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Factors associated with COVID-19 vaccine uptake in adolescents: a national cross-sectional study, August 2021–January 2022, England

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ABSTRACT

Objectives To assess socioeconomic and geographical factors associated with COVID-19 vaccine uptake in pupils attending state-funded secondary schools in England.

Design Cross-sectional observational study.

Setting State-funded schools in England.

Participants Pupils aged 12–17 years attending state-funded schools in England for the academic year 2021/2022.

Outcome measures Demographic, socioeconomic and geographical factors associated with vaccination uptake. We linked individual-level data from the English Schools Census to the National Immunisation Management System to obtain COVID-19 vaccination status of 3.2 million adolescents. We used multivariable logistic regression to assess demographic, socioeconomic and geographical factors associated with vaccination.

Results By 9 January 2022, 56.8% of adolescents aged 12–17 years old had received at least one dose, with uptake increasing from 48.7% in those aged 12 years old to 77.2% in those aged 17 years old. Among adolescents aged 12–15 years old, there were large variations in vaccine uptake by region and ethnic group. Pupils who spoke English as an additional language (38.2% vs 55.5%), with special educational needs (48.1% vs 53.5%), eligible for free school meals (35.9% vs 58.9%) and lived in more deprived areas (36.1% in most deprived vs 70.3% in least deprived) had lower vaccine uptake. Socioeconomic variables had greater impact on the odds of being vaccinated than geographical variables. School-level analysis found wide variation in vaccine uptake between schools even within the same region. Schools with higher proportions of pupils eligible for free school meals had lower vaccine uptake.

Conclusions We found large differences in vaccine uptake by geographical region and ethnicity. Socioeconomic variables had a greater impact on the odds of being vaccinated than geographical variables. Further research is required to identify evidence-based interventions to improve vaccine uptake in adolescents.

STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ Large cohort size representing over 3.2 million pupils aged 12–17 years attending state-funded schools in England.
⇒ The dataset contains a rich source of background characteristics which allow analysis of COVID-19 vaccine uptake by sociodemographic characteristics and examine the extent to which these differences are driven by other factors.
⇒ The COVID-19 vaccination programme was ongoing during the analysis period, so some adolescents be vaccinated after January 2022.
⇒ Not all adolescents were captured in English Schools Census or due to data linkage issues or changing schools between the academic year.

INTRODUCTION

COVID-19 vaccines have been critical in the control of the current pandemic and have significantly reduced morbidity and mortality caused by SARS-CoV-2.[1] The greatest risk factors for COVID-19 are old age and underlying comorbidity. Compared with adults, children have a very low risk of severe COVID-19,[2] and, therefore, have received lower priority in the rollout of COVID-19 vaccine programmes globally.[3] In England, COVID-19 vaccination began in December 2020, with the BNT162b2 mRNA vaccine (Pfizer-BioNTech) and the Oxford-AstraZeneca adenovirus vector vaccine offered to older adults, immunosuppressed people, those with high-risk comorbidities and health and social care workers. The last adult cohort recommended for vaccination were those aged 18–24 years old in June 2021. Unlike other countries, the UK recommended an extended interval of 12 weeks between the two COVID-19 doses to expedite the rollout of the first dose,[4 5] because the first dose was shown in pre-licensure clinical trials to provide very high levels of protection within 2 weeks.[6]

In adolescents, the UK Joint Committee on Vaccination and Immunisation (JCVI)

recommended COVID-19 vaccination for children aged ≥12 years with severe neurodisabilities as early as January 2021 because of their high risk of severe COVID-19, even though the vaccines were not authorised for those 12–15 years old at the time.[7]

With the emergence of rare cases of myocarditis associated with mRNA vaccines, mainly after the second dose in adolescent and young adult males, the JCVI took a more cautious approach with COVID-19 vaccination in adolescents, initially recommending one dose for those 16–17 years old from 23 August 2021 because of the very low risk of severe COVID-19 in the context of the uncertain risk, severity or outcomes of vaccine-induced myocarditis.[8] For healthy adolescents 12–15 years old, the JCVI recommended against vaccination on 3 September 2021, but this decision was overturned by government ministers on 22 September 2021, on the basis that the vaccines would reduce educational disruption by preventing SARS-CoV-2 infection and transmission in educational settings.[9] In England, COVID-19 vaccination for adolescents 12–15 years old was delivered primarily through educational settings, and later extended to national vaccination centres.[10]

