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The influence of school and area level factors on HPV and MenACWY vaccine coverage in England in 2016/17

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ABSTRACT

Background

There are currently three adolescent school-based programmes in the UK which protect against human papilloma virus (HPV vaccine, females only), meningococcal A, C, W and Y (MenACWY vaccine), and diphtheria, tetanus and polio (Td/IPV vaccine). We described school and area-level factors that influence vaccine coverage.

Methods

School-level vaccine coverage data was voluntarily submitted to Public Health England by Screening and Immunisation Teams in England at the end of the 2016/17 academic year. Data were analysed for school year 9 (13-14 year olds) for HPV (females only, two-dose coverage) and MenACWY (all adolescents, one-dose coverage). School level factors included school religious affiliation, school type, urban/rural, sex and region. A sub-analysis of mixed-sex state-funded secondary schools also included area-level factors such as deprivation. The analyses were weighted by school size.

Results

Data were received from 1,407 schools for HPV and 1,432 for MenACWY. In the adjusted analysis, Muslim and Jewish schools had lower coverage than schools of no religious character for HPV (24.0% and 20.5% lower respectively) but not for MenACWY. Independent, special schools and pupil referral units (smallest school type) had increasingly lower vaccine coverage than state-funded secondary schools (largest school type) for both HPV and MenACWY. In the sub-analysis schools located in least deprived areas had the highest coverage for both vaccines.

Discussion

Tailored approaches are required to improve HPV vaccine coverage in Muslim and Jewish schools. In addition better ways of reaching pupils in smaller specialist schools are needed.

Strengths and limitations of this study

- This study is the first school-level analysis of factors influencing the coverage of school-delivered vaccines in England
- The data set includes a large number of schools across the country and the school level variables collected allow to determine associations between vaccine coverage and previously unstudied factors such as school type or faith affiliation
- The voluntary nature of the school-level data return means the dataset is not complete
- For some types of schools, the dataset only includes a small number of schools, limiting the precision of some of the results
- The analysis of socio economic factors was restricted to mixed-sex state-funded secondary schools only, based on the assumption that they were more likely to represent pupils from their immediate geographical area

INTRODUCTION

Offering vaccination at school enables large numbers of children to be vaccinated without requiring individual appointments. School vaccination achieves higher coverage than primary care for adolescent vaccines(1,2). There are four school-based vaccination programmes in the UK which protect against human papilloma virus (HPV vaccine, females only), meningococcal A, C, W and Y (MenACWY vaccine), diphtheria, tetanus and polio (Td/IPV vaccine), and seasonal influenza(3).

HPV vaccine was introduced for females only in the UK in 2008, initially as a three-dose schedule offered in Year 8 (children aged 12-13 years). In September 2014 this changed to a two-dose schedule(4). The recommendation, for operational ease, is for the first (priming) dose to be offered in Year 8 and the second (completing) dose in Year 9 (age 13-14 years) but NHS England (the agency responsible for commissioning the services) can choose to offer both doses in Year 8. In 2015/16, 85/152 (56%) LAs offered both doses within Year 8(5). HPV vaccine coverage in Year 9 is the final year of assessment for both delivery models.

MenACWY vaccine was introduced in August 2015 in response to the rising number of meningococcal W (MenW) cases(6). From autumn 2013 adolescent MenC booster had been offered in school years Year 9 or 10 (age 14-15 years) but increasingly LAs were aligning to all offer MenC vaccine in Year 9(7). In 2016/17 82% (124/152) of LAs offered MenACWY routinely in Year 9 through the schools based programme(8). The Td/IPV ('school leaver booster') vaccine is usually offered alongside MenACWY vaccine.

An previous analysis of vaccine coverage data for the school-based seasonal influenza programme in England using population-level characteristics at the Lower Super Output Area level (LSOA, small areas with an average of approximately 1,500 residents or 650 households(9)) in which the school was located identified deprivation, non-white ethnicity, religious beliefs and urban areas to be associated with lower coverage(10-12). 2016/17 is the first year that school-level data have been available nationally for the adolescent vaccination programmes, enabling us to explore specific school-level factors that might affect vaccine coverage.

METHODS

In September 2017, the 14 Screening and Immunisation Teams (SITs) in England were asked to voluntarily submit school-level vaccine coverage data for 2016/17 for all schools in their area using a standardised MS Excel data collection tool. Reminders to submit school-level data were sent out as each submission of LA-level data was received and validated.

School level data for the 2016/17 academic year includes vaccines given up to and including 31 August 2017. For HPV some will have been scheduled the previous academic year (2015/16))

Queries on data were sent back to providers if:

- Denominators or numerators were missing for particular schools. For the small number of schools where denominators were unavailable from the provider, nationally published school roll data were used instead(13).

- A numerator was greater than a denominator (coverage >100%).
- Coverage was 100% for schools with >20 pupils in the denominator.
- All schools in an LA were queried if substantial changes were made to any individual schools queried above, and/or if total numerators, denominators or coverage differed by more than 5% from published statistics for LA coverage(8,14).

MenACWY and Td/IPV are generally co-administered so only MenACWY data were used and the findings relating to MenACWY should be generalisable to Td/IPV.

Data were analysed for school year 9 pupils (13-14 year olds), born 1 September 2002 to 31 August 2003. Vaccine coverage of a completed course was calculated by dividing the number of year 9 females receiving two doses of HPV vaccine and the number of year 9 pupils receiving one dose of MenACWY vaccine by the total number of females and adolescents respectively in the school year.

School characteristics (table 1) were obtained from the Department for Education 2017 school census and were linked to vaccine coverage using each school' unique reference number. The LSOA-level geographical factors (Table 1) based on the location of each school were assigned to mixed-sex state-funded secondary schools only, as these schools were considered most likely to represent pupils from their immediate geographical area. All schools were assigned an NHS commissioning region (South of England, London, Midlands and East of England, North of England) based on their geographical location.

