to 1.3)	1.0
NHS region								
East of England	1.5 (0.7 to 3.0)	<0.001	1.1 (0.5 to 2.4)	<0.001	1.1 (0.5 to 2.3)	<0.001	1.0 (0.4 to 2.3)	<0.001
London	6.0 (3.7 to 9.5)		3.1 (1.9 to 5.2)		3.1 (1.8 to 5.2)		3.0 (1.7 to 5.3)	
Midlands	1.7 (0.9 to 3.2)		1.2 (0.6 to 2.5)		1.2 (0.6 to 2.4)		1.1 (0.5 to 2.4)	
North East and Yorkshire	2.7 (1.6 to 4.3)		1.9 (1.1 to 3.2)		1.8 (1.1 to 3.1)		1.8 (1.0 to 3.2)	
North West	4.7 (2.9 to 7.5)		2.9 (1.7 to 5.2)		2.8 (1.6 to 4.9)		2.8 (1.6 to 5.0)	
South East	1 (ref)		1 (ref)		1 (ref)		1 (ref)	
South West	1.8 (1.0 to 3.0)		1.6 (0.9 to 2.8)		1.6 (0.9 to 2.8)		1.6 (0.9 to 2.9)	
Time period								
Pre-pandemic (01 Oct 2019–31 Mar 2020)		<0.001		<0.001		<0.001		<0.001
First wave (01 Apr 2020–31 May 2020)	0.2 (0.1 to 0.3)		0.2 (0.1 to 0.4)		0.2 (0.1 to 0.4)			
Post-first wave (01 Jun 2020–31 Aug 2020)	0.2 (0.1 to 0.3)		0.2 (0.1 to 0.3)		0.2 (0.1 to 0.3)		0.2 (0.1 to 0.3)	
Schools reopening and second wave (01 Sep 2020–31 Dec 2020)	0.4 (0.2 to 0.5)		0.4 (0.2 to 0.6)		0.4 (0.3 to 0.6)		0.4 (0.3 to 0.6)	
Post-second wave (01 Jan 2021–31 Mar 2021)	1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Emergence of delta variant (01 Apr 2021–30 Jun 2021)	1.2 (0.8 to 1.7)		1.0 (0.7 to 1.5)		1.0 (0.7 to 1.6)		1.0 (0.7 to 1.6)	
Ethnicity								
White	1 (ref)	<0.001	1 (ref)		1 (ref)		1 (ref)	
Minority ethnic group§	2.5 (1.8 to 3.3)		1.4 (1.0 to 2.0)	0.04	1.4 (1.0 to 2.0)	0.04	1.4 (1.0 to 2.0)	0.07
IMD deprivation quintile								
Most deprived 1	2.5 (1.7 to 3.7)	<0.001	1.4 (0.8 to 2.2)	0.1			1.6 (0.9 to 2.6)	0.04
2	1.6 (1.0 to 2.5)		0.8 (0.5 to 1.2)				0.7 (0.4 to 1.2)	
3	1.1 (1.0 to 2.3)		1.0 (0.6 to 1.5)				1.1 (0.7 to 1.7)	
4	1.5 (1.0 to 2.2)		1.2 (0.8 to 1.9)				1.3 (0.8 to 2.0)	
Least deprived 5	1 (ref)		1 (ref)				1 (ref)	
IDACI deprivation quintile								
Most deprived 1	1.9 (1.3 to 2.8)	<0.001			1.2 (0.8 to 1.9)	0.1		
2	1.1 (0.7 to 1.6)				0.6 (0.4 to 1.0)			
3	1.2 (0.8 to 1.7)				1.0 (0.6 to 1.5)			
4	1.0 (0.7 to 1.5)				0.9 (0.6 to 1.4)			
Least deprived 5	1 (ref)				1 (ref)			
Urban/rural								
Rural	0.3 (0.2 to 0.5)	<0.001	0.6 (0.3 to 1.0)	0.03	0.6 (0.3 to 1.0)	0.03	0.6 (0.4 to 1.1)	0.07
Urban	1 (ref)		1 (ref)		1 (ref)		1 (ref)	
HCW*								
No	1 (ref)	0.002					1 (ref)	
Yes	1.5 (1.2 to 2.0)						1.6 (1.2 to 2.2)	0.001

Multivariable analysis adjusts for age, sex, NHS region, time period, ethnicity, socioeconomic deprivation (using either IMD or IDACI), urban/rural geography and presence of HCWs within the household.
*Fewer results available for this analysis due to incomplete data in HCW field (see online supplemental table 3).
†IDACI measures the proportion of all children aged 0–15 years living in income-deprived families.
‡LR for each risk factor calculated with overall p value displayed.
§Minority ethnic group includes all minority groups apart from white minorities.
HCW, healthcare worker; IDACI, Income Deprivation Affecting Children Index; IMD, Index of Multiple Deprivation; LR, likelihood ratio; NHS, National Health Service.

when the presence of a healthcare worker in the household was included in the multivariable analysis, although this also may reflect the limitations of a smaller dataset. Nevertheless, the increased susceptibility among minority ethnic groups requires further study as to whether it reflects reduced access to healthcare or other social equalities.

Unlike COVID Warriors, we did not demonstrate that gastrointestinal symptoms were predictive of seropositivity.[3] This may reflect a symptomatology specific to ancestral lineages A and B which were in circulation when COVID Warriors collected their initial data,[16] or differing methods of data collection. Of note is that in our study, symptomatology questionnaires were adapted as the study progressed, with some symptoms collected retrospectively creating the potential for recall bias. Furthermore, while the age discrepancy in reporting of anosmia and ageusia is striking, this may reflect difficulties in children <10 years of age communicating these symptoms.

The strengths of this study are that it includes participants aged 0–18 years old and has sampled from all NHS regions in England which allows generalisations to be made to England as a whole. To our knowledge, at the time of publication, this is the only paediatric study in England that has a community-based recruitment strategy with efforts to recruit a representative sample of the region. The study has several limitations, including having been adapted from a pre-pandemic design. One-quarter of participants were children of healthcare workers, which is higher than the general population.[24] Both the RocheS and RocheN assays have primarily been validated in the adult, rather than paediatric population, and there is the possibility that the SARS-CoV-2 nucleocapsid-specific IgG response to infection, and the longevity of that response, may differ in younger age groups.[25] Of note is the increased divergence between RocheS and RocheN assays in later time periods. As participants with known COVID-19 vaccinations (which would lead to a positive RocheS while RocheN remained negative) were excluded from the analysis, and widespread immunisation was not conducted in the relevant age groups during the period studied, this may reflect more rapid waning of RocheN than RocheS, which has been seen in the adult literature.[26]

This study has provided a gold-standard SARS-CoV-2 seroprevalence dataset as part of a unique biobank of serum samples from children and young adults aged 0–24 years with a comprehensive history of immunisation and demography. The willingness of participants and their families to participate in research has created an invaluable resource for understanding COVID-19 and other infectious diseases.

Author affiliations
[1]Department of Paediatrics, University of Oxford, Oxford, UK
[2]Statistics, Modelling and Economics Department, Health Protection Agency, London, UK
[3]Immunisation, Hepatitis and Blood Safety Department, Public Health England, London, UK
[4]St George's Vaccine Institute, St. George's University Hospitals NHS Foundation Trust, London, UK
[5]Academic Unit of Clinical & Experimental Sciences, Faculty of Medicine, University of Southampton, Southampton, UK
[6]NIHR Wellcome Trust Clinical Research Facility, University Hospital Southampton NHS Foundation Trust, Southampton, UK
[7]Department of Paediatrics, Royal Manchester Children's Hospital, Manchester, UK
[8]Respiratory Group, University of Manchester, Manchester, UK
[9]Paediatric Infectious Diseases and Immunology, University Hospitals Bristol NHS Foundation Trust, Bristol, UK
[10]Immunology, Allergy and Infectious Diseases, Sheffield Children's Hospital NHS Foundation Trust, Sheffield, UK
[11]Bradford Neonatology, Bradford Teaching Hospitals NHS Foundation Trust, West Yorkshire, UK
[12]Paediatric Respiratory Medicine, Leeds Teaching Hospitals NHS Trust, Leeds, UK
[13]School of Life Sciences, University of Nottingham and Nottingham University Hospitals NHS Trust, Nottingham, UK
[14]Department of Paediatrics, University Hospitals Plymouth NHS Trust, Plymouth, UK
[15]Paediatric Immunology and Infectious Diseases, Newcastle upon Tyne Hospitals NHS Foundation Trust, Newcastle upon Tyne, UK
[16]Population Health Sciences Institute, Newcastle University, Newcastle upon Tyne, UK
[17]Section of Paediatrics, Imperial College London, London, UK
[18]Department of Paediatrics, West Suffolk NHS Foundation Trust, Bury Saint Edmunds, UK
[19]Vaccine Evaluation Unit, UK Health Security Agency, London, UK
[20]Virus Reference Department, Public Health England, Colindale, UK

Twitter Stephen Owens @owens_stephen

Acknowledgements The investigators express their gratitude for the contribution of all trial participants.