In England, COVID-19 vaccine uptake was highest in older adults and declined with younger age, with the lowest uptake among adolescents,[11] despite early surveys reporting high acceptability of COVID-19 vaccines among parents. The School Infection Survey in a sample of schools conducted during April–May 2021, for example, found that 88% of parents of recruited secondary school students would definitely (53%) or probably (35%) vaccinate their child against COVID-19.[12]

Vaccination is part of a multitude of factors employed by the government to manage the COVID-19 pandemic. Vaccines play an important role in preventative and protective measures to reduce the risk of infection, transmission and severity of disease.[13] Analysing COVID-19 vaccination uptake in the population provides an opportunity to identify vulnerable populations, and develop targeted campaigns where appropriate, to help reduce health inequalities. The factors associated with vaccine uptake in adolescents have not been widely explored, compared with the adult population.[14–16] This national study aimed to investigate demographic, socioeconomic and regional factors associated with COVID-19 vaccine uptake in adolescents.

METHODS AND ANALYSIS

We assessed factors associated with vaccine uptake in over 3.2 million adolescents 12–17 years old attending state-funded secondary schools in England.

English Schools Census

The English Schools Census (ESC) is a mandatory annual return to the Department for Education by state-funded schools and local authorities. All pupils attending state-funded primary schools, secondary schools (including sixth forms attached to schools), nurseries and special schools in England are recorded. This is over 3.2 million adolescents aged 12–17 years old, comprising 92% of those 12–15 years old and 65% of those 16–17 years old in England (age as of 31 August 2021). The data available for analysis do not cover all pupils aged 12–17 years in England. Pupils will be missing for the following reasons:

- They attended an independent school or were not enrolled in a school on 21 January 2021.
- They moved into England after the ESC date (conversely pupils in state schools on the ESC date who have since left England and are still registered with a general practitioner will be included).
- Coverage will be lower among those who have finished year 11 (16–17 years old as of 31 August 2021); those studying in years 12/13 in sixth forms attached to schools will be included but those studying in further education colleges or sixth form colleges will not be included.
- They have never registered with a doctor or accessed National Health Service (NHS) services or their personal details are not recorded consistently and will not be linked to National Immunisation Management System (NIMS) and, therefore, not included.

The ESC covers pupil and school characteristics for a set date (21 January 2021 for this analysis). Individual characteristics extracted for this analysis include age, symptoms, ethnicity, Income Deprivation Affecting Children Index (IDACI), region, eligible for free school meals (FSM) if they accessed FSM within the previous 6 years, English as an additional language (EAL), from an urban/rural area, special education needs (SEN) support and sex. School-level characteristics included region and FSM. We used the 2019 IDACI, which calculates deprivation deciles based on the proportion of children aged 0–15 years living in deprived income households (not working or working on low incomes eligible for means-tested benefits). The index ranks the 32 844 small administrative areas from the 2011 census in England from most deprived to least deprived and divides them into 10 equal groups.[17] Adolescents with SEN were identified in the ESC. Pupils attending SEN schools are included in all analyses except the school-level analysis, which focuses on secondary schools.

National Immunisation Management System

The NIMS records England's coronavirus (COVID-19) vaccination programme.[18] The extract used contains data for COVID-19 vaccinations administered across all settings up to 9 January 2022.

Data linkage

Pupils with ESC records were linked to their unique NHS number held on the personal demographic service (PDS) using their name, date of birth, sex and postcode,[19] and then to their vaccination records in NIMS. Pupils who did not link to PDS (2%) were excluded from the analysis.

Logistic regression

We used multivariable logistic regression to estimate the ORs of receiving at least one COVID-19 vaccine dose associated with each demographic, socioeconomic and geographical factor. Analysis was restricted to those 12–15 years old because they were a more homogeneous group for analysis as they all attended secondary schools, had more complete data in ESC (for reasons already described above), were all offered the vaccine at around the same time and had the lowest uptake compared with older adolescents and adults. For non-ordered categorical variables, the baseline category was chosen as the largest (for example, for ethnicity, white British was the baseline as the largest group). The following factors were entered separately into an age and sex-adjusted model, to assess their association with vaccine uptake: ethnicity, SEN, EAL, FSM eligibility, IDACI, region and urban/rural residence. A 'fully adjusted' model was then fitted by including all factors simultaneously in the model.