Table 1.School and geographical characteristics included in the analysis		
Type of characteristics	**Categories**	**notes**
Denomination*	No religious character	
	Church of England/Other Christian faith excluding Roman Catholic	includes Anglican, Free Church, Methodist, Other Anglican Faith, Other Christian Faith, Plymouth Brethren Christian Church
	Roman Catholic	
	Islam/Muslim	
	Other	includes Hindu, Sikh and other
School type*	State-funded secondary	
	Independent	
	Special school	combines state-funded and non-maintained, schools for children with special educational needs
	Pupil referral unit	schools for children excluded from mainstream education because of behaviour, sickness, or other reasons
Urban/rural*	Urban	
	Rural	
Sex*	Mixed	
	Female	
	Male	
% of population classifying themselves as black or minority ethnic (BME)**	<5%,	Includes any ethnic group other than 'White: English/Welsh/Scottish/Northern Irish/British, based on 2011 census categories (15). The thresholds are aligned with those used for influenza vaccine coverage school-level analyses in England (10,16).
	>=5% and <12%	
	>=12% and <34%	
	>=34%	
Index of multiple deprivation 2015**	quintiles	1 represents the most deprived, 5 the least deprived. Quintiles were obtained by combining published deciles which rank the 32,844 LSOAs in England from most deprived to least deprived and dividing them into ten equal groups (17).
*School characteristic ** LSOA characteristic		

Statistical analyses

To take account of school variability and size, individual coverage was calculated for each school, and the analysis was weighted by the denominator of each school.

Unadjusted and adjusted linear regression models including all school-level factors and region were used to explore differences in coverage from the baseline for each factor. In addition to school-level

factors, the association between ethnicity and deprivation LSOA level factors (proportion of BME in school LSOA, deprivation) and vaccine coverage were explored for mixed-sex state-funded secondary schools, using the same models.

This analysis was undertaken using aggregated data as part of routine monitoring of the vaccination programme. No specific funding was sought and no formal ethical approval was required. The school level dataset (anonymised to prevent school-level disclosure) can be requested by emailing the corresponding author .

Analyses were undertaken in STATA SE/V.13.1 statistical software.

Patient and Public Involvement

This study used routinely collected aggregated data and patients were not involved.

RESULTS

Representativeness of dataset

HPV vaccine coverage school-level data for Year 9 was received from 41 LAs. One LA was excluded because their programme was run in primary care during 2015/16. The final HPV analysis therefore included 40/152 (26.3%) LAs (Figure 1a) and 1,407 schools.

MenACWY vaccine coverage school level data for Year 9 was received from 50 LAs. Two were excluded: one ran a selective (males only) vaccination programme and the other delivered their programme through primary care. In total, 48/152 (31.6%) LAs (Figure 1b) representing 1,432 schools were included in the MenACWY analysis.

The overall school-level dataset HPV vaccine coverage was 82.1% compared to national Year 9 coverage in 2016/17 of 83.1%(14). MenACWY vaccine coverage nationally in Year 9 in 2016/17 was 83.6%(8), and within the dataset was 83.0%. LAs from all four quartiles of nationally published LA-level HPV vaccine coverage were represented for both HPV and MenACWY.

It was not possible to compare the distribution of the sample with all schools in England because the Department of Education's school dataset does not report the number of independent and special schools or pupil referral units separately between primary and secondary education.

Delivery model

Of the 40 LAs included in the HPV analysis, 14 (35.0%) LAs offered both doses of HPV in Year 8 (12-13 year olds) in 2015/16, and 26 (65.0%) LAs offered the first dose in Year 8 in 2015/16 and the second dose in Year 9 in 2016/17. LAs that delivered >70% of their total second doses in Year 8 were considered to have delivered two doses within one year whilst those reporting >70% of their total second doses in Year 9 in 2016/17 were considered to have delivered two doses across two years. This is different to the national ratio which was 55.3% of LAs (84/152) delivering in Year 8 in

2015/16, and 40.8% (62/152) delivering across Year 8 and 9 (four LAs had unclear delivery models, two LAs ran GP programmes).

School type

In the HPV vaccine coverage dataset there were 952 state-funded secondary schools, 235 independent schools, 179 special schools and 41 pupil referral units. HPV vaccine coverage was >80% in 67.1% of state-funded secondary schools, 40.4% of independent schools, 33.5% of special schools and 19.5% of pupil referral units (Figure 2).

In the MenACWY vaccine coverage dataset there were 903 state-funded secondary schools, 263 independent schools, 208 special schools and 58 pupil referral units. MenACWY vaccine coverage was >80% in 68.0% of state-funded secondary schools, 55.1% of independent schools, 26.9% of special schools and 20.7% of pupil referral units (Figure 3).

Factors associated with HPV and MenACWY vaccine uptake

In the adjusted analysis, Muslim and Jewish schools had significantly lower HPV coverage than schools of no religious character (24.0% and 20.5% lower respectively, Table 2) but this was not the case for MenACWY vaccine coverage (Table 3).

Table 2. HPV vaccine coverage and unadjusted/adjusted impact on coverage determined through linear regression, weighted by school size, of school-level predictors, 13-14 year olds, England, 2016/17. *Estimates are in bold if p<0.05. Estimates were adjusted for all variables.*

Variable (significance)	Number of schools	Number of children	Crude vaccine coverage* (%)	Standard deviation of school-level coverage	Unadjusted difference in coverage from baseline (95% confidence interval)	Adjusted difference in coverage from baseline (95% confidence interval)
Denomination of school (p<0.001)						
No religious character	1,140	73,834	82.4	25.4	*Baseline*	
Church of England/Other Christian faith excluding Roman Catholic	164	9,201	79.8	21.8	**-2.5 (-4.7, -0.4)**	-0.7 (-2.9, 1.5)
Roman Catholic	90	6,736	84.3	12.2	2.0 (-0.6, 4.5)	1.9 (-0.6, 4.3)
Islam/Muslim	7	178	56.7	24.7	**-25.6 (-40.5, -10.7)**	**-24 (-38.2, -9.8)**
Jewish	5	356	59.6	33.6	**-22.8 (-33.4, -12.3)**	**-20.5 (-30.7, -10.4)**
Other (Hindu, Sikh, Other)	1	48	93.8	-	11.4 (-17.3, 40.0)	10.4 (-16.9, 37.7)
Type of school (p<0.001)						
State-funded secondary	952	83,741	83.1	13.0	*Baseline*	
Independent school	235	5,693	72.8	30.9	**-10.3 (-12.9, -7.7)**	**-10.3 (-13.0, -7.5)**
Special school	179	819	56.7	35.6	**-26.4 (-33.2, -19.7)**	**-26.1 (-32.7, -19.4)**
Pupil referral unit	41	100	42.0	38.9	**-41.1 (-60.3, -21.8)**	**-41.1 (-60.0, -22.2)**
Urban/rural classification of school (p=0.03)						
Urban	1,165	77,645	82.0	24.4	*Baseline*	
Rural	242	12,708	83.1	25.2	1.1 (-0.8, 3.0)	**2.0 (0.1, 3.9)**
Sex of school pupils (p=0.07)						
Mixed	1,289	78,114	82.2	25.0	*Baseline*	
Males	-	-	-	-	-	-
Females	118	12,239	81.7	19.8	-0.5 (-2.5, 1.4)	1.8 (-0.1, 3.7)
Region (p<0.001)						
South of England	580	36,855	81.0	24.8	*Baseline*	
London	47	3,416	77.0	14.7	**-4.0 (-7.6, -0.4)**	-3.3 (-6.8, 0.1)
Midlands and East of England	572	36,669	82.8	24.0	**1.8 (0.4, 3.3)**	**2.0 (0.6, 3.4)**
North of England	208	13,413	84.6	26.7	**3.6 (1.6, 5.6)**	**3.6 (1.6, 5.5)**
Proportion BME in school LSOA **(p<0.001)						
<5%	243	20,210	85.5	13.3	*Baseline*	
>=5 and <12%	302	25,210	83.7	12.1	-1.8 (-3.7, 0.1)	-1.6 (-3.5, 0.3)
>=12 and <34%	233	19,614	81.8	13.3	**-3.7 (-5.6, -1.7)**	**-3.7 (-6.0, -1.5)**
>=34%	109	8,742	78.0	12.9	**-7.5 (-10.0, -5.0)**	**-6.3 (-9.7, -3.0)**
Deprivation quintile of school LSOA (p<0.001)**						
1 (most deprived)	149	11,295	78.6	15.3	*Baseline*	
2	157	12,318	84.0	11.4	**5.3 (2.8, 7.9)**	**4.4 (1.7, 7.0)**
3	171	14,177	82.3	13.1	**3.7 (1.2, 6.2)**	**2.6 (0.0, 5.2)**
4	218	18,892	83.3	13.1	**4.6 (2.3, 7.0)**	**3.5 (1.0, 6.1)**
5 (least deprived)	192	17,094	85.5	11.6	**6.9 (4.5, 9.3)**	**5.2 (2.6, 7.8)**
Total	***1,407***	***90,353***	***82.1***	***24.6***		