Collaborators What's the STORY research group: K Bell, Newcastle NHS Trust; C Kennedy, Newcastle NHS Trust; A Bell, Newcastle NHS Trust; C L Coates, Newcastle NHS Trust; S Crulley, Newcastle NHS Trust; A Davies, Newcastle NHS Trust; S King, Newcastle NHS Trust; D T J Metcalfe, Newcastle NHS Trust; C Reigan, Newcastle NHS Trust; D T J Fabian, Newcastle NHS Trust; R A Sarjeant, Newcastle NHS Trust; C Smith, Newcastle NHS Trust; L B Baxter, Newcastle NHS Trust; E Thompson, Newcastle NHS Trust; R Wane, Bradford Children's Research Team; R Swingler, Bradford Children's Research Team; C Bass-Woodcock, Bradford Children's Research Team; L Ingram, Bradford Children's Research Team; J Pearce, St George's Vaccine Institute, St George's University Hospital NHS Trust/St George's University of London; C Hultin, St George's Vaccine Institute, St George's University Hospital NHS Trust/St George's University of London; J I Pereira, St George's Vaccine Institute, St George's University Hospital NHS Trust/St George's University of London; H Foife, St George's Vaccine Institute, St George's University Hospital NHS Trust/St George's University of London; P Fox, St George's Vaccine Institute, St George's University Hospital NHS Trust/St George's University of London; E Stefanova, St George's Vaccine Institute, St George's University Hospital NHS Trust/St George's University of London; F Mabesa, St George's Vaccine Institute, St George's University Hospital NHS Trust/St George's University of London; S Hawkins, Oxford Vaccine Group; V H Murphy, Oxford Vaccine Group; J Muller, Oxford Vaccine Group; R Cooper, Oxford Vaccine Group; R White, Oxford Vaccine Group; S Koleva, Oxford Vaccine Group; D T J Kerr, Oxford Vaccine Group; R Drake-Brockman, Oxford Vaccine Group; J McEwan, Oxford Vaccine Group; H Roberts, Oxford Vaccine Group; K O'Brien, Oxford Vaccine Group; A Yao, Oxford Vaccine Group; H Trari Belhadef, Oxford Vaccine Group; H Robinson, Oxford Vaccine Group; S Roberts, Bristol Vaccine Centre (BVC); E B Burch, Bristol Vaccine Centre (BVC); S Thomson-Hill, Bristol Vaccine Centre (BVC); K Jahans-Baynton, Bristol Vaccine Centre (BVC); Z B Jordan, Bristol Vaccine Centre (BVC); D Ellis, Leeds Teaching Hospitals NHS Trust; R Lidstone-Scott, Leeds Teaching Hospitals NHS Trust; E Storr Plymouth NHS Trust; A Carney Plymouth NHS Trust; S Sharman, Plymouth NHS Trust; N J Oldfield, University of Nottingham Health Service; S Royal, University of Nottingham Health Service; S Belton, University of Nottingham Health Service; D Hammersley, University of Nottingham Health Service; J Wilson, Royal Manchester Children's Hospital; N Philips, Royal Manchester Children's Hospital; F Jennings, Royal Manchester Children's Hospital; I Mayor, Royal Manchester Children's Hospital; K Wilkins, Royal Manchester Children's Hospital; S Williams, Royal Manchester Children's Hospital; S Akter, Royal Manchester Children's Hospital; E Ashworth, Royal Manchester Children's Hospital; H Dalgleish, Royal Manchester Children's Hospital; A Wheeler, Royal Manchester Children's Hospital; S Persand, Imperial College London; S J Burrell, Imperial College London; R Harrison, Sheffield Children's Hospital NHS Trust; S J Hill, Sheffield Children's Hospital NHS Trust; S Gormley, Sheffield Children's Hospital NHS Trust; R Owens, University Hospital Southampton NHS Foundation Trust and University of Southampton; P S Munro, University Hospital Southampton NHS Foundation Trust and University of Southampton.

Contributors MDS, NA, GA and JLB conceived the study, while MDS is the chief investigator. MDS, NA, JLB, GA, MR and HR contributed to the protocol and design of the study. PA, EP, IV, EM, NLD, SM and HR led the implementation of the study. EPG, SNF, SH, CSM, MR, FS, SJO, TL, DPJT, MR, SO, PT and HC were site leads who contributed to the adaptation of the study design during the SARS-CoV-2 pandemic, to implementation of the study in the context of the pandemic and acquisition of data. KB, EL and RB were responsible for performing laboratory testing. KST and HR conducted the statistical analysis and verified the underlying data under the supervision of NA and MV. HR, KST and MDS drafted the initial version of the paper which was critically reviewed by all other authors for important intellectual content. All other authors contributed to the implementation and data collection. All authors reviewed and approved the final report. MDS is the guarantor.

Funding This research is funded by the National Institute for Health Research (NIHR) Policy Research Programme and the UK Research and Innovation (UKRI) Medical Research Council (PR-R17-0916-22001, CV220-036, CV220-036/1). The research is supported by the NIHR Oxford Clinical Research Facility and Biomedical Research Centre, the NIHR Clinical Research Network and the NIHR-funded National Immunisation Schedule Evaluation Consortium (PR-R17-0916-22001). The study sponsor is the University of Oxford. The processing of samples was completed by the COVID-19 serology team within Virus Reference Department at UKHSA. CSM is supported by NIHR Manchester BRC.

Competing interests MDS acts on behalf of the University of Oxford as an investigator on studies funded or sponsored by vaccine manufacturers, including

AstraZeneca, GlaxoSmithKline, Pfizer, Novavax, Janssen, Medimmune and MCM. He receives no personal financial payment for this work. SNF acts on behalf of University Hospital Southampton National Health Service (NHS) Foundation Trust as an investigator or providing consultative advice, or both, on clinical trials and studies of COVID-19 and other vaccines funded or sponsored by vaccine manufacturers including Janssen, Pfizer, AstraZeneca, GlaxoSmithKline, Novavax, Seqirus, Sanofi, Medimmune, Merck and Valneva. He receives no personal financial payment for this work. MR and EL, through the Immunisation Department, provide vaccine manufacturers (including Pfizer) with post-marketing surveillance reports about pneumococcal and meningococcal disease which the companies are required to submit to the UK Licensing authority in compliance with their Risk Management Strategy. A cost recovery charge is made for these reports. PA acts on behalf of the University of Oxford as the director of operations at the Oxford Vaccine Group and has received funding from the Vaccine Taskforce via the NIHR and AstraZeneca.

Patient consent for publication Not required.

Ethics approval This study involves human participants and ethical approval was obtained from the London-Surrey Research Ethics Committee (REC Reference: 19/LO/1040). Participants gave informed consent to participate in the study before taking part.

Provenance and peer review Not commissioned; internally peer reviewed.

Data availability statement Data are available upon reasonable request. After publication, anonymised individual patient data will be made available upon request to the corresponding author for secondary research, conditional on assurance from the secondary researcher that the proposed use of the data is compliant with the Medical Research Council Policy on Data Sharing regarding scientific quality, ethical requirements, and value for money, and is compliant with the National Institute for Health Research policy on data sharing. A minimum requirement with respect to scientific quality will be a publicly available prespecified protocol describing the purpose, methods, and analysis of the secondary research (eg, a protocol for a Cochrane systematic review), approved by a UK Research Ethics Committee or other similar, approved ethics review body. Participant identifiers will not be passed on to any third party. Data will be available for 5 years after publication.

ORCID iDs
Helen Ratcliffe http://orcid.org/0000-0002-4048-1035
Saul N Faust http://orcid.org/0000-0003-3410-7642
Clare S Murray http://orcid.org/0000-0002-8961-8055
Sam J Oddie http://orcid.org/0000-0001-8701-4912
Stephen Owens http://orcid.org/0000-0002-6979-9207
Paul Turner http://orcid.org/0000-0001-9862-5161

REFERENCES

1 Ward H, Atchison CJ, Whitaker M. Antibody prevalence for SARS-CoV-2 in England following first peak of the pandemic: REACT2 study in 100,000 adults. *medRxiv*2020:2020.08.12.20173690.
2 Elliott P, Haw D, Wang H, *et al*. Exponential growth, high prevalence of SARS-CoV-2, and vaccine effectiveness associated with the delta variant. *Science* 2021;374:eabl9551.
3 Waterfield T, Watson C, Moore R, *et al*. Seroprevalence of SARS-CoV-2 antibodies in children: a prospective multicentre cohort study. *Arch Dis Child* 2021;106:680–6.
4 Ismail SA, Saliba V, Lopez Bernal J, *et al*. SARS-CoV-2 infection and transmission in educational settings: a prospective, cross-sectional analysis of infection clusters and outbreaks in England. *Lancet Infect Dis* 2021;21:344–53.
5 Mensah AA, Sinnathamby M, Zaidi A, *et al*. SARS-CoV-2 infections in children following the full re-opening of schools and the impact of national lockdown: prospective, National observational cohort surveillance, July-December 2020, England. *J Infect* 2021;82:67–74.
6 Ministry of housing calg. *The English Indices of Deprivation 2019 (IoD2019) - Statistical release*. Ministry of housing, communities and local government, 2019.
7 NHS. Digital NHS, 2021. Available: https://digital.nhs.uk [Accessed 17 Jan 2022].
8 association Lg. Child health information services, 2021. Available: https://www.local.gov.uk/topics/social-care-health-and-integration/public-health/children-public-health-transfer/child-health-information-services [Accessed 17 Jan 2022].
9 de Lusignan S, Joy M, Oke J, *et al*. Disparities in the excess risk of mortality in the first wave of COVID-19: cross sectional study of the English sentinel network. *J Infect* 2020;81:785–92.
10 Hartley JEK, Levin K, Currie C. *A new version of the HBSC Family Affluence Scale - FAS III : Scottish qualitative findings from the international FAS Development Study Child Indicators Research*, 2016: 233–45.
11 Statistics OoN. Household questionnaire England, 2011. Available: https://www.ons.gov.uk/file?uri=/census/censustransformationprogramme/consultations/the2021censusinitialviewoncontentforenglandandwales/2011censusquestionnaireenglandh1.pdf [Accessed 17 Jan 2022].
12 Hobza V, Hamrik Z, Bucksch J, *et al*. The family affluence scale as an indicator for socioeconomic status: validation on regional income differences in the Czech Republic. *Int J Environ Res Public Health* 2017;14:1540.
13 Duggan J, Andrews N, Brooks T. *Evaluation of Roche Elecsys anti- SARS-CoV-2 serology assay for the detection of anti-SARS-CoV-2 antibodies*. England PH, assets publishing service, 2020.
14 Duggan J, Otter A, Andrews N. *Evaluation of Roche Elecsys anti- SARS-CoV-2 S serology assay for the detection of anti-SARS-CoV-2 S antibodies*. assets publishing service, 2021.
15 analysis IfG. Timeline of UK government coronavirus lockdowns, 2021. Available: https://www.instituteforgovernment.org.uk/charts/uk-government-coronavirus-lockdowns [Accessed 19 Jan 2022].
16 England PH. National COVID-19 surveillance reports, 2022. Available: https://www.gov.uk/government/publications/national-covid-19-surveillance-reports [Accessed 19 Jan 2022].
17 Wohland PBM, Rees P, Norman P, *et al*. NewETHPOP- evaluation, revision and extension of ethnic population projections.
18 StataCorp. *Stata statistical software: release 17*. College Station: TX: StataCorp LLC, 2021.
19 (DHSC) OatDfHaSC. Coronavirus (COVID-19) infection survey, antibody and vaccination data, 2021. Available: ons.gov.uk
20 J A. COVID-19 schools infection survey, England: round 6, pupil antibody data, 2021. Available: https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases/bulletins/covid19schoolsinfectionsurveyengland/round6pupilantibodydatajune2021 [Accessed 27 Jan 2022].
21 Hoschler K, Ijaz S, Andrews N, *et al*. Sars antibody testing in children: development of oral fluid assays for IgG measurements. *Microbiol Spectr* 2022;10:e0078621.
22 Statistics OfN. Coronavirus (COVID-19), 2022. Available: https://www.ons.gov.uk/peoplepopulationandcommunity/healthandsocialcare/conditionsanddiseases [Accessed 26 Jan 2022].
23 Ladhani SN, Baawuah F, Beckmann J, *et al*. SARS-CoV-2 infection and transmission in primary schools in England in June-December, 2020 (sKIDs): an active, prospective surveillance study. *Lancet Child Adolesc Health* 2021;5:417–27.
24 Workforce Team ND. *NHS Workforce Statistics - November 2021 (Including selected provisional statistics for December 2021*. Digital N, 2022.
25 Roarty C, Tonry C, McFetridge L, *et al*. Kinetics and seroprevalence of SARS-CoV-2 antibodies in children. *Lancet Infect Dis* 2021;21:30884–7.
26 Harris RJ, Whitaker HJ, Andrews NJ. Serological surveillance of SARS-CoV-2: six-month trends and antibody response in a cohort of public health workers. *medRxiv* 2021:2020.10.21.20216689.