School-level analysis

School-level uptake was calculated as the percentage of adolescents aged 12–15 years old who were vaccinated, and the univariable association with school-level characteristics was explored using box plots. The IQR was calculated to create box plots for percentage of pupils vaccinated by region.

Patient and public involvement

There was no patient or public involvement in the design of this study.

RESULTS

Nationally, 98% of pupils aged 12–17 years on the ESC were linked to their unique NHS number and 99% of these were subsequently linked to their vaccination record on NIMS. COVID-19 vaccine uptake among those aged 12–17 years old in England increased rapidly at the start of the programme in October 2021 and then started to plateau at the end of December 2021 (online supplemental file 1). Vaccine uptake increased with age (table 1) from 48.7% in those 12 years old to 77.2% in those 17 years old on 9 January 2022. Vaccine uptake for both the first and second doses among adolescents aged 16–17 years old was higher than among those 12–15 years old; the former group was offered the vaccine earlier than the latter.

Vaccine uptake by pupil characteristics for pupils 12–15 years old

There was little difference in crude COVID-19 vaccination rates between males (52.4%, 658 703 of 1 256 147) and females (52.8%, 632 858 of 1 199 374) (table 2), but large crude differences by ethnicity, with a 63% difference between the most and least vaccinated ethnic groups. Chinese (75.5%, 7237 of 9586) and Indian (65.7%, 49 420 of 75 189) pupils were most likely to have been vaccinated, while Gypsy or Roma and black Caribbean (both 12.4%, 840 of 6792 and 3383 of 27 210) pupils were least likely to have been vaccinated (table 3 and figure 1A).

Table 1 Number and proportion of pupils aged 12–17 years to have received a COVID-19 vaccine by age and number of doses up to 9 January 2022, England

Age (years)	Number of pupils to have received at least one dose of COVID-19 vaccine	Total population	Vaccination uptake: at least 1 dose (%)
12	305 672	627 968	48.7
13	324 479	631 937	51.4
14	328 783	607 958	54.1
15	331 200	587 658	56.4
16	383 099	574 748	66.7
17	177 054	229 455	77.2
Total	1 850 287	3 259 724	56.8

Differing population sizes mean some ethnic groups with higher vaccination uptake may still have higher absolute numbers of unvaccinated pupils than those with lower vaccination uptake. For example, despite a vaccine uptake of 59.1%, more than 650 000 of 1 625 000 unvaccinated pupils aged 12–15 years old were white British, meaning 57% of all unvaccinated pupils are white British; and the numbers of unvaccinated in Indian pupils were similar to black Caribbean pupils.

Pupils recorded as speaking EAL were less likely to have been vaccinated (38.2%, 153 096 of 401 036) than those reporting English as their first language (55.5%, 1 132 706 of 2 039 965). SEN pupils were also less likely to have been vaccinated (48.1%, 197 728 of 411 489) than those without SEN (53.5%, 1 093 833 of 2 044 032). Pupils aged 12–15 years living in more deprived areas were less likely to be vaccinated; 36.1% of pupils in IDACI decile 1 (most deprived) had been vaccinated compared with 70.3% in IDACI decile 10 (least deprived) (table 2, figure 1B and online supplemental file 2). In the baseline regression, IDACI was the main factor with the widest variation affecting vaccine uptake. Similarly, pupils eligible for FSM had lower vaccine uptake (35.9%, 241 379 of 672 592) than those not eligible for FSM (58.9%, 1 050 176 of 1 782 921) (table 2).

Regional vaccine uptake

There was variation in vaccine uptake by regions (table 3 and figure 1C), with South East England having the highest uptake (60.7%, 237 348 of 391 264) among those 12–15 years old and London having the lowest uptake (40.8%, 146 935 of 359 777). Pupils living in rural areas had higher vaccine uptake (62.6%, 185 110 of 295 781) than those in urban areas (51.2%, 1 105 367 of 2 157 901).