**Crude coverage calculated as total numerators divided by total denominators*

*** based on subset of mixed-sex state-funded secondary schools (n=887)*

Table 3. MenACWY vaccine coverage and unadjusted/adjusted impact on coverage determined through linear regression, weighted by school size, of school-level predictors, 13-14 year olds, England, 2016/17. *Estimates are in bold if p<0.05. Estimates were adjusted for all variables.*

Variable (significance)	Number of schools	Number of children	Crude vaccine coverage* (%)	Standard deviation of school-level coverage	Unadjusted difference in coverage from baseline (95% confidence interval)	Adjusted difference in coverage from baseline (95% confidence interval)
Denomination of school (p=0.685)						
No religious character	1,170	140,011	83.1	22.4	*Baseline*	
Church of England/Other Christian faith excluding Roman Catholic	158	17,765	82.8	15.8	-0.3 (-2.6, 2.0)	-0.3 (-2.6, 1.9)
Roman Catholic	91	13,374	83.0	14.1	-0.1 (-2.7, 2.5)	-0.3 (-2.7, 2.2)
Islam/Muslim	6	60	56.7	34.2	-26.4 (-63.4, 10.5)	-23.3 (-58.4, 11.8)
Jewish	5	605	79.3	13.4	-3.7 (-15.4, 7.9)	1.2 (-9.9, 12.3)
Other (Hindu, Sikh, Other)	2	153	92.8	30.7	9.7 (-13.4, 32.9)	17.6 (-4.4, 39.6)
Type of school (p<0.001)						
State-funded secondary	903	155,760	83.6	14.3	*Baseline*	
Independent school	263	13,238	81.0	25.4	**-2.6 (-5.1, -0.1)**	**-2.8 (-5.4, -0.2)**
Special school	208	2,402	65.3	25.7	**-18.2 (-23.9, -12.4)**	**-18.0 (-23.6, -12.4)**
Pupil referral unit	58	568	43.7	33.0	**-40.0 (-51.7, -28.3)**	**-39.6 (-51.0, -28.2)**
Urban/rural classification of school (p=0.003)						
Urban	1,162	144,682	82.6	20.7	*Baseline*	
Rural	270	27,286	85.4	24.2	**2.8 (0.9, 4.7)**	**2.0 (0.1, 3.8)**
Sex of school pupils (p=0.599)						
Mixed	1,268	154,500	82.9	21.5	*Baseline*	
Males	63	6,452	83.3	24.2	0.4 (-3.2, 4.0)	**3.7 (0.2, 7.2)**
Females	101	11,016	84.4	18.0	1.4 (-1.4, 4.3)	**4.8 (2.0, 7.6)**
Region (p<0.001)						
South of England	569	66,632	83.2	21.5	*Baseline*	
London	168	21,097	76.2	22.6	**-7.1 (-9.3, -4.8)**	**-7.8 (-10.0, -5.5)**
Midlands and East of England	298	36,382	83.7	19.9	0.5 (-1.4, 2.3)	0.6 (-1.2, 2.4)
North of England	397	47,857	85.3	21.5	**2.1 (0.4, 3.7)**	**2.3 (0.6, 3.9)**
Proportion BME in school LSOA (p<0.001)**						
<5%	274	45,727	84.9	14.9	*Baseline*	
>=5 and <12%	263	47,521	84.9	13.7	0.1 (-2.0, 2.1)	0.8 (-1.3, 2.9)
>=12 and <34%	182	32,394	83.6	13.0	-1.3 (-3.6, 1.0)	0.8 (-1.7, 3.4)
>=34%	100	16,853	75.6	17.4	**-9.3 (-12.1, -6.5)**	-1.8 (-5.9, 2.3)
Deprivation quintile of school LSOA (p<0.001)**						
1 (most deprived)	108	17,574	76.0	15.3	*Baseline*	
2	148	23,107	82.8	16.8	**6.8 (3.7, 9.9)**	**7.2 (4.1, 10.3)**
3	161	26,006	82.0	16.3	**6.0 (3.0, 9.0)**	**5.9 (2.9, 9.0)**
4	206	37,777	83.6	14.3	**7.6 (4.7, 10.4)**	**7.5 (4.6, 10.3)**
5 (least deprived)	196	38,031	88.2	8.8	**12.2 (9.4, 15.0)**	**11.8 (8.9, 14.7)**
Total	***1,432***	***171,968***	***83.0***	***21.4***		

*****Crude coverage calculated as total numerators divided by total denominators*

*** based on subset of mixed-sex state-funded secondary schools (n=887)*

Independent, special schools and pupil referral units had increasingly lower vaccine coverage than state-funded secondary schools for both HPV and MenACWY. This ranged from 10.3% lower for independent schools to 41.1% lower for pupil referral units for HPV (Table 2) and from 2.8% lower for independent schools to 39.6% lower for pupil referral units for MenACWY (Table 3).