Table 1 Recruiting sites NHS region(s) and postcode districts where applicable

Site	NHS region(s)	Date of first recruit	Selected postcode districts						
Bradford	Yorkshire and Humber	31/3/2020	BD15	BD6					
Bristol	South West	9/4/2020	BS2	BS20	BS3	BS37	BS41	BS8	
Imperial	London	8/2/2021	SW1	SW3	NW6	NW8	W11	WC2	
Leeds	Yorkshire and Humber	5/6/2020	LS25	WF2					
Manchester	North West	12/6/2020	M1	M12	M20	M23	M25	M6	
Newcastle	North East	7/1/2021	NE3	NE12	NE13	NE20	NE23	NE28	
Nottingham*	Midlands	10/7/2020							
Oxford	South East East of England	15/10/2019	HP17	HP22	HP23	MK13	OX1	OX11	OX28
Plymouth*	South West	3/6/2020							
Sheffield	Yorkshire and Humber Midlands	20/4/2020	S14	S43					
Southampton	South East	12/4/2020	SO16	SO23	SO24	SO50	SO51	SO52	
St Georges London	London South East	26/3/2020	CR4	KT18	KT6	SM3	SW11	SW20	
West Suffolk	East of England	21/1/2021	CB8	CB9	CO10	IP14	IP24	IP28	

**recruitment not restricted by postcode district*

Table 2 Sensitivity, specificity and thresholds of positivity for anti-SARS-CoV-2 IgG spike protein antibodies (RocheS) and anti-SARS-CoV-2 IgG nucleocapsid antibodies (RocheN) [13,14]

	RocheS	RocheN
Threshold of positivity	0·8U/ml	1·0 COI
Sensitivity	95·5% (95%CI 93·2-97·1)	83·9% (95% CI 74·8-90·7)
Specificity	100% (95% CI 99·1-100)	100% (95% CI 99·1-100)

COI – cut off index
U/ml - *units per millilitre*

Table 3 Summary of participants aged 0-18 years tested for COVID-19 with RocheS - Anti-SARS-CoV-2 IgG spike protein antibodies and RocheN - Anti-SARS-CoV-2 IgG nucleocapsid antibodies assays

	Seroprevalence		Symptoms		Risk factor	
	RocheS	RocheN	RocheS	RocheN	RocheS	RocheN
Age group						
0-4 years	532 (21·5%)	529 (21·4%)	289 (21·6%)	287 (21·5%)	516 (21·4%)	513 (21·3%)
5-9 years	636 (25·7%)	636 (25·7%)	344 (25·7%)	344 (25·7%)	620 (25·7%)	620 (25·7%)
10-14 years	721 (29·1%)	721 (29·1%)	377 (28·2%)	377 (28·2%)	705 (29·2%)	705 (29·3%)
15-18 years	588 (23·7%)	589 (23·8%)	329 (24·6%)	329 (24·6%)	571 (23·7%)	572 (23·7%)
Sex						
Female	1230 (49·7%)	1230 (49·7%)	689 (51·5%)	688 (51·5%)	1198 (49·7%)	1198 (49·7%)
Male	1247 (50·3%)	1245 (50·3%)	650 (48·7%)	649 (48·5%)	1214 (50·3%)	1212 (50·3%)
NHS region						
East of England	171 (6·9%)	171 (6·9%)	96 (7·2%)	96 (7·2%)	156 (6·5%)	156 (6·5%)
London	289 (11·7%)	289 (11·7%)	181 (13·6%)	181 (13·5%)	287 (11·9%)	287 (11·9%)
Midlands	210 (8·5%)	211 (8·5%)	138 (10·3%)	138 (10·3%)	207 (8·6%)	208 (8·6%)

Ratcliffe H, *et al. Arch Dis Child* 2022;0:1–8. doi: 10.1136/archdischild-2022-324375

North East and Yorkshire	419 (16·9%)	419 (16·9%)	232 (17·3%)	232 (17·4%)	410 (17·0%)	410 (17·0%)
North West	331 (13·4%)	331 (13·4%)	141 (10·5%)	141 (10·5%)	326 (13·5%)	326 (13·5%)
South East	633 (25·6%)	631 (25·5%)	260 (19·4%)	258 (19·3%)	607 (25·2%)	605 (25·1%)
South West	424 (17·1%)	423 (17·1%)	291 (21·7%)	291 (21·8%)	419 (17·4%)	418 (17·3%)
Time period						
Pre-pandemic (01 Oct 2019 - 31 Mar 2020)	125 (5·0%)	125 (5·1%)	32 (2·4%)	32 (2·4%)	125 (5·2%)	125 (5·2%)
First wave (01 Apr 2020 - 31 May 2020)	335 (13·5%)	335 (13·5%)	74 (5·5%)	74 (5·5%)	334 (13·8%)	334 (13·9%)
Post first wave (01 Jun 2020 - 31 Aug 2020)	516 (20·8%)	515 (20·8%)	111 (8·3%)	111 (8·3%)	507 (21·0%)	506 (21·0%)
Schools reopening and second wave (01 Sep 2020 - 31 Dec 2020)	464 (18·7%)	464 (18·7%)	298 (22·3%)	297 (22·2%)	456 (18·9%)	456 (18·9%)
Post second wave (01 Jan 2021 - 31 Mar 2021)	771 (31·1%)	770 (31·1%)	617 (46·1%)	616 (46·1%)	736 (30·5%)	735 (30·5%)
Emergence of delta variant (01 Apr 2021 - 30 Jun 2021)	266 (10·7%)	266 (10·7%)	207 (15·5%)	207 (15·5%)	254 (10·5%)	254 (10·5%)
Ethnicity						
White (White and White minorities)	1991 (80·4%)	1989 (80·4%)	1073 (80·1%)	1071 (80·1%)	1987 (82·4%)	1985 (82·4%)
Black (African, Caribbean, Other Black background)	51 (2·1%)	51 (2·1%)	29 (2·2%)	29 (2·2%)	51 (2·1%)	51 (2·1%)
Asian (Bangladeshi, Pakistani, Indian, Chinese, Arab, other Asian background and other ethnic group)	144 (5·8%)	144 (5·8%)	99 (7·4%)	99 (7·4%)	144 (6·0%)	144 (6·0%)
Multiple ethnic backgrounds	231 (9·3%)	231 (9·3%)	134 (10·0%)	134 (10·0%)	230 (9·5%)	230 (9·5%)
Not specified	60 (2·4%)	60 (2·4%)	4 (0·3%)	4 (0·3%)		

IMD quintile						
Most deprived 1	357 (14·4%)	357 (14·4%)	179 (13·4%)	179 (13·4%)	352 (14·6%)	352 (14·6%)
2	337 (13·6%)	336 (13·6%)	178 (13·3%)	177 (13·2%)	328 (13·6%)	327 (13·6%)
3	461 (18·6%)	461 (18·6%)	247 (18·4%)	247 (18·5%)	446 (18·5%)	446 (18·5%)
4	535 (21·7%)	534 (21·6%)	289 (21·6%)	289 (21·6%)	518 (21·5%)	517 (21·5%)
Least deprived 5	782 (31·6%)	782 (31·6%)	441 (33·0%)	440 (32·9%)	768 (31·8%)	768 (31·9%)
Not specified	5 (0·2%)	5 (0·2%)	5 (0·4%)	5 (0·4%)		
IDACI quintile						
Most deprived 1	374 (15·1%)	374 (15·1%)	188 (14·0%)	188 (14·1%)	368 (15·3%)	368 (15·3%)
2	348 (14·0%)	347 (14·0%)	194 (14·5%)	193 (14·4%)	342 (14·2%)	341 (14·1%)
3	451 (18·2%)	451 (18·2%)	225 (16·8%)	225 (16·8%)	433 (18·0%)	433 (18·0%)
4	549 (22·2%)	541 (21·9%)	305 (22·8%)	305 (22·8%)	538 (22·3%)	537 (22·3%)
Least deprived 5	750 (30·3%)	750 (30·3%)	422 (31·5%)	421 (31·5%)	731 (30·3%)	731 (30·3%)
Not specified	5 (0·2%)	5 (0·2%)	5 (0·4%)	5 (0·4%)		
Urban/rural						
Urban	1984 (80·1%)	1982 (80·1%)	1076 (80·4%)	1075 (80·4%)	1933 (80·1%)	1931 (80·1%)
Rural	493 (19·9%)	493 (19·9%)	263 (19·6%)	262 (19·6%)	479 (19·9%)	479 (19·9%)
Member of family is a healthcare worker						
Yes	628 (25·4%)	627 (25·3%)	421 (31·5%)	421 (31·5%)	626 (26·0%)	625 (25·9%)
No	1269 (51·2%)	1268 (51·2%)	804 (60·0%)	802 (60·0%)	1262 (52·3%)	1261 (52·3%)
Not specified	580 (23·4%)	580 (23·4%)	114 (8·5%)	114 (8·5%)	524 (21·7%)	524 (21·7%)
Total	2477	2475	1339	1337	2412	2410