School-level analysis

SEN schools were excluded from the school-level analysis, as they tend to be small which can mean that small differences in the number of pupils vaccinated can have a large impact on

Table 2 Number and proportion of pupils aged 12–15 years to have received a COVID-19 vaccine up to January 2022 by sex, English as an additional language status, special educational needs status, free school meal status and IDACI decile

	Number of pupils to have received at least one dose of COVID-19 vaccine up to 9 January 2022	Total population	Vaccination uptake: at least 1 dose (%)
Sex			
Male	658 703	1 256 147	52.4
Female	632 858	1 199 374	52.8
English as an additional language			
Speaks English as their first language	1 132 706	2 039 965	55.5
Speaks English as an additional language	153 096	401 036	38.2
Special educational needs			
Has accessed to special educational needs support	197 728	411 489	48.1
Has not accessed to special educational needs support	1 093 833	2 044 032	53.5
Free school meals			
Has accessed to free school meals in the past 6 years	241 379	672 592	35.9
Has not accessed to free school meals in the past 6 years	1 050 176	1 782 921	58.9
IDACI			
1 (most deprived area)	114 333	316 493	36.1
2	116 047	295 562	39.3
3	118 347	268 685	44.0
4	125 378	255 520	49.1
5	127 933	239 527	53.4
6	131 279	227 691	57.7
7	134 538	219 847	61.2
8	137 772	214 502	64.2
9	141 576	210 856	67.1
10 (least deprived area)	143 438	203 966	70.3

IDACI, Income Deprivation Affecting Children Index.

the reported percentages. Schools in the South East had the greatest median vaccine uptake, with 60.7% of its pupils vaccinated against COVID-19, compared with a median of 40.8% in London (table 3). Even within the same region, however, vaccination rates varied greatly between schools, and to a greater extent than between regions, with the greatest variation observed in the West Midlands region, where 90% of schools had between 22.3% and 73.2% of vaccinated pupils (figure 1C).

Schools with higher proportions of pupils eligible for FSM had lower vaccine uptake rates, with schools reporting <5% of pupils accessing FSM having the largest median vaccination rate (73.2%). By comparison, the median was 29.2% for schools with more than 50% of pupils accessing FSM (figure 1D).

Multivariable regression

After controlling for demographic and socioeconomic characteristics in the 'fully adjusted' multivariable logistic regression model on pupil-level data, variations between regions remained. Pupils in the North West had a lower likelihood of being vaccinated than pupils in London, whereas in the baseline model for region, pupils in London had the lowest likelihood of vaccination. The relative odds of vaccination were lower for most minority ethnic groups compared with white British pupils. Additionally, socioeconomic variables, such as EAL and FSM status, had larger ORs than the geographical variables (region and urban/rural status). These socioeconomic factors accounted for almost all the differences in the lower vaccine uptake among Bangladeshi pupils compared with white British pupils, demonstrated with similar likelihood of vaccination in the fully adjusted compared with univariate model (figure 2). Among black students, and particularly black Caribbean students, demographic and socioeconomic factors were also important but even after controlling for these differences, large differences in vaccine uptake remained compared with rates in white British pupils (figure 2).

DISCUSSION

In England, 52.5% of pupils 12–15 years old and 69.7% of those 16–17 years old had received at least one vaccine

Table 3 Number and proportion of pupils aged 12–17 years to have received a COVID-19 vaccine by ethnicity, region and area type up to 9 January 2022

	Number of pupils to have received at least one dose of COVID-19 vaccine	Total population	Vaccination uptake: at least 1 dose (%)
Ethnicity			
Chinese	7237	9586	75.5
Indian	49 420	75 189	65.7
White British	961 132	1 625 148	59.1
White Irish	3896	6670	58.4
Asian other	25 375	44 549	57.0
Mixed white Asian	19 832	35 423	56.0
Bangladeshi	19 328	42 240	45.8
Mixed other	23 008	53 350	43.1
Refused	9145	21 773	42.0
Not obtained	11 140	27 231	40.9
Mixed white black African	8465	21 033	40.2
Other	18 807	46 771	40.2
Pakistani	37 060	108 045	34.3
White other	50 784	150 535	33.7
Mixed white black Caribbean	11 797	38 785	30.4
Black African	25 936	95 858	27.1
Black other	4687	18 181	25.8
Traveller Irish	289	1152	25.1
Black Caribbean	3383	27 210	12.4
Gypsy/Roma	840	6792	12.4
Region			
South East	237 348	391 264	60.7
South West	134 107	229 387	58.5
East of England	159 523	278 683	57.2
East Midlands	117 701	214 510	54.9
North East	62 750	115 323	54.4
Yorkshire and the Humber	129 486	250 010	51.8
West Midlands	138 194	277 442	49.8
North West	165 517	339 125	48.8
London	146 935	359 777	40.8
Area type			
Rural	185 110	295 781	62.6
Urban	1 105 367	2 157 901	51.2