Rural schools had 2.0% higher coverage than urban schools for both HPV and MenACWY (Tables 2 and 3).

Single-sex schools had higher coverage than mixed schools for MenACWY (3.7% higher for males, 4.8% higher for females, Table 2) but there was no difference between mixed and female-only schools for HPV (Table 2).

There was regional variation in vaccine coverage for both HPV and MenACWY, but this was most marked for MenACWY where coverage in London was 7.8% lower than in the South of England (Table 3).

Mixed-sex state-funded secondary schools located in LSOAs with the largest BME populations (>=34%) had HPV vaccine coverage 6.3% below those located in LSOAs with BME populations of <5% (Table 2). In contrast, there was no association between MenACWY vaccine coverage and BME population proportion within the school LSOA (Table 3). There was no clear trend in vaccination coverage by school LSOA deprivation quintiles, though schools located in the least deprived LSOAs had the highest coverage for both HPV and MenACWY (5.2% and 11.8% higher than schools located in the most deprived LSOAs for HPV and MenACWY respectively, Tables 2 and 3).

DISCUSSION

Key findings

Although national HPV and MenACWY vaccine coverage is high, This first school-level analysis has identified important school-level factors associated with wide variations in vaccine coverage.

The lower coverage in Muslim and Jewish schools for HPV but not for MenACWY suggests that there are no issues with vaccination acceptance or access in general, but there may be less acceptance of the need for HPV vaccine in particular within these religious communities. In contrast, coverage for both vaccines in Roman Catholic schools was similar or higher than coverage in schools of no religious character. Factors underlying these differences require further investigation.

The vast majority of schools in England participate in the school-based vaccination programmes. A survey of SITs undertaken by Public Health England (PHE)'s national immunisation team highlighted that only a small number of minority faith/anthroposophic (Steiner) schools in specific areas declined to allow immunisation teams access. In these instances it is sometimes possible for immunisation teams to provide letters and/or leaflets directing pupils to external clinics however, uptake is likely to be lower in these settings than in school-based sessions.

The marked variation in coverage across school types is likely to be multi-factorial. School size could be a factor; state-funded secondary schools are the largest, followed by independent, special schools and pupil referral units. Identifying and reaching eligible pupils in referral units, where pupil numbers are likely to be small and change throughout the year, with possibly only one eligible child in a particular year, is more challenging than in larger schools. Immunisation teams may also find it more resource-efficient to visit and offer mop-up sessions in larger schools where a greater number of pupils can be reached at any one visit. Pupils in special schools in particular may have specific health needs that are typically managed by their general or specialist practitioner, and children with medical conditions are less likely to be immunised(19). Information about vaccines given by other health practitioners may not always get back to the immunisation teams responsible for providing vaccine coverage data to PHE. In addition, the independent school category may include some small schools that cater for children with special educational or health needs so there could be some overlap between categories. Steiner schools, identified by several SITs as not offering vaccination, are typically independent schools and could not be identified separately in our analysis (they are categorised as having no religious character).

There was no difference in HPV coverage between mixed and female-only schools. The reason behind the higher Men ACWY coverage in single-sex schools is unclear, though in the case of female-only schools it may partly be because MenACWY can be offered alongside the existing HPV programme. It could also be that in mixed schools, boys have lower coverage than girls, although this cannot be verified because gender specific coverage is not collected.

Coverage was lower for London compared with other areas, as seen across other childhood immunisation programmes (19). Participation from London was low in this study particularly for HPV so that may partly explain the lack of a difference for HPV coverage compared to MenACWY when adjusted for other factors.

The ability to study school-specific factors was a major strength of this study. Although we did a restricted, mixed-sex state-funded secondary schools only sub-analysis (i.e. schools most likely to have pupil catchment areas in the immediate locality) to determine the association between coverage and deprivation and ethnicity factors, the influence of these factors on vaccine coverage is less clear. However, the fact that schools in the most deprived areas had lowest coverage across both programmes suggests that even within a school-based programme deprivation has an influence on coverage. These findings may be less reliable in London as students may travel in other parts of the city to attend school.

The lower HPV coverage in schools located in areas with the highest BME proportion, could relate to the school-level finding of particular religious schools having lower coverage for HPV. These results suggest some religious and possibly ethnic groups have objections to offering or receiving the HPV vaccine in particular. These results were not observed for the MenACWY vaccination programme.

Limitations of the data

This dataset relied on voluntary submissions of school-level data. Although the dataset contained schools from only 26% and 32% of LAs for HPV and MenACWY respectively, overall coverage aligned well with national coverage so the dataset appeared to be broadly representative. Because the schools census does not allow to easily distinguish primary and secondary schools, we could not ascertain whether the proportion of religious, independent, and special schools were similar in our sample compared with all schools in England. This may affect the precision of the findings and may lead to failing to detect associations between particular characteristics and uptake for school types that are underrepresented.

Although the numerator for each school should include any vaccine given up to and including 31 August 2017, it could be underestimated as some schools/areas may only include vaccines given in the particular academic year, which ends in July in most schools. The extent to which this is an issue is unclear, but likely small as only a limited number of individuals in these age groups receive HPV and MenACWY through general practice. Some local school-level datasets may only capture vaccines given in school, not in other healthcare settings such as general practice.

Similarity/difference to results of other studies

HPV vaccine uptake by school denomination has previously been studied in Scotland though no difference in uptake was found between denominational and non-denominational schools(20). This may be because the denomination category did not allow the detail of individual types of denominational schools to be explored, and because the number of non-Christian faith schools is small. Similar to our findings, the Scottish study found that those in schools with the highest deprivation quintile (as measured by the percentage of pupils eligible for free school meals) had a significantly lower uptake than those in schools with the lowest percentage of pupils eligible for free school meals(20), deprivation was also significantly associated with lower vaccine coverage for the influenza programme(12). A previous study in South West England found no evidence of an association of HPV vaccination and deprivation (assigned by LSOA of residence), but did find an association by ethnicity (individual-level), and that young women attending non-mainstream educational settings were less likely to initiate vaccination(21). A systematic review of factors

associated with HPV vaccine initiation and completion in teenage girls found that having a Caucasian ethnic background was associated with higher rates vaccine initiation and completion(22).