Table 4 Comparing regional populations (0-18 years) with the STORY sample (0-18 years olds) including vaccinated individuals

NHS region	East of England		London		Midlands		North East and Yorkshire		North West		South East		South West	
	Region (0-18 years (%))	STORY sample (0-18 years (%))	Region (0-18 years (%))	STORY sample (0-18 years (%))	Region (0-18 years (%))	STORY sample (0-18 years (%))	Region (0-18 years (%))	STORY sample (0-18 years (%))	Region (0-18 years (%))	STORY sample (0-18 years (%))	Region (0-18 years (%))	STORY sample (0-18 years (%))	Region (0-18 years (%))	STORY sample (0-18 years (%))
White*	1146365·8 (82·4)	140 (88·6)	998497·8 (45·4)	199 (67·7)	852484·5 (75·4)	178 (84·8)	941658·8 (89·5)	361 (86·8)	1309834·6 (80·8)	235 (68·5)	1709830·1 (82·5)	531 (84·4)	1045274·7 (90·7)	393 (91·2)
Black**	46559·0 (3·3)	2 (1·3)	374912·9 (17·0)	19 (6·5)	37043·3 (3·3)	4 (1·9)	19364·3 (1·8)	7 (1·7)	36393·4 (2·2)	14 (4·1)	55537·4 (2·7)	4 (0·6)	18522·2 (1·6)	2 (0·5)
Asian***	111665·8 (8·0)	4 (2·5)	518125·2 (23·5)	30 (10·2)	169453·2 (15·0)	12 (5·7)	32584·5 (3·1)	17 (4·0)	190051·5 (11·7)	49 (14·3)	174174·6 (8·4)	28 (4·4)	36856·3 (3·2)	10 (2·3)
Multiple ethnic backgrounds	86007·6 (6·2)	12 (7·6)	310162·9 (14·1)	46 (15·6)	71616·5 (6·3)	16 (7·6)	58044·7 (5·5)	31 (7·5)	84851·4 (5·2)	45 (13·1)	131887·0 (6·4)	67 (10·6)	51275·7 (4·5)	26 (6·0)
total	1390598·2	158·0	2201698·7	294·0	1130597·5	210·0	1051652·4	416·0	1621130·9	343·0	2071429·2	630·0	1151928·9	431·0

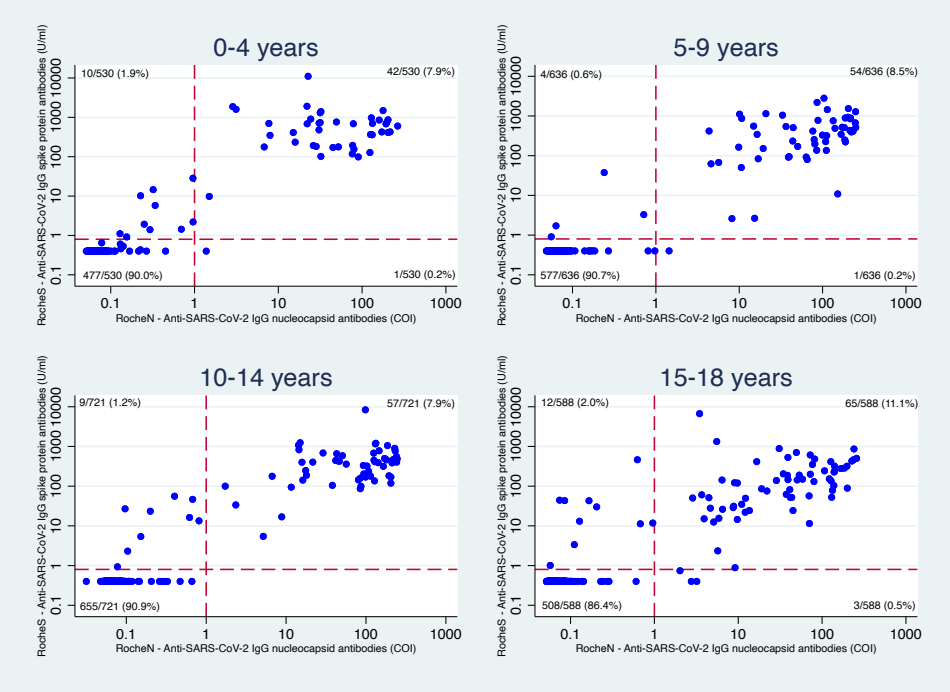
*White including white minorities
**Black (African, Caribbean, Other Black background)
*** Asian (Bangladeshi, Chinese, Indian, Pakistani, Other Asian background)

Table 5 Comparing children aged 0-15 years on IDACI and IMD by region as a measure of socioeconomic deprivation in children IMD and IDACI derived from postcode of participant, FASiii and Census 2011 home ownership and house size questions data were collected on the questionnaire

		Quintile				
		1	2	3	4	5
Overall	**IMD**	303	280	409	453	663
	Number (%) of families that own their own home in each IMD quintile	50·8	69·4	77·9	81·7	85·8
	Average number of rooms in home in each IMD quintile	5·6	6·1	6·6	7·0	7·3
	Average Number of bedrooms in home in each IMD quintile	2·9	3·2	3·5	3·6	3·8
	Mean FASiii score in each IMD quintile	6·5	7·7	8·7	8·9	9·5
	IDACI	315	304	481	476	632
	Number (%) of families that own their own home in each IDACI quintile	49·8	66·4	79·8	81·6	87·7
	Average number of rooms in home in each IDACI quintile	5·6	6·1	6·6	6·8	7·5
	Average Number of bedrooms in home in each IDACI quintile	2·9	3·2	3·5	3·6	3·8
	Mean FASiii score in each IDACI quintile	6·6	7·7	8·6	8·9	9·5
East of England	**IMD**	16	22	44	40	25
	Number (%) of families that own their own home in each IMD quintile	30·8	59·1	65·8	86·1	100·0
	Average number of rooms in home in each IMD quintile	5·8	6·6	6·8	7·4	7·8
	Average Number of bedrooms in home in each IMD quintile	2·9	3·5	3·3	3·9	3·7
	Mean FASiii score in each IMD quintile	6·4	7·6	7·8	9·3	9·7
	IDACI	24	22	30	40	31
	Number (%) of families that own their own home in each IDACI quintile	33·3	59·1	72·0	88·6	93·1
	Average number of rooms in home in each IDACI quintile	6·2	5·2	7·2	7·1	8·0
	Average Number of bedrooms in home in each IDACI quintile	3·0	3·4	3·8	3·5	3·8
	Mean FASiii score in each IDACI quintile	6·5	7·2	9·2	8·5	9·7
London	**IMD**	9	41	61	48	79
	Number (%) of families that own their own home in each IMD quintile	22·2	36·6	73·8	83·3	84·6
	Average number of rooms in home in each IMD quintile	4·8	5·1	5·9	6·7	6·8
	Average Number of bedrooms in home in each IMD quintile	2·3	2·9	3·2	3·5	3·8
	Mean FASiii score in each IMD quintile	5·8	7·5	8·5	9·3	9·7
	IDACI	18	55	35	61	69
	Number (%) of families that own their own home in each IDACI quintile	27·8	50·9	74·3	80·3	88·2
	Average number of rooms in home in each IDACI quintile	4·6	5·3	6·1	6·4	7·0
	Average Number of bedrooms in home in each IDACI quintile	2·5	2·9	3·3	3·6	3·9
	Mean FASiii score in each IDACI quintile	7·2	7·5	8·3	9·2	10·1
Midlands	**IMD**	17	30	34	30	44
	Number (%) of families that own their own home in each IMD quintile	58·8	67·9	84·8	86·7	95·3
	Average number of rooms in home in each IMD quintile	6·8	6·3	6·4	7·1	7·8
	Average Number of bedrooms in home in each IMD quintile	3·6	3·4	3·5	3·7	4·0
	Mean FASiii score in each IMD quintile	7·5	8·3	8·8	9·1	9·8
	IDACI	23	32	31	35	34
	Number (%) of families that own their own home in each IDACI quintile	52·2	75·9	83·9	91·2	97·1
	Average number of rooms in home in each IDACI quintile	6·6	6·4	6·3	7·3	7·9
	Average Number of bedrooms in home in each IDACI quintile	3·4	3·5	3·4	3·9	4·0
	Mean FASiii score in each IDACI quintile	7·7	8·5	8·7	9·5	9·7
North East and Yorkshire	**IMD**	88	59	61	57	89
	Number (%) of families that own their own home in each IMD quintile	58·8	82·5	81·7	91·1	88·6
	Average number of rooms in home in each IMD quintile	5·5	6·3	6·8	7·1	7·4

	Average Number of bedrooms in home in each IMD quintile	2·9	3·2	3·6	3·6	3·7
	Mean FASiii score in each IMD quintile	6·8	7·2	8·7	9·3	9·0
	IDACI	83	57	68	41	105
	Number (%) of families that own their own home in each IDACI quintile	60·0	73·2	83·3	87·5	92·3
	Average number of rooms in home in each IDACI quintile	5·6	6·3	6·8	6·7	7·4
	Average Number of bedrooms in home in each IDACI quintile	3·0	3·2	3·5	3·5	3·7
	Mean FASiii score in each IDACI quintile	6·7	7·3	8·6	8·8	9·1
North West	**IMD**	119	54	71	51	2
	Number (%) of families that own their own home in each IMD quintile	51·7	86·5	81·7	85·7	50·0
	Average number of rooms in home in each IMD quintile	5·7	6·5	7·3	7·8	8·0
	Average Number of bedrooms in home in each IMD quintile	2·9	3·4	3·9	4·2	4·5
	Mean FASiii score in each IMD quintile	6·5	8·4	9·0	8·7	9·5
	IDACI	116	27	50	41	63
	Number (%) of families that own their own home in each IDACI quintile	52·2	74·1	87·5	70·0	91·9
	Average number of rooms in home in each IDACI quintile	5·7	6·0	7·3	6·4	8·1
	Average Number of bedrooms in home in each IDACI quintile	3·0	3·2	3·7	3·7	4·3
	Mean FASiii score in each IDACI quintile	6·5	8·0	8·3	8·5	9·3
South East	**IMD**	23	40	81	112	293
	Number (%) of families that own their own home in each IMD quintile	27·3	63·2	73·7	76·9	80·4
	Average number of rooms in home in each IMD quintile	5·6	5·9	6·1	7·1	7·3
	Average Number of bedrooms in home in each IMD quintile	2·7	3·1	3·3	3·5	3·9
	Mean FASiii score in each IMD quintile	6·3	7·6	8·4	9·4	9·4
	IDACI	19	68	104	152	206
	Number (%) of families that own their own home in each IDACI quintile	23·5	65·7	72·6	77·7	82·5
	Average number of rooms in home in each IDACI quintile	5·3	6·1	6·5	7·0	7·5
	Average Number of bedrooms in home in each IDACI quintile	2·5	3·2	3·5	3·6	3·8
	Mean FASiii score in each IDACI quintile	5·5	8·0	8·7	9·2	9·6
South West	**IMD**	31	34	57	115	131
	Number (%) of families that own their own home in each IMD quintile	54·8	75·8	83·6	76·1	91·3
	Average number of rooms in home in each IMD quintile	5·1	5·8	6·9	6·4	7·3
	Average Number of bedrooms in home in each IMD quintile	2·8	3·4	3·5	3·5	3·8
	Mean FASiii score in each IMD quintile	6·1	7·5	8·5	8·2	9·5
	IDACI	32	43	63	106	124
	Number (%) of families that own their own home in each IDACI quintile	51·6	71·4	85·2	84·8	85·8
	Average number of rooms in home in each IDACI quintile	5·2	6·5	6·4	6·7	7·2
	Average Number of bedrooms in home in each IDACI quintile	2·9	3·3	3·3	3·7	3·7
	Mean FASiii score in each IDACI quintile	6·3	7·6	8·5	8·6	9·2