dose by 9 January 2022, while 5.8% and 46.0%, respectively, had received two doses. Vaccine uptake increased with age, but did not vary by sex, and was higher among pupils 16–17 years old than those 12–15 years old, consistent with the earlier implementation of the immunisation programme in the former cohort. Vaccine uptake was highly variable by region and was higher in rural than urban areas. There were large variations in vaccine uptake by ethnicity with up to 63% difference between the most and least vaccinated ethnic groups. Among pupils aged 12–15 years old, Chinese (75.5%) and Indian (65.7%) pupils were most likely to have been vaccinated, while Gypsy or Roma and black Caribbean (both 12.4%) pupils were least likely to have been vaccinated. Vaccine uptake was lower in pupils reporting EAL, attending SEN schools, living in more deprived areas and being eligible for FSM. In a multivariable logistic regression model, socioeconomic variables had a greater relative association with being vaccinated than geographical variables (region and urban/rural status); but the difference in uptake between ethnic groups persists after adjusting for socioeconomic and regional differences (online supplemental file 2). School-level analysis found that vaccine uptake varied greatly between schools even within the same regions and was inversely correlated with the proportions of pupils eligible for FSM.

We analysed factors associated with the low vaccine uptake in adolescents to provide policymakers with a better understanding of those who were least likely to engage with the vaccine rollout.[20] When compared with other UK regions, COVID-19 vaccine uptake among adolescents in England was higher than in Wales and Northern Ireland at the time, but lower than in Scotland.[21]

In the UK, the Medicines and Healthcare products Regulatory Agency approved the Pfizer-BioNTech vaccine for those 12–15 years old in June 2022,[22] and the Moderna vaccine for those 12–17 years old in August 2021.[23] Compared with other countries, however, COVID-19 vaccination for adolescents was recommended later in the UK, which may explain the lower vaccine uptake.

In Europe, the European Medicines Agency approved the use of the Pfizer-BioNTech vaccine for adolescents 12–15 years old in May 2021 and the Moderna vaccine for those 12–17 years old in July 2021. Across Europe, in early February 2022, the median uptake of the two-dose primary vaccination course among adolescents 15–17 years old was 70.9% in 17 reported countries, and 35.5% in those 10–14 years old in 16 reported countries, but with wide variability between countries. Some countries such as Denmark, Italy, Ireland, France, Portugal and Spain have achieved very high vaccine uptake among adolescents, while in other countries such as Austria and Sweden, vaccine uptake remained below 50% and others, particularly in eastern Europe, have reported very low vaccine uptake in this age group.[21]

By the time vaccination was implemented for UK adolescents, many had already been infected by SARS-CoV-2, especially in England where more than half of