Vaccine uptake for the school-based influenza programme by area (LSOA) level factors has identified variation by religious beliefs with adjusted uptake in 4-11 year olds in the highest Muslim population tertile 8% lower than the lowest Muslim population tertile, but this could be specific to the influenza vaccine because of the porcine origin gelatine component(10). Similarly to MenACWY and HPV, Influenza vaccine uptake in schools was higher in rural areas than in urban areas, and similarly to HPV coverage decreased with increasing proportion of BME population in the LSOA, although the association was stronger with the influenza vaccine(10). The school based influenza vaccine programme targets a much younger age group, and there may be other factors influencing uptake such as perceptions and attitudes to each disease.(23)

Finally, in addition to school-based programmes, variation in uptake by ethnicity, deprivation and geography is also found in primary care-based programme(24,25) and while some factors influencing uptake are school specific, others may be more closely related to characteristics of the population attending these schools.

Conclusions

Although school delivery programmes achieve high coverage for adolescent vaccine programmes overall, there are particular types of schools that have lower coverage and where alternative approaches to improve coverage might be beneficial. This includes particular religious schools, where further understanding of acceptance of particular vaccinations would be helpful. Tailored approaches, such as the World health Organization's "Tailoring immunization programmes" (TIP), that aim to understand barriers that are context specific(26) , could help improve uptake in these schools. Because factors influencing uptake are likely to be a mix of school based and community based factors, tailored strategies addressing both aspects are most likely to succeed. In addition it could be helpful to share best practice regarding the best ways of reaching pupils in small specialist schools and pupil referral centres. It is important to bear in mind that as well as considering school-level factors, the individual relationship between a school and immunisation nursing teams must be mutually supportive for successful vaccine delivery(27). It is hoped that, given these findings, submission of school-level data returns will improve to enable continued monitoring of these influences on vaccine coverage.