Figure 1 A comparison of results by the RocheN - Anti-SARS-CoV-2 IgG nucleocapsid antibodies assay and RocheS - Anti-SARS-CoV-2 IgG spike protein antibodies assay by age



Assay positivity thresholds indicated as red dashed lines (0.8 U/ml for Spike and 1 COI for Nucleocapsid)
COI – cut off index, U/ml (units per millilitre)

Table 6 SARS-CoV-2 seroprevalence (RocheS - Anti-SARS-CoV-2 IgG spike protein antibodies and RocheN - Anti-SARS-CoV-2 IgG nucleocapsid antibodies) by age group and time period October 2019 to June 2021 in England, adjusted for age, region and ethnicity

	RocheS			RocheN		
Period	**N**	**Crude rate**	**Adjusted rate**	**N**	**Crude rate**	**Adjusted rate**
Pre-pandemic (Oct 19 - Mar 20)	125	0·0%	0·0%	125	0·0%	0·0%
First wave (Apr 20 - May 20)	335	3·9%	2·2% (0·9%-3·4%)	335	3·6%	1·8% (0·8%-2·8%)
Post first wave (Jun 20 - Aug 20)	516	3·9%	5·2% (3·2%-7·2%)	515	3·7%	5·1% (3·1%-7·2%)
Schools reopening and second wave (Sep 20 - Dec 20)	464	6·9%	7·1% (5·5%-8·6%)	464	6·0%	7·3% (5·5%-9·1%)
Post second wave (Jan 21 - Mar 21)	771	17·5%	17·6% (14·4%-20·9%)	770	15·2%	16·2% (12·9%-19·4%)
Emergence of delta variant (Apr 21 - Jun 21)	266	19·9%	19·9% (16·1%-23·7%)	266	17·7%	16·8% (13·1%-20·6%)

Table 7 SARS-CoV-2 seroprevalence (RocheS - Anti-SARS-CoV-2 IgG spike protein antibodies and RocheN - Anti-SARS-CoV-2 IgG nucleocapsid antibodies) by age group and time period October 2019 to June 2021 in England, adjusted for NHS region and ethnicity

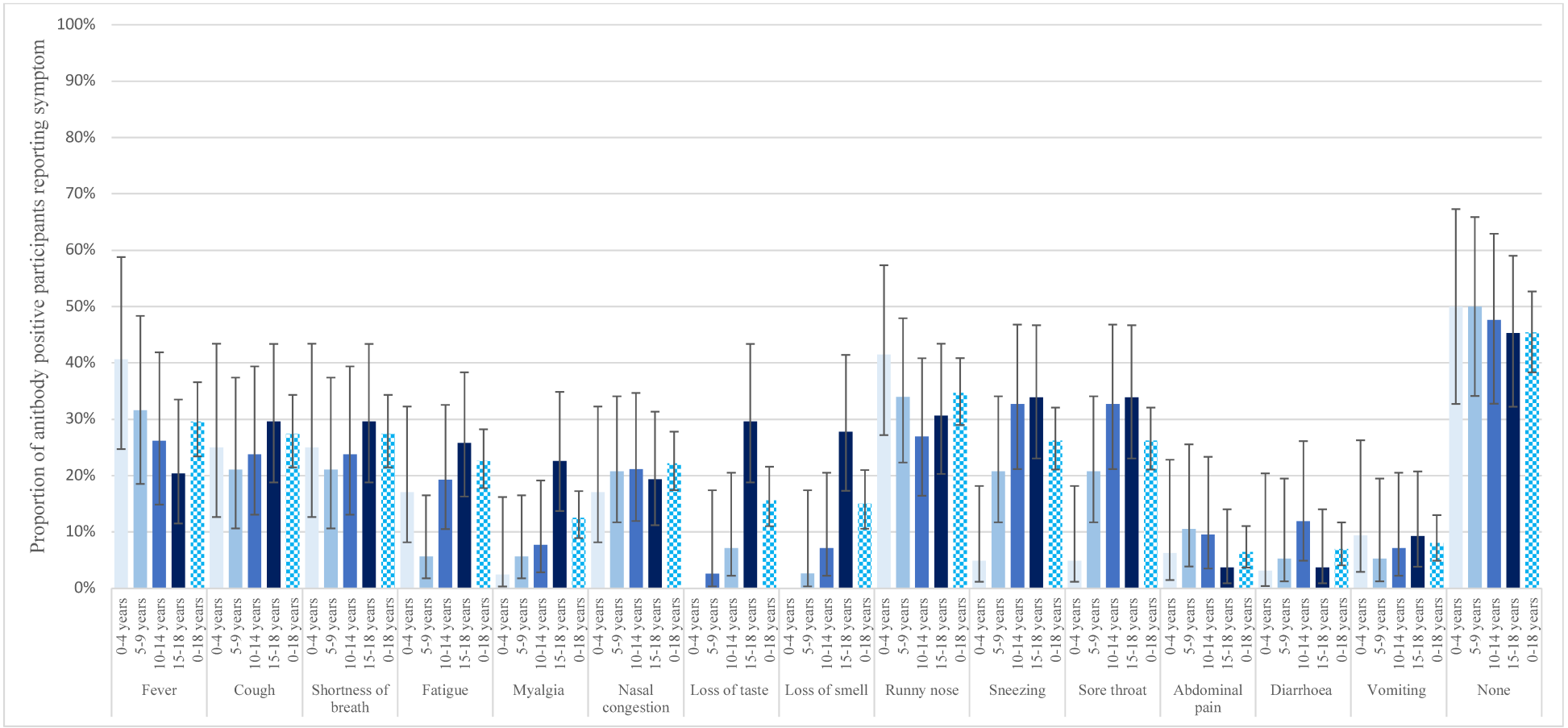
		RocheS			RocheN		
		N	Crude	Adjusted	N	Crude	Adjusted
0-4 years	**Pre-pandemic (Oct 19 - Mar 20)**	25	0·0%	0·0%	25	0·0%	0·0%
	First wave (Apr 20-May 20)	62	1·6%	0·7% (0·0%-2·1%)	62	1·6%	0·7% (0·0%-2·1%)
	Post first wave (Jun 20 - Aug 20)	64	4·7%	4·7% (0·0%-10·2%)	63	4·8%	4·7% (0·0%-10·3%)
	Schools reopening and second wave (Sep 20 - Dec 20)	77	5·2%	5·3% (2·2%-8·4%)	76	6·6%	6·2% (2·7%-9·8%)
	Post second wave (Jan 21 -Mar 21)	200	13·5%	13·0% (6·7%-19·3%)	199	10·1%	11·7% (5·5%-18·0%)
	Emergence of delta variant (Apr 21 - Jun 21)	104	16·3%	13·9% (4·5%-23·2%)	104	13·5%	12·2% (3·1%-21·4%)
5-9 years	**Pre-pandemic (Oct 19 - Mar 20)**	31	0·0%	0·0%	31	0·0%	0·0%
	First wave (Apr 20-May 20)	83	3·6%	2·5% (0·0%-5·0%)	83	3·6%	2·5% (0·0%-5·0%)
	Post first wave (Jun 20 - Aug 20)	144	4·9%	9·5% (8·2%-10·9%)	144	3·5%	8·9% (7·9%-10·0%)
	Schools reopening and second wave (Sep 20 - Dec 20)	119	3·4%	1·8% (0·0%-3·5%)	119	3·4%	3·6% (0·0%-7·3%)
	Post second wave (Jan 21 -Mar 21)	187	15·0%	17·8% (11·5%-24·1%)	187	15·0%	17·8% (11·5%-24·1%)
	Emergence of delta variant (Apr 21 - Jun 21)	72	22·2%	18·9% (15·5%-22·3%)	72	20·8%	18·5% (15·2%-21·9%)
10-14 years	**Pre-pandemic (Oct 19 - Mar 20)**	41	0·0%	0·0%	41	0·0%	0·0%
	First wave (Apr 20-May 20)	108	3·7%	3·2% (0·0%-6·5%)	108	2·8%	1·7% (0·0%-3·5%)
	Post first wave (Jun 20 - Aug 20)	174	2·3%	0·9% (0·0%-1·8%)	174	2·3%	0·9% (0·0%-1·8%)
	Schools reopening and second wave (Sep 20 - Dec 20)	152	5·3%	2·5% (0·6%-4·4%)	152	5·3%	2·5% (0·6%-4·4%)
	Post second wave (Jan 21 -Mar 21)	195	21·5%	20·6% (13·6%-27·6%)	195	17·9%	18·1% (11·3%-24·9%)
	Emergence of delta variant (Apr 21 - Jun 21)	51	15·7%	17·6% (9·7%-25·5%)	51	13·7%	16·6% (8·9%-24·3%)
15-18 years	**Pre-pandemic (Oct 19 - Mar 20)**	28	0·0%	0·0%	28	0·0%	0·0%
	First wave (Apr 20-May 20)	82	6·1%	2·5% (0·5%-4·5%)	82	6·1%	2·5% (0·5%-4·5%)
	Post first wave (Jun 20 - Aug 20)	134	4·5%	4·6% (0·5%-8·7%)	134	5·2%	5·1% (1·0%-9·3%)
	Schools reopening and second wave (Sep 20 - Dec 20)	116	13·8%	23·2% (17·4%-29·0%)	117	9·4%	20·7% (15·3%-26·0%)
	Post second wave (Jan 21 -Mar 21)	189	20·1%	19·5% (13·8%-25·1%)	189	18·0%	17·0% (11·5%-22·4%)
	Emergence of delta variant (Apr 21 - Jun 21)	39	30·8%	32·7% (23·6%-41·8%)	39	28·2%	21·2% (12·1%-30·4%)