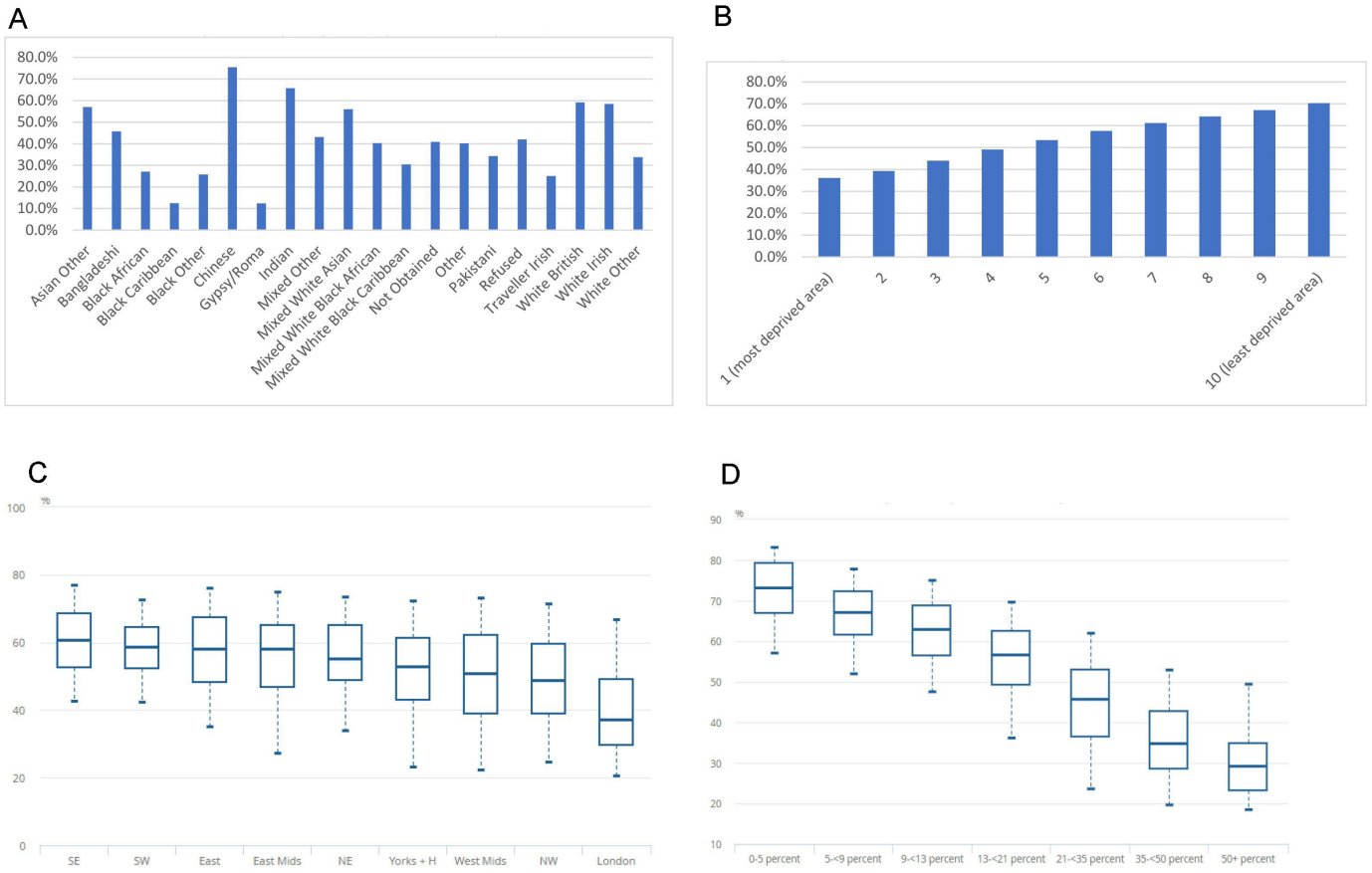

Figure 1 (A) Percentage of pupils aged 12–15 years in state-funded schools who have been vaccinated by ethnicity, England, up to 9 January 2022. (B) Proportion of pupils aged 12–15 years to have received a COVID-19 vaccine by Income Deprivation Affecting Children Index decile up to 9 January 2022, England. (C) Percentage of pupils aged 12–15 years in state-funded secondary schools who have been vaccinated by region, England, up to 9 January 2022. (D) Percentage of pupils in state-funded secondary schools who have been vaccinated against coronavirus grouped by the percentage of pupils accessing free school meals, England, up to 9 January 2022. East Mids, East Midlands; NE, North East; NW, North West; SE, South East; SW, South West; West Mids, West Midlands; Yorks + H, Yorkshire and the Humber.

adolescents 12–15 years old were seropositive for SARS-CoV-2 antibodies by September 2021.[24] This could have led parents to reconsider the need for vaccinating their children. Additionally, the emergence of the Omicron variant in November 2021[25] was associated with a large surge in cases across all age groups. The UK currently recommends waiting 12 weeks after infection before vaccinating against COVID-19,[26] which likely led to delays in both the first and second doses of vaccine in adolescents. Furthermore, the high infection rates with the Omicron variant in adults despite very high vaccination coverage including boosters could have led parents to question the value of vaccinating their children, given their low risk of severe COVID-19, especially if their child had been exposed to the virus.

There are other potential reasons for COVID-19 vaccine uptake among adolescents. Parental perception of their personal risks to COVID-19 is likely to influence their decision to vaccinate themselves and their children.[27] Not surprisingly, parental vaccination status is strongly associated with the adolescents' attitudes towards vaccination.[27–30] At the same time, concerns about a small but potentially severe risk of vaccine-induced myocarditis could have further contributed to lower vaccine uptake among adolescents and young adults, especially in countries such as the UK where there was strong messaging of children being at low risk of severe disease, a critical factor in opening schools first and closing them last throughout the pandemic.[31] Surveys in England have found that parents who were unwilling to vaccinate their children were particularly concerned about vaccine safety, the short-term side-effects of the vaccine and unknown long-term side-effects of vaccination,[12] similar to surveys in other countries.[27 29 32] Additionally, the contradictory decision between the UK JCVI and the government ministers may have created uncertainty among parents and adolescents with regard to vaccination. In the USA, lack of trust in the government and vaccines, along with the belief that the COVID-19 vaccine is not needed or effective, have been cited as reasons by parents who chose not to vaccinate their children.[33]