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Competing interests: none

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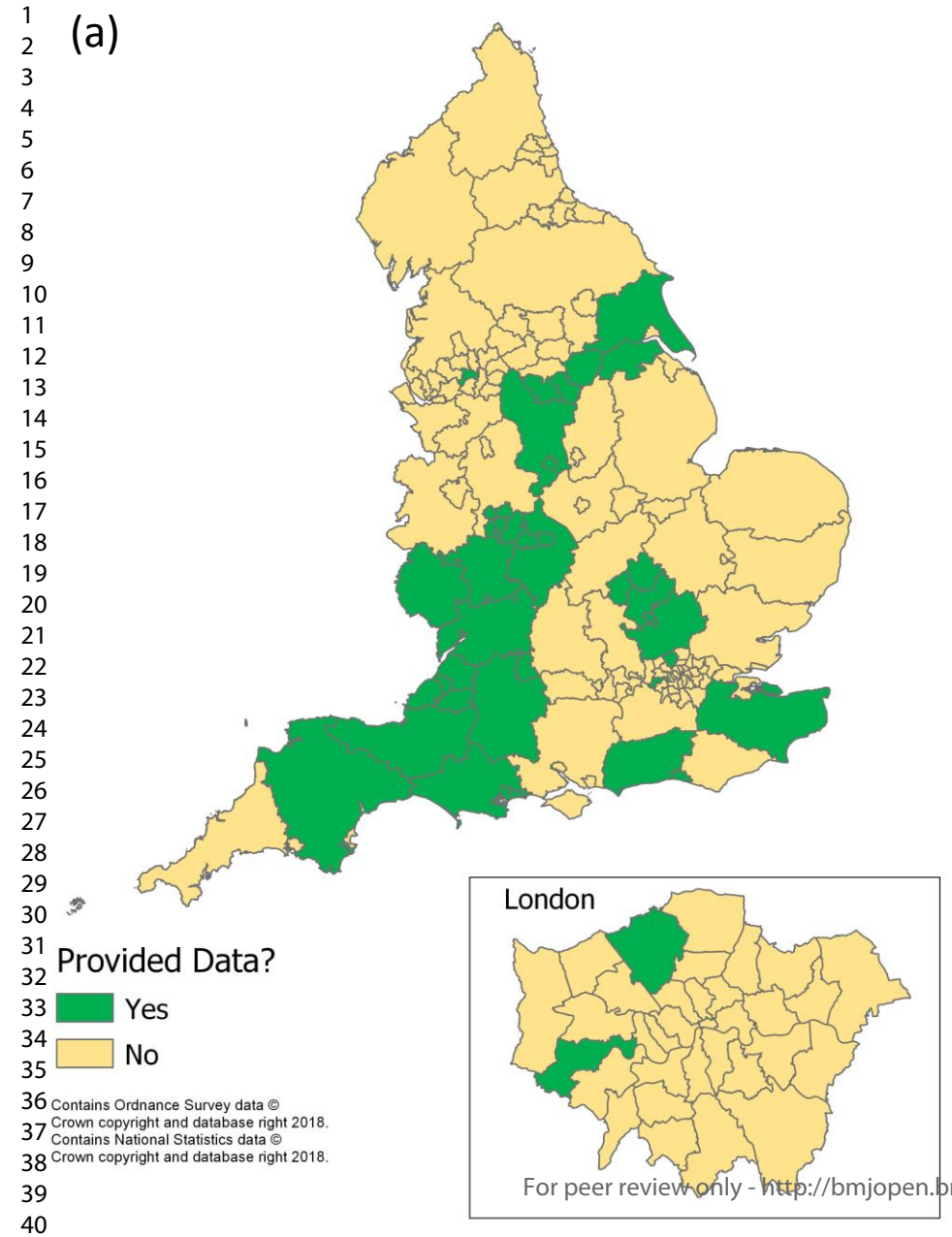
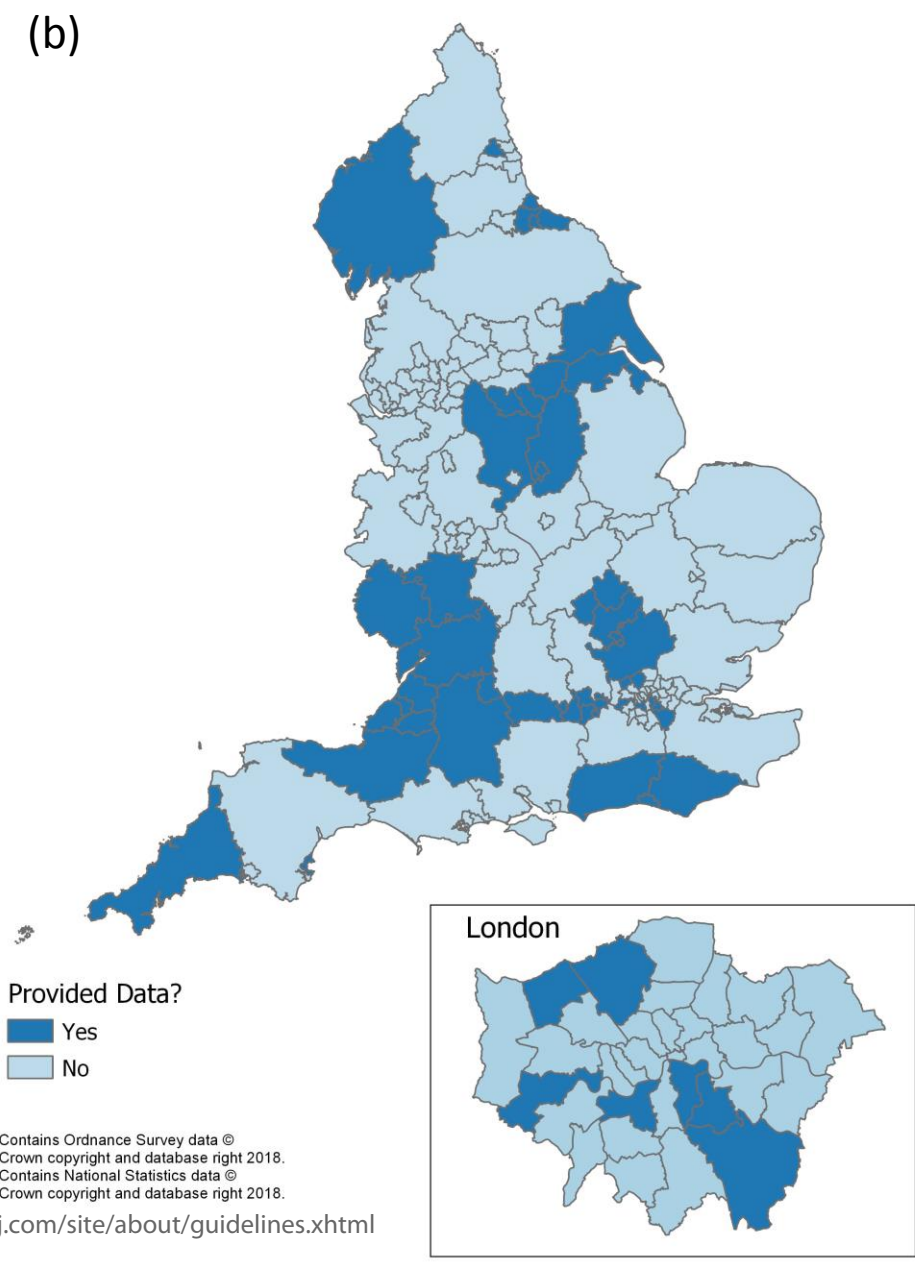
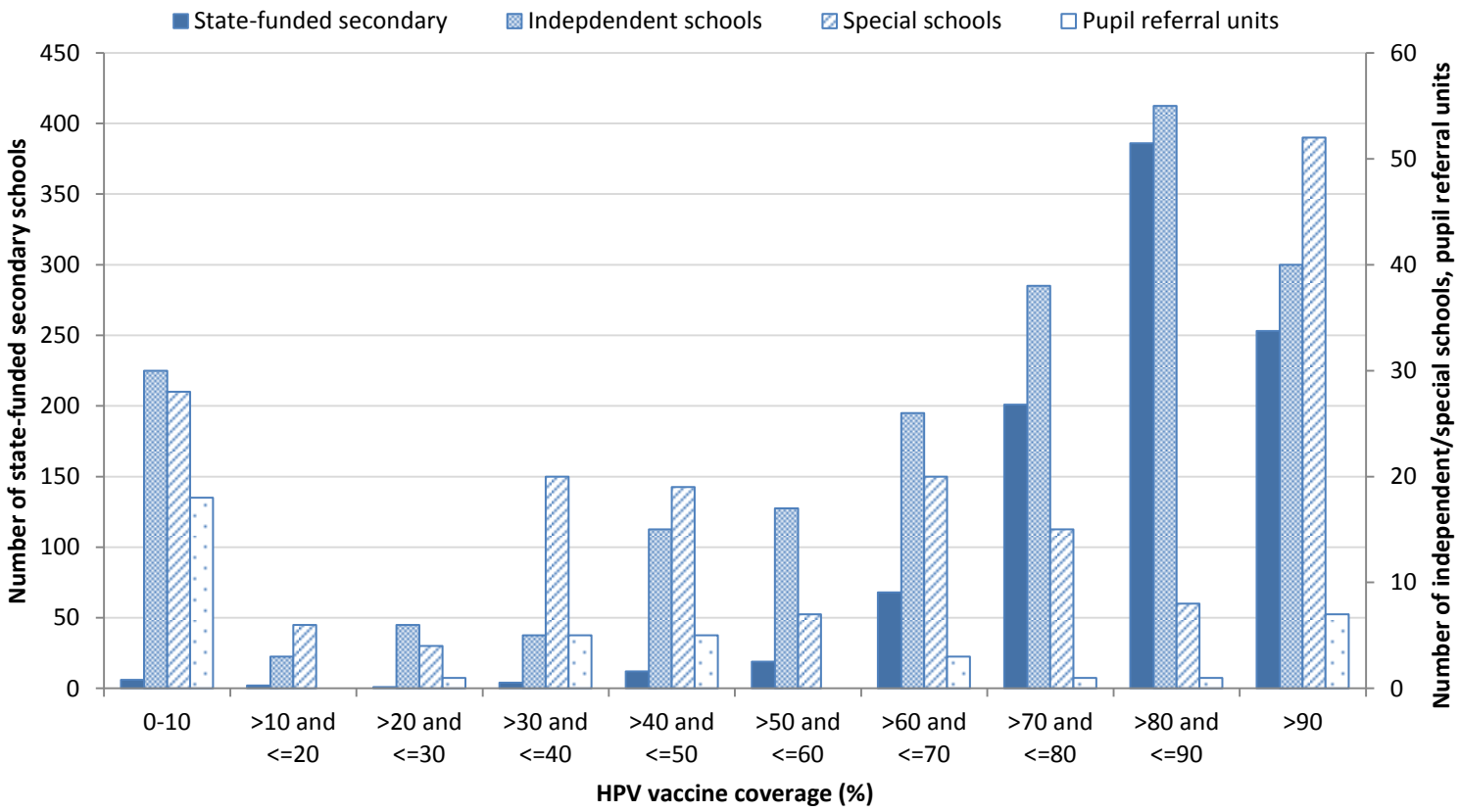
Figure 1. Local Authorities providing school-level (a) HPV vaccine coverage data (n=40), and (b) MenACWY vaccine coverage data (n=48) included in the analysis in 2016/17