Table 8 SARS-CoV-2 seroprevalence (RocheS - Anti-SARS-CoV-2 IgG spike protein antibodies and RocheN - Anti-SARS-CoV-2 IgG nucleocapsid antibodies) by region and time period October 2019 to June 2021 in England, adjusted for age and ethnicity·

		RocheS			RocheN		
		N	Crude	Adjusted	N	Crude	Adjusted
Pre-pandemic (Oct 19 - Mar 20)	**East of England**	21	0·0%	0·0%	21	0·0%	0·0%
	London	10	0·0%	0·0%	10	0·0%	0·0%
	Midlands	0	0·0%	0·0%	0	0·0%	0·0%
	North East & Yorkshire	2	0·0%	0·0%	2	0·0%	0·0%
	North West	0	0·0%	0·0%	0	0·0%	0·0%
	South East	92	0·0%	0·0%	92	0·0%	0·0%
	South West	0	0·0%	0·0%	0	0·0%	0·0%
First wave (Apr 20 - May 20)	**East of England**	16	6·3%	3·3% (0·0%-9·3%)	16	6·3%	0·0%
	London	55	12·7%	10·2% (3·0%-17·3%)	55	12·7%	10·2% (3·0%-17·3%)
	Midlands	27	0·0%	0·0%	27	0·0%	0·0%
	North East & Yorkshire	64	3·1%	3·8% (0·0%-8·4%)	64	3·1%	3·8% (0·0%-8·4%)
	North West	0	0·0%	0·0%	0	0·0%	0·0%
	South East	134	2·2%	1·5% (0·0%-3·1%)	133	2·3%	1·5% (0·0%-3·1%)
	South West	39	0·0%	0·0%	39	0·0%	0·0%
Post first wave (Jun 20- Aug 20)	**East of England**	9	0·0%	0·0%	9	0·0%	0·0%
	London	14	21·4%	33·9% (18·7%-49·1%)	14	21·4%	33·9% (18·7%-49·1%)
	Midlands	46	2·2%	0·9% (0·0%-2·7%)	46	2·2%	0·9% (0·0%-2·7%)
	North East & Yorkshire	73	0·0%	0·0%	73	0·0%	0·0%
	North West	127	6·3%	5·8% (1·9%-9·7%)	125	6·4%	5·9% (2·0%-9·8%)
	South East	97	0·0%	0·0%	94	0·0%	0·0%
	South West	39	0·0%	0·0%	39	0·0%	0·0%
Schools reopening and second wave (Sep 20- Dec 20)	**East of England**	11	0·0%	0·0%	11	0·0%	0·0%
	London	12	16·7%	8·4% (2·0%-14·7%)	12	16·7%	8·4% (2·0%-14·7%)
	Midlands	77	6·5%	2·6% (0·1%-5·0%)	75	5·3%	5·2% (0·1%-10·3%)
	North East & Yorkshire	62	11·3%	11·6% (5·7%-17·4%)	61	9·8%	10·5% (5·0%-16·0%)
	North West	61	11·5%	15·1% (9·5%-20·7%)	61	11·5%	15·4% (9·3%-21·4%)
	South East	127	3·9%	3·8% (0·7%-6·9%)	122	4·1%	3·0% (0·2%-5·8%)
	South West	114	5·3%	5·1% (0·0%-10·2%)	114	5·3%	4·6% (0·0%-9·6%)
Post second wave (Jan 21 - Mar 21)	**East of England**	88	9·1%	13·2% (8·9%-17·5%)	76	10·5%	11·2% (7·7%-14·8%)
	London	115	26·1%	24·1% (15·1%-33·1%)	115	26·1%	22·8% (13·9%-31·8%)
	Midlands	49	14·3%	15·5% (5·4%-25·6%)	48	14·6%	15·5% (5·4%-25·6%)
	North East & Yorkshire	193	16·1%	14·8% (9·9%-19·7%)	187	16·6%	12·4% (7·7%-17·0%)
	North West	116	28·4%	26·8% (18·0%-35·7%)	115	27·8%	24·0% (15·4%-32·6%)
	South East	120	10·8%	11·5% (5·3%-17·8%)	109	11·0%	11·6% (5·3%-17·9%)
	South West	90	14·4%	18·5% (10·8%-26·2%)	89	14·6%	16·4% (9·1%-23·7%)
	East of England	26	7·7%	2·0% (0·0%-5·8%)	23	4·3%	2·0% (0·0%-5·8%)

Emergence of delta variant (Apr 21 - Jun 21)	**London**	83	24·1%	25·8% (13·8%-37·8%)	83	24·1%	20·6% (9·7%-31·5%)
	Midlands	11	18·2%	11·3% (0·7%-21·9%)	11	18·2%	11·3% (0·7%-21·9%)
	North East & Yorkshire	25	24·0%	23·7% (20·3%-27·0%)	25	24·0%	7·8% (4·8%-10·9%)
	North West	27	40·7%	51·9% (33·4%-70·5%)	26	42·3%	51·9% (33·4%-70·5%)
	South East	63	11·1%	6·0% (0·1%-11·9%)	57	10·5%	5·6% (0·0%-11·5%)
	South West	31	16·1%	26·6% (22·0%-31·2%)	31	16·1%	28·9% (23·3%-34·6%)

Figure 2 Summary of symptoms reported by seropositive participants on RocheN Anti-SARS-CoV nucleocapsid antibodies assay by age group· Error bars show 95% confidence intervals



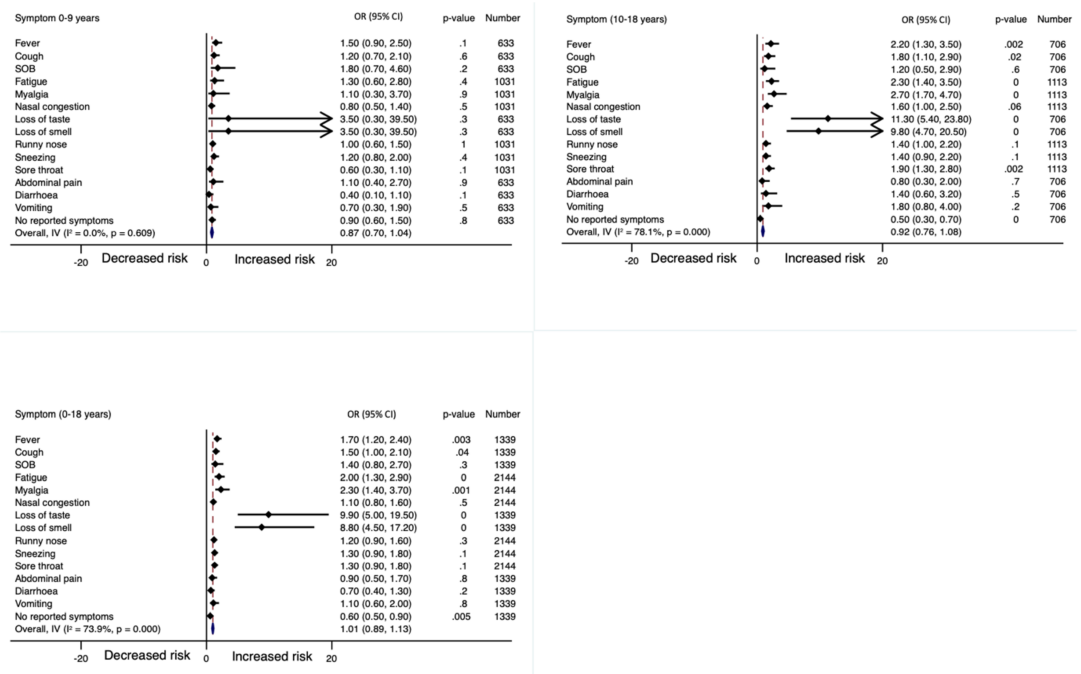


Figure 3a Univariate analysis of symptoms by age band (RocheS - Anti-SARS-CoV-2 IgG spike protein antibodies)

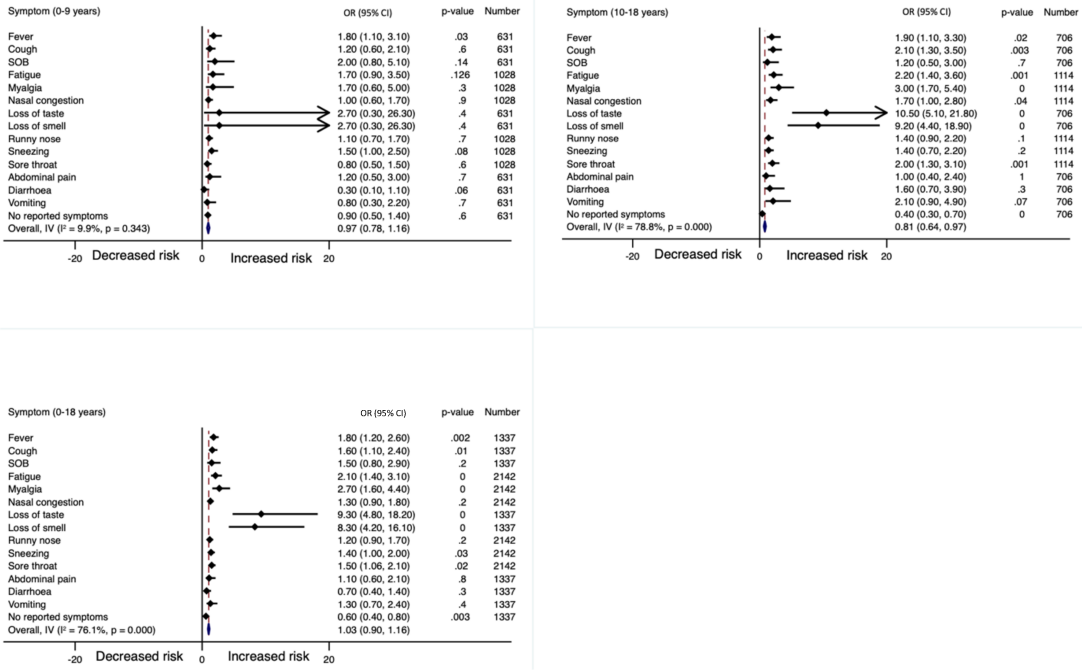


Figure 3b Univariate analysis of symptoms by age band (RocheN - Anti-SARS-CoV-2 IgG nucleocapsid antibodies)

Table 9a Logistic regression models to determine symptoms associated with positivity the RocheS - Anti-SARS-CoV-2 IgG spike protein antibodies assay results. Symptoms with the highest p-value were sequentially excluded and model Akaike Information Criterion (AIC) values were compared until a model with the lowest AIC value had been reached. Separate models created for 0-9 years and 10-18 years.