In our analysis, we identified socioeconomic variables and, to a lesser extent, geographical variables to be important determinants of COVID-19 vaccine uptake among adolescents. This is similar to the experience of other countries,[29 34] and consistent with other childhood

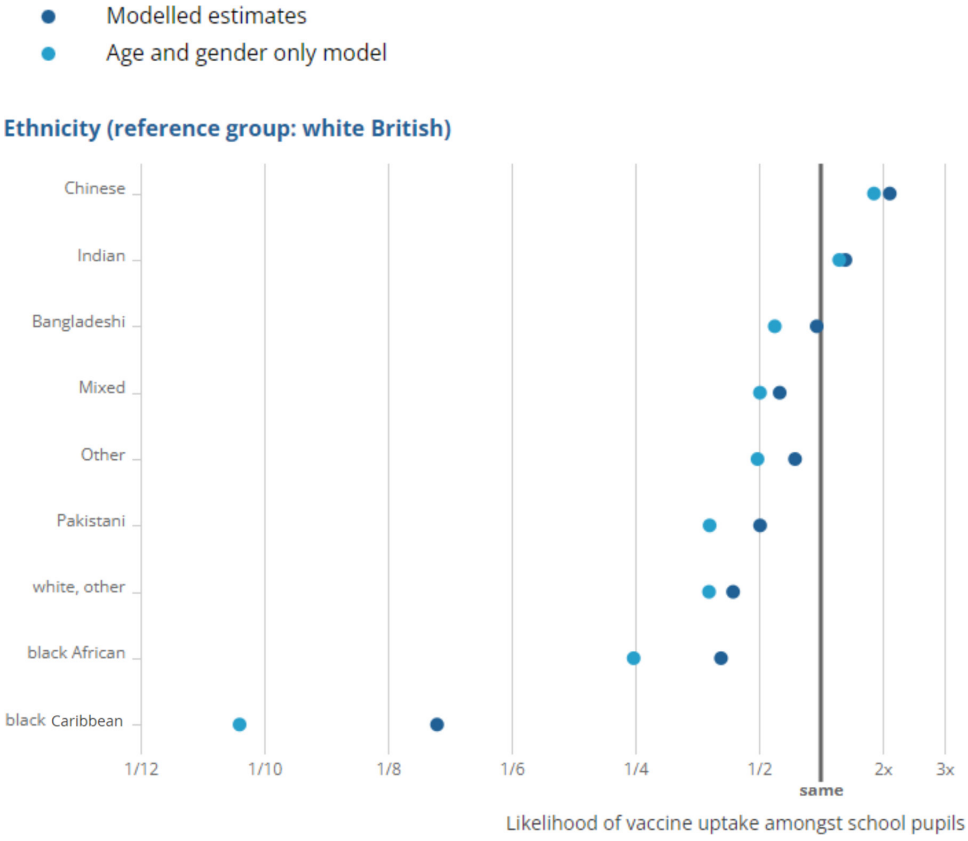

Figure 2 Modelled estimates of the OR of pupils being vaccinated by ethnicity, as of 9 January 2022 in England. The baseline model contains ethnicity, age and sex (light blue dots). The fully adjusted model contains, ethnicity, age, sex and, in addition, English as an additional language, special educational needs, free school meals, Income Deprivation Affecting Children Index, region and urban/rural (dark blue dots).

vaccinations.[35] Notably, too, parents of children who were underimmunised pre-pandemic may have been less likely to vaccinate their child against COVID-19.[29] A Canadian survey also found that parents of younger children were less inclined to have their child vaccinated.[34] Using multivariable regression analysis, we found that when compared with baseline models, socioeconomic factors could explain nearly all variance in lower uptake among some ethnic groups such as Bangladeshi adolescents but not entirely among other ethnic groups such as black Caribbean adolescents, where other factors including, for instance, perceived or actual poorer experiences of healthcare services, as well as accessibility and availability of vaccination centres, are likely to contribute to lower vaccine uptake. While there has been some research into nationality-specific factors associated with vaccine uptake,[36] further studies are needed to better understand these differences and identify effective interventions to overcome any barriers identified within specific groups.[16 37]