Figure 2. HPV vaccine coverage distribution by school type 2016/17

Figure 3. MenACWY vaccine coverage distribution by school type 2016/17






State-funded secondary
Indepdendent schools
Special schools
Pupil referral units
Number of state-funded secondary schools
Number of independent/special schools, pupil referral units
450
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300
250
200
150
100
50
0
60
50
40
30
20
10
0
0-10
>10 and <=20
>20 and <=30
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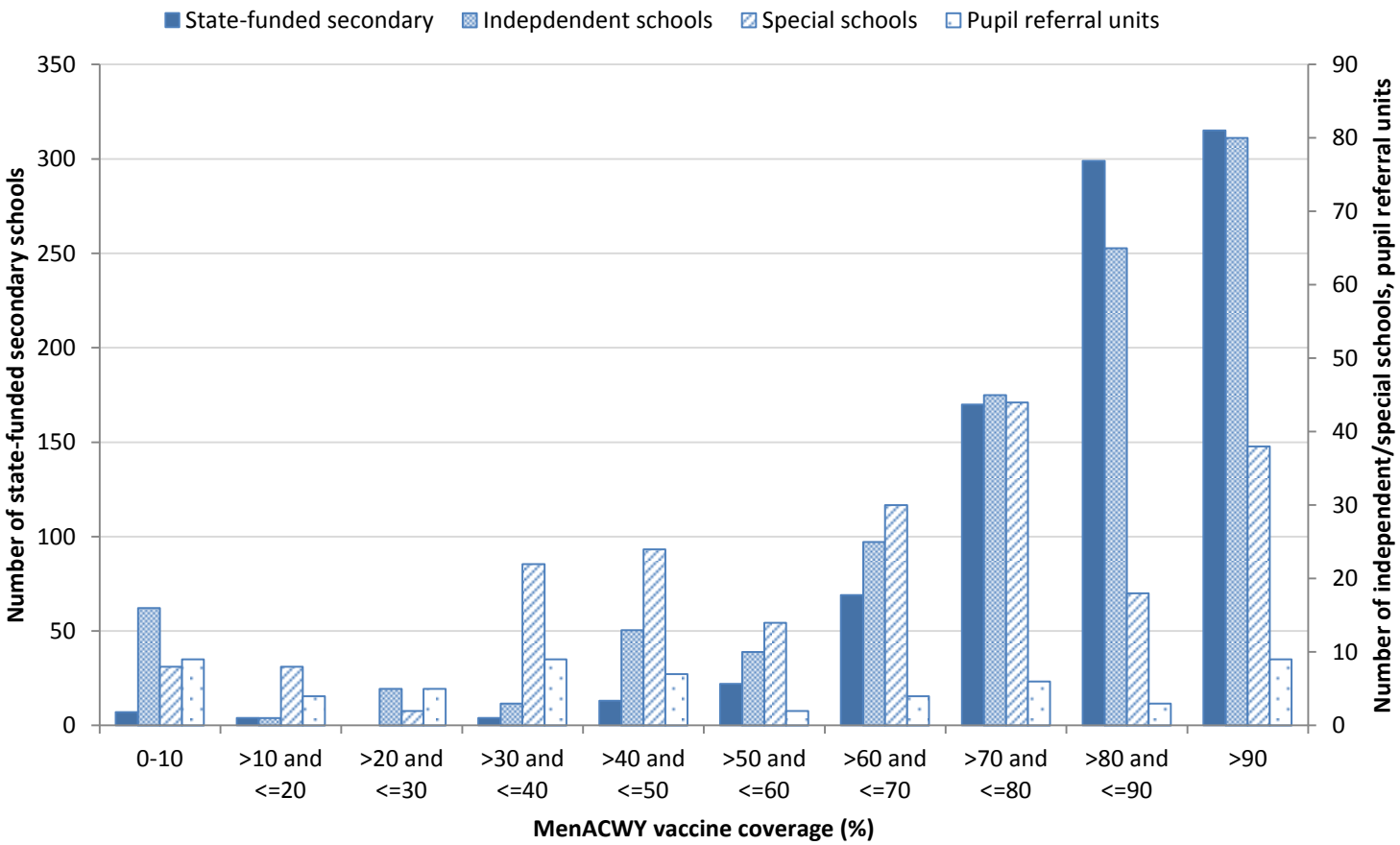
>60 and <=70
>70 and <=80
>80 and <=90
>90
HPV vaccine coverage (%)


State-funded secondary
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>50 and <=60
>60 and <=70
>70 and <=80
>80 and <=90
>90
MenACWY vaccine coverage (%)

BMJ Open

What school and area level factors influenced HPV and MenACWY vaccine coverage in England in 2016/17? An ecological study

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What school and area level factors influenced HPV and MenACWY vaccine coverage in England in 2016/17? An ecological study

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ABSTRACT

objectives: To describe school and area-level factors that influence HPV and MenACWY vaccine coverage among adolescents.

design: Ecological study

setting and participants: Aggregated 2016/17 vaccine coverage data from Year 9 pupils were received from 1,407 schools for HPV and 1,432 schools for MenACWY. The unit of analysis was the school.

primary and secondary outcome measures: Percentage points difference in vaccine coverage by school religious affiliation, school type, urban/rural, single sex/mixed and region. A sub-analysis of mixed-sex state-funded secondary schools also included deprivation, proportion of population from black and ethnic minorities, and school size.

results: Muslim and Jewish schools had significantly lower vaccine coverage than schools of no religious character for HPV (24.0 (95%CI -38.2, -9.8) and 20.5 (95%CI -30.7, -10.4) percentage points lower respectively) but not for MenACWY. Independent, special schools and pupil referral units had increasingly lower vaccine coverage compared with state-funded secondary schools for both HPV and MenACWY. In the sub-analysis, schools located in least deprived areas had the highest coverage for both vaccines (3.8 (0.9, 6.8) and 10.4 (7.0, 13.8) percentage points for HPV and MenACWY respectively), and the smallest schools had the lowest coverage (-10.4 (-14.1, -6.8) and -7.9 (-12, -3.8) for HPV and MenACWY, respectively).

conclusions: Tailored approaches are required to improve HPV vaccine coverage in Muslim and Jewish schools. In addition, better ways of reaching pupils in smaller specialist schools are needed.