RocheS	OR (95% CI)	p-value
Age group: 0-9 years (N=663 observations)		
Male	1·0 (0·6-1·7)	0·89
Fever	1·7 (1·0-2·9)	0·05
Gastrointestinal symptoms	0·6 (0·3-1·1)	0·09
Age group: 10-18 years (N=873 observations)		
Male	0·9 (0·6-1·3)	0·57
Fever	1·6 (1·0-2·7)	0·05
Loss of taste and smell	9·2 (5·1-16·3)	<0·001

OR: odds ratio

Table 9b Logistic regression models to determine symptoms associated with positivity the RocheN - Anti-SARS-CoV-2 IgG nucleocapsid antibodies assay results· Symptoms with the highest p-value were sequentially excluded and model Akaike Information Criterion (AIC) values were compared until a model with the lowest AIC value had been reached· Separate models created for 0-9 years and 10-18 years

RocheN	OR (95% CI)	p-value
Age group: 0-9 years (N=631 observations)		
Male	1·1 (0·6-1·8)	0·80
Fever	2·1 (1·2-3·6)	0·009
Gastro intestinal symptoms	0·5 (0·3-1·1)	0.09
Age group: 10-18 years (N=873 observations)		
Male	0·9 (0·6-1·4)	0·65
Cough	1·6 (1·0-2·6)	0·07
Loss of taste or smell	8·0 (4·5-14·4)	<0·001

OR: odds ratio

Table 10 A univariate and multivariable logistic regression models to establish risk of SARS-CoV-2 seropositivity on Roche Elecsys Anti-SARS-CoV-2 serological assays for the detection of anti-SARS-CoV-2 IgG nucleocapsid antibodies (RocheN) in children aged 0-18 years·

	Univariate		Multivariable					
			IMD* deprivation quintiles		IDACI** deprivation quintiles		IMD and incl· HCW†	
Number of participants in model			2285		2285		1886	
	Odds ratio (95%CI)	**LR test (p value)**	**Odds ratio (95% CI)**	**LR test‡ (p value)**	**Odds ratio (95% CI)**	**LR test (p value)**	**Odds ratio (95% CI)**	**LR test (p value)**
Age group								
0-4 years	1·0 (0·7-1·6)	0·1	0·8 (0·5-1·3)	0·02	0·8 (0·1-1·3)	0·02	0·8 (0·5-1·3)	0·07
5-9 years	1·1 (0·7-1·6)		1·1 (0·7-1·7)		1·1 (0·7-1·7)		1·1 (0·7-1·6)	
10-14 years	1 (ref)		1 (ref)		1 (ref)		1 (ref)	
15-18 years	1·5 (1·1-2·2)		1·6 (1·1-2·4)		1·6 (1·1-2·4)		1·5 (1·0-2·2)	
Sex								
Female	1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Male	0·9 (0·7-1·2)	0·7	1·0 (0·7-1·3)	0·9	1·0 (0·7-1·3)	0·9	1·0 (0·7-1·3)	0·9
NHS region								
East of England	1·1 (0·5-2·6)	<0·001	0·8 (0·3-2·0)	<0·001	0·8 (0·3-2·0)	0·001	0·9 (0·3-2·2)	0·001
London	5·5 (3·3-8·9)		2·7 (1·6-4·7)		2·6 (1·5-4·4)		2·7 (1·5-4·8)	
Midlands	1·7 (0·8-3·2)		1·3 (0·6-2·6)		1·2 (0·6-2·5)		1·2 (0·6-2·6)	
North East and Yorkshire	2·3 (1·3-3·8)		1·5 (0·9-2·7)		1·5 (0·8-2·6)		1·5 (0·8-2·7)	
North West	4·5 (2·8-7·4)		2·7 (1·5-4·9)		2·6 (1·5-4·6)		2·7 (1·4-4·9)	
South East	1 (ref)		1 (ref)		1 (ref)		1 (ref)	
South West	1·7 (0·9-3·0)		1·5 (0·8-2·7)		1·5 (0·8-2·7)		1·5 (0·8-2·7)	
Time period								
Pre-pandemic (01 Oct 2019 - 31 Mar 2020)		<0·001		<0·001		<0·001		<0·001
First wave (01 Apr 2020 - 31 May 2020)	0·2 (0·1-0·4)		0·2 (0·1-0·5)		0·2 (0·1-0·5)			
Post first wave (01 Jun 2020 - 31 Aug 2020)	0·2 (0·1-0·4)	<0·001	0·2 (0·1-0·3)		0·2 (0·1-0·3)		0·2 (0·1-0·3)	
Schools reopening and second wave (01 Sep 2020 - 31 Dec 2020)	0·4 (0·2-0·6)	<0·001	0·4 (0·3-0·6)		0·4 (0·2-0·6)		0·4 (0·3-0·6)	
Post second wave (01 Jan 2021 - 31 Mar 2021)	1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Emergence of delta variant (01 Apr 2021 - 30 Jun 2021)	1·2 (0·8-1·7)	0·3	1·0 (0·7-1·6)		1·0 (0·7-1·6)		1·0 (0·7-1·6)	
Ethnicity								
White	1 (ref)		1 (ref)		1 (ref)		1 (ref)	
Minority ethnic group ††	2·5 (1·9-3·5)	<0·001	1·5 (1·0-2·1)	0·04	1·5 (1·0-2·1)	0·04	1·4 (1·0-2·1)	0·06
IMD deprivation quintile								

Most deprived 1		2·8 (1·8-4·2)	0·002	1·5 (0·9-2·4)	0·02			1·7 (1·0-2·9)	0·009
	2	1·4 (0·9-2·3)		0·7 (0·4-1·2)				0·7 (0·4-1·2)	
	3	1·5 (1·0-2·3)		0·9 (0·6-1·5)				1·0 (0·6-1·7)	
	4	1·7 (1·1-2·5)		1·4 (0·9-2·2)				1·5 (0·9-2·4)	
Least deprived 5		1 (ref)		1 (ref)				1 (ref)	
IDACI deprivation quintile									
Most deprived 1		2·0 (1·3-2·9)	<0·001			1·2 (0·7-1·8)	0·04		
	2	1·0 (0·6-1·6)				0·6 (0·4-1·0)			
	3	0·8 (0·5-1·3)				0·6 (0·4-1·0)			
	4	1·0 (0·7-1·5)				1·0 (0·6-1·5)			
Least deprived 5		1 (ref)				1 (ref)			
Urban/rural									
Rural		0·2 (0·1-0·4)	<0·001	0·4 (0·2-0·8)	0·002	0·4 (0·2-0·7)	<0·001	0·5 (0·2-0·9)	0·009
Urban		1 (ref)		1 (ref)		1 (ref)		1 (ref)	
HCW †									
No		1 (ref)						1 (ref)	
Yes		1·5 (1·1-2·0)	0·003					1·7 (1·3-2·4)	<0·001

**IMD Index of Multiple Deprivation*

***IDACI Income Deprivation Affecting Children Index (IDACI) measures the proportion of all children aged 0 to 15 living in income deprived families*

†,fewer results available for this analysis due to incomplete data in HCW (healthcare worker) field (see Table 2)

††,Minority ethnic group includes all minority groups apart from white minorities·

‡Likelihood ratio for each risk factor calculated with overall p value displayed

Appendix 1 Questionnaire used in What's the STORY? (Serum Testing Of Representative Youngsters)

Participant Number: |__| |__| |__| |__|

Most of the questions below are taken from the UK census. They are included here to check how well the participants taking part in this study match those of the general population in your area. These data will be stored securely by your site and analysed anonymously in accordance with General Data Protection Regulation (GDPR).

Today's date: _ _ / _ __ _ / _ _ _ _

Q1. What is your child's date of birth? (month and year only)

Q2. What was their birth gender? male female

Q3. Which country was your child born in?

Q4. How many years has your child lived in the UK?

Q5. Which country were you (the Parent/Guardian) born in?

Q6. How many years have you (the Parent/Guardian) lived in the UK?

Q7. In which country/countries did your child (the participant) receive their vaccinations?

UK Other

Q8. Does your child attend a childcare setting? **(This question is for under 5 year olds only)**

Yes no

If Yes which setting? Nursery □ Childminder □ Nanny □ Other □ Please specify _____

If the answer is yes to Q8. please indicate how many hours a week?

1-4 hours	4-8 hours	8-12 hours
12-20 hours	21-30 hours	30 + hours

The following questions is for school aged children

Q9. Is your child enrolled in full time education?

Yes No

Q10. If yes to Q9, which setting are they being educated in?

Primary school
Middle school
Secondary school
College
Homeschooling
Other □ please specify

Q11. If in full time education please provide the name of the institution_____
or N/A □ (if N/A please move to question 14)

Q12. If enrolled at an institution, is it open? Yes no (if no please move to question 14)

Q13. If your child's institution is open are they attending? Yes no N/A

Q14. Who is your child's GP? _____

Q15. Name and address of surgery _____

Q16. Has your child had any symptoms such as those listed below since February 2020?