Implications of findings

While a vaccine uptake of 60% in adolescents aged 12–15 years old may be considered low in the context of a global pandemic, such an uptake would not be out of place when compared with routine adolescent immunisation programmes. Adolescents and young adults have always been a challenging group to vaccinate. This is often due to perceived good health and low risk of severe illness, lack of disease awareness or concerns about vaccine side-effects.[38–40] With the emergency implementation of an adolescent meningococcal ACWY conjugate vaccine programme in 2015 to control a national outbreak of group W meningococcal disease, for example, vaccine uptake among those 18 years old was only 36.6% although delivered through primary care.[41] Vaccine uptake was, however, significantly higher at 77.2% when the programme was delivered through schools,[42] which is why England opted for school delivery for COVID-19 vaccines for adolescents. Such a delivery programme also has the advantage of overcoming the social inequalities of access to vaccination, although this was still evidenced in our cohort, highlighting the need for increased efforts to reach disadvantaged and marginalised populations with tailored strategies and trusted sources of information to promote informed decision-making and facilitate access to vaccination.[34 43]

Strengths and limitations

A major strength of this analysis is the size of the cohort. The ESC contains pupil-level data collected from all state-funded schools in England, representing over 3.2 million pupils aged 12–17 years. The dataset contains a rich source of background characteristics which allow analysis

of COVID-19 vaccine uptake by sociodemographic characteristics and examine the extent to which these differences are driven by other factors.

There are, however, some limitations. Not all adolescents will be captured in ESC as explained in the Methods section. Additionally, the latest ESC data available relate to the previous academic year, so some pupils may not be attending the same school in the current academic year. Therefore, school-level analysis relates to pupils 11–14 years old at the start of the previous academic year (those now aged 12–15 years, equivalent to academic years 8–11) as the majority of these pupils will still be in the same school. Additionally, it was not possible to link a small minority of adolescents (2%) to PDS to obtain their unique NHS number and subsequently link to the NIMS database for their COVID-19 vaccination status. Additionally, the vaccination programme was ongoing during the time of this analysis, and data since January 2022 have not been presented here, so we cannot exclude some catch up in groups with a lower uptake that may have occurred since then.

Furthermore, this was a national cohort study of pupils in England, so the results may not be applicable to other countries with differing vaccine programmes and demographics.

Conclusion and policy recommendation

This national data study examines sociodemographic and geographical factors associated with vaccine uptake in adolescents in England. We found large differences in vaccine uptake between ethnic groups, with those of Chinese and Indian ethnicity having the highest vaccine rates, compared with Gypsy or Roma and black Caribbean pupils. Importantly, socioeconomic variables had a greater impact on the odds of being vaccinated than geographical variables. Further research is required to identify evidence-based interventions to improve vaccine uptake in adolescents, especially in under-represented demographics. The UK Government has committed to reducing health inequalities, as outlined in the National Healthcare Inequalities Improvement Programme.[44] Vaccine policy aimed at improving vaccine uptake in low-uptake regions and populations, namely those living in urban and deprived areas, and those of black African and Caribbean and Gypsy/Roma ethnicity, would benefit from targeted vaccination programmes.

Collaborators SIS Study Group includes (1) sKIDs investigators: Shazaad Ahmad, Frances Baawuah, Joanne Beckmann, Andrew Brent, Bernadette Brent, Kevin E Brown, Joanna Garstang, Ifeanyichukwu O Okike, Mary E Ramsay; (2) ONS: James McCrae, Joe Kelly, Dylan Stocker, Ian Diamond, Emma Rourke, Fiona Dawe, Pete Jones; (3) LSHTM: Sarah Cook, Elliot McClenahan, Gillian McKay, Jody Phelan, Liang-Yu Lin, Charlotte Warren-Gash. Alex Lewin.

Contributors The SIS Study Group members (SNL, PM, PN-D, AJ) conceived the work. AJ, BD and AS acquired the data and performed the analysis, with input from PM, PN-D and SNL and together with the SIS Study Group members provided initial findings for ONS bulletins. FA and SNL wrote the first draft of the manuscript. GI, AP, CNJC, PM, PN-D and the SIS Study Group made substantial contributions to the drafting of the work for important intellectual content. SNL is guarantor of this study. All authors have read and approved the final version of the manuscript.

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Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not required.

Ethics approval The ONS had access to individual-level data under S45a of the Statistics and Registration Services Act (2007) as amended by the Digital Economy Act (2017). UKHSA 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 to access records.

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