Fever

Dry Cough

Shortness of breath

Fatigue
Myalgia (muscle aches)
Nasal congestion
Loss of sense of taste
Loss of sense of smell
Runny nose
Sneezing

Sore throat
Abdominal pain or cramps (not including menstrual cramps)
Diarrhoea
Vomiting
Other Please specify_____
None of the above

Q17. If yes to any of the symptoms in question 16, when was the **start** of their most recent episode of symptoms? DD/MM/2020 N/A
Q18. Has your child ever been tested for COVID-19? (throat and/or nose swab specifically for COVID-19) Yes No
Q19. Has the result of your child's throat and/or nose swab for COVID-19 been positive? Yes No N/A
Q20. What was the date of the test? DD/MM/YYYY N/A
Q21. Has your child ever been tested for COVID-19 antibodies (blood test/saliva test)? Yes No
Q22. If yes to Q21, has the result of your child's antibody testing been positive?
Q23. Yes No N/A
Q24. What was the date of the antibody test? DD/MM/YYYY N/A

The following questions refer to any household contacts. A household contact is defined as a person who stays overnight in the same residence the participant.

Q25. Has anyone in your child's household(s) had a new loss of taste or smell since February 2020? Yes No
Q26. If yes to question 26, how many people in your child's household been affected? ……..
Q27. If yes to question 26 when was the ***start*** of their symptoms? DD/MM/2020
Q28. If yes to question 26, how old are they?
Q29. Has anyone in your child's household had any symptoms listed below since February 2020?
Fever
Dry cough
Shortness of breath
Muscle aches
Feeling tired
Loss of appetite
Abdominal pain or cramps (not including menstrual cramps)
Diarrhoea
Vomiting
Other Please specify_____
None of the above
Q30. If yes to question 28, how many people in your child's household been affected? ……..
Q31. If yes to any symptoms in question 28, when was the start of their most recent episode of symptoms? DD/MM/ YYYY If yes to any symptoms in question 28, how old are they?
Q32. If yes to any symptoms in question 28 have they ever been tested for COVID-19? (throat and/or nose swab specifically for COVID-19) Yes No
Q33. If yes to any symptoms in question 28 have they ever been diagnosed with laboratory confirmed throat and/or nose swab for COVID-19? Yes No
Q34. If yes to question 33, when was their positive test? DD/MM/ YYYY Has the individual in question ever been tested for COVID-19 antibodies (blood test/saliva test)? Yes No N/A
Q35. If yes to Q35, has the result of the individual's antibody testing been positive?
Q36. Yes No N/A
Q37. What was the date of the antibody test? DD/MM/ YYYY N/A
Q38. Has anyone in the household without symptoms been tested for COVID-19? (throat and/or nose swab specifically for COVID-19) Yes No
Q39. If yes to Q38 was it positive? Yes No

Q40. What was the date of the test? DD/MM/ YYYY N/A

Q41. Has anyone in the household without symptoms been tested for COVID-19 antibodies (blood test/saliva test)? Yes No N/A

Q42. If yes to Q40 was it positive? Yes No

Q43. What was the date of the antibody test? DD/MM/ YYYY N/A

Q44. Which of the following best describes **your child? (the participant)**

White

English/Welsh/Scottish/Northern Irish/ British

Irish

Gypsy or Irish Traveller

Other White background please specify ……

Mixed/ multiple ethnic groups

White and Black Caribbean

White and Black African

White and Asian

Any other mixed/ multiple ethnic background please specify

Asian/ Asian British

Indian

Pakistani

Bangladeshi

Chinese

Any other Asian background please specify

Black/ African/ Caribbean/Black British

African

Caribbean

Any other Black/ African/ Caribbean background please specify

Other ethnic group

Arab

Any other ethnic group please specify What is **your child's** (the participant) religion? (This question is optional)

No religion

Christian (including Church of England, Catholic, Protestant and all other Christian denominations)
Buddhist
Hindu
Jewish
Muslim
Sikh
Other please specify
Prefer not to say

Please complete questions 46 -59 for the main household in which your child lives?

Q45. How many adults (16+ years old)?

Q46. How many children (under the age of 16)?

Q47. How would you describe the main household?

A whole house or bungalow that is:
Detached
Semidetached
Terraced (including end-terrace)
A flat, maisonette or apartment that is:
In a purpose built block of flats or tenement
Part of a converted or shared house (including bedsits)
In a commercial building (for example, in an office building, hotel, or over a shop)
A mobile or temporary structure
A caravan or other mobile or temporary structure

Q48. Is this household's accommodation self-contained?

This means that all the rooms, including the kitchen, bathroom and toilet, are behind a door that only this household can use:

Yes, all the rooms are behind a door that only this household can use
No

Q49. How many rooms are available for use only by this household?

Do **NOT** count
Bathrooms
Toilets
Halls or landing
Rooms that can only be used for storage such as cupboards
Count all other rooms e.g.
Kitchens
Living rooms
Utility rooms
Bedrooms
Studies
Conservatories
If two rooms have been converted into one, count them as one room
Number of rooms ……

How many of these rooms are bedrooms?Include all rooms built or converted for use as bedrooms even if they are not currently used as bedrooms

Number of rooms……..

Q50. Which of the following best describes your child's household's current accommodation?

Own you own home outright
Own your home with a mortgage
Renting from the council
Renting from a housing association
Renting from a private landlord
In shared accommodation with a housing association
Living with relatives
In housing tied to your job
Lodging within another household
Other Please specify

Q51. Your employment – Parent or Guardian to answer (please select only one as your main form of employment)

Working full time

Working part time
Unemployed
Retired
In full time or further education
Claiming Job Seekers Allowance
Incapacity Benefit
Other

Q52. Does anyone in the household work in either social care or health care?
Yes
No

Thinking about your child's immediate family (parents and siblings in the same household) please can you tell us the following?

Q53. Does your family own a car, van or truck (include company cars or vans available for private use)?
None
One
Two
Three
Four or more

Q54. Does your child have their own bedroom to themselves?
No
Yes

Q55. How many computers does your family own? (including laptops and tablets, not including games consoles and smartphones)
None
One
Two
More than two

Q56. How many bathrooms (room with a bath/shower or both) are in your home?
None
One
Two
More than two

Q57. Does your family have a dishwasher at home?
No
Yes

Q58. How many times did you travel out of the UK for a holiday/vacation last year either alone or with friends/family (in the 12 months preceding lockdown for COVID-19)?
Not at all
Once
Twice
More than Twice

Table 10 STORY research team

Name	Research Group
K. Bell	Newcastle NHS Trust
C. Kennedy	Newcastle NHS Trust
A. Bell	Newcastle NHS Trust
C. L. Coates	Newcastle NHS Trust
S. Crulley	Newcastle NHS Trust
A. Davies	Newcastle NHS Trust

S. King	Newcastle NHS Trust
D.T.J. Metcalfe	Newcastle NHS Trust
C. Reigan	Newcastle NHS Trust
D.T.J. Fabian	Newcastle NHS Trust
R.A. Sarjeant	Newcastle NHS Trust
C. Smith	Newcastle NHS Trust
L.B. Baxter	Newcastle NHS Trust
E. Thompson	Newcastle NHS Trust
R. Wane	Bradford Children's Research Team
R. Swingler	Bradford Children's Research Team
C. Bass-Woodcock	Bradford Children's Research Team
L. Ingram	Bradford Children's Research Team
J. Pearce	St George's Vaccine Institute, St George's University Hospital NHS Trust/St George's University of London
C. Hultin	St George's Vaccine Institute, St George's University Hospital NHS Trust/St George's University of London
J.I. Pereira	St George's Vaccine Institute, St George's University Hospital NHS Trust/St George's University of London
H. Foife	St George's Vaccine Institute, St George's University Hospital NHS Trust/St George's University of London
P. Fox	St George's Vaccine Institute, St George's University Hospital NHS Trust/St George's University of London
E. Stefanova	St George's Vaccine Institute, St George's University Hospital NHS Trust/St George's University of London
F. Mabesa	St George's Vaccine Institute, St George's University Hospital NHS Trust/St George's University of London
S. Hawkins	Oxford Vaccine Group
V.H. Murphy	Oxford Vaccine Group
J. Muller	Oxford Vaccine Group
R. Cooper	Oxford Vaccine Group
R. White	Oxford Vaccine Group
S. Koleva	Oxford Vaccine Group
D.T.J. Kerr	Oxford Vaccine Group
R. Drake-Brockman	Oxford Vaccine Group
J. McEwan	Oxford Vaccine Group
H. Roberts	Oxford Vaccine Group
K. O'Brien	Oxford Vaccine Group
A. Yao	Oxford Vaccine Group
H. Trari Belhadef	Oxford Vaccine Group
H. Robinson	Oxford Vaccine Group
S. Roberts	Bristol Vaccine Centre (BVC)

E.B. Burch	Bristol Vaccine Centre (BVC)
S. Thomson-Hill	Bristol Vaccine Centre (BVC)
K. Jahans-Baynton	Bristol Vaccine Centre (BVC)
Z.B. Jordan	Bristol Vaccine Centre (BVC)
D. Ellis	Leeds Teaching Hospitals NHS Trust
R. Lidstone-Scott	Leeds Teaching Hospitals NHS Trust
E. Storr	Plymouth NHS trust
A. Carney	Plymouth NHS trust
S. Sharman	Plymouth NHS trust
N.J. Oldfield	University of Nottingham Health Service
S. Royal	University of Nottingham Health Service
S. Belton	University of Nottingham Health Service
D. Hammersley	University of Nottingham Health Service
J. Wilson	Royal Manchester Children's Hospital
N. Philips	Royal Manchester Children's Hospital
F. Jennings	Royal Manchester Children's Hospital
I. Mayor	Royal Manchester Children's Hospital
K. Wilkins	Royal Manchester Children's Hospital
S. Williams	Royal Manchester Children's Hospital
S. Akter	Royal Manchester Children's Hospital
E. Ashworth	Royal Manchester Children's Hospital
H. Dalgleish	Royal Manchester Children's Hospital
A. Wheeler	Royal Manchester Children's Hospital
S. Persand	Imperial College London
S.J. Burrell	Imperial College London
R. Harrison	Sheffield Children's Hospital NHS Trust
S.J. Hill	Sheffield Children's Hospital NHS Trust
S. Gormley	Sheffield Children's Hospital NHS Trust
R. Owens	University Hospital Southampton NHS Foundation Trust and University of Southampton.
P.S. Munro	University Hospital Southampton NHS Foundation Trust and University of Southampton.