Year 9**Strengths and limitations of this study**

- This study is the first school-level analysis of factors influencing the coverage of school-delivered vaccines among adolescents in England
- The data set includes a large number of schools across the country and the school level variables collected allow determination of associations between vaccine coverage and previously unstudied factors such as school type or faith affiliation
- The voluntary nature of the school-level data return means the dataset is not complete
- For some types of schools, the dataset only includes a small number of schools, limiting the precision of some of the results
- The analysis of socio economic factors was restricted to mixed-sex state-funded secondary schools only, based on the assumption that they were more likely to represent pupils from their immediate geographical area

INTRODUCTION

Offering vaccination at school enables large numbers of children to be vaccinated without requiring individual appointments. School vaccination achieves higher coverage than primary care for adolescent vaccines(1,2). There are four school-based vaccination programmes in the UK which protect against human papillomavirus (HPV vaccine, females only), meningococcal A, C, W and Y (MenACWY vaccine), diphtheria, tetanus and polio (Td/IPV vaccine), and seasonal influenza(3).

HPV vaccine was introduced for females only in the UK in 2008, initially as a three-dose schedule offered in Year 8 (children aged 12-13 years). In September 2014 this changed to a two-dose schedule(4). The recommendation, for operational ease, is for the first (priming) dose to be offered in Year 8 and the second (completing) dose in Year 9 (age 13-14 years) but NHS England (the agency responsible for commissioning the services) can choose to offer both doses in Year 8. In 2015/16, 85/152 (56%) local authorities (LAs) offered both doses within Year 8(5). HPV vaccine coverage by the end of Year 9 is the final year of assessment for both delivery models. In 2016/17, national Year 9 coverage for HPV was 83.1%(6). MenACWY vaccine was introduced in August 2015 in response to the rising number of meningococcal W (MenW) cases(7). From autumn 2013 adolescent MenC booster had been offered inYear 9 or 10 (age 14-15 years) but increasingly LAs were aligning to all offer MenC vaccine in Year 9(8). In 2016/17 82% (124/152) of LAs offered MenACWY routinely in Year 9 through the schools-based programme(9). The Td/IPV ('school leaver booster') vaccine is usually offered alongside MenACWY vaccine. In 2016/17, MenACWY vaccine coverage nationally by the end of Year 9 was 83.6%(9).

Previous studies of the national immunisation programme in England have identified inequalities in terms of geography, ethnicity and deprivation for vaccines delivered in primary care (10,11). A previous analysis of vaccine coverage data for the primary school-based seasonal influenza programme in England, using population-level characteristics at the Lower Super Output Area level (LSOA, small areas with an average of approximately 1,500 residents or 650 households(12)) in which the school was located identified deprivation, non-white ethnicity, religious beliefs and urban areas to be associated with lower coverage(13,14,15). 2016/17 is the first year that school-level data were available nationally for the adolescent vaccination programmes, delivered in secondary schools. This study aims to determine whether school-level and other local area factors are associated with vaccine coverage for those adolescent programmes.

METHODS

In England, school-based vaccination is delivered by a variety of public and private healthcare providers and commissioned and coordinated through Screening and Immunisation Teams (SITs). Data are routinely collected in each school through tally sheets, aggregated at local LA level and submitted to PHE. Therefore prior to 2016/17 school-level data, although collected, were not routinely available at national level. In September 2017, the 14 SITs in England were asked to voluntarily submit school-level vaccine coverage data for 2016/17 for all schools in their area using a

standardised MS Excel data collection tool. Reminders to submit school-level data were sent out as each submission of LA-level data was received and validated.

School level data for the 2016/17 academic year includes vaccines given up to and including 31 August 2017. For HPV the data will have included some doses given in the previous academic year (2015/16))

Queries on data were sent back to providers if:

- Denominators or numerators were missing for particular schools. For the small number of schools where denominators were unavailable from the provider, nationally published school roll data were used instead(16).
- A numerator was greater than a denominator (coverage >100%).
- Coverage was 100% for schools with >20 pupils in the denominator.
- All schools in an LA were queried if substantial changes were made to any individual schools queried above, and/or if total numerators, denominators or coverage differed by more than 5% from published statistics for LA coverage(9,6).

School delivery of the MenACWY and Td/IPV vaccines are generally organised concurrently and given on the same day, so only MenACWY data were used and the findings relating to MenACWY should be generalisable to Td/IPV.

Data were analysed for Year 9 pupils (13-14 year olds), born 1 September 2002 to 31 August 2003. Vaccine coverage of a completed course was calculated by dividing the number of YYear 9 females receiving two doses of HPV vaccine and the number of YYear 9 pupils receiving one dose of MenACWY vaccine by the total number of females and adolescents respectively in the school year.

School characteristics (table 1) were obtained from the Department for Education 2017 school census and were linked to vaccine coverage using each school's unique reference number. The LSOA-level geographical factors (Table 1), based on the location of each school were assigned to mixed-sex state-funded secondary schools only, as these schools were considered most likely to represent pupils from their immediate geographical area. All schools were assigned an NHS commissioning region (South of England, London, Midlands and East of England, North of England) based on their geographical location. We described the geographical distribution of schools included in the study and compared state-funded secondary schools in the study with all state-funded secondary schools in terms of distribution by school size, graphically and using chi-square test. It was not possible to compare the distribution of the sample with all schools in England because the Department of Education's school dataset does not report the number of independent and special schools or pupil referral units separately between primary and secondary education.

Table 1. School and geographical characteristics included in the analysis		
Type of characteristics	**Categories**	**notes**
Religious affiliation*	No religious character	
	Church of England/Other Christian faith excluding Roman Catholic	includes Anglican, Free Church, Methodist, Other Anglican Faith, Other Christian Faith, Plymouth Brethren Christian Church
	Roman Catholic	
	Jewish	
	Islam/Muslim	
	Other	includes Hindu, Sikh and other
School type*	State-funded secondary	
	Independent	
	Special school	combines state-funded and non-maintained, schools for children with special educational needs
	Pupil referral unit	schools for children excluded from mainstream education because of behaviour, sickness, or other reasons
Urban/rural*	Urban	
	Rural	
Single sex/mixed*	Mixed	
	Female	
	Male	
School Size (number of pupils)++	Up to 400 (small)	Mean headcount was 728 pupils (range 1-2945)
	>400 to 1000 (average)	
	>1000 (large)	
% of population classifying themselves as black or minority ethnic (BME)**	<5%,	includes any ethnic group other than 'White: English/Welsh/Scottish/Northern Irish/British, based on 2011 census categories (17). The thresholds are aligned with those used for influenza vaccine coverage school-level analyses in England (13,18).
	>=5% and <12%	
	>=12% and <34%	
	>=34%	
Index of multiple deprivation 2015**	quintiles	1 represents the most deprived, 5 the least deprived. Quintiles were obtained by combining published deciles which rank the 32,844 LSOAs in England from most deprived to least deprived and dividing them into ten equal groups (19).

*School characteristic
** Lower super output (LSOA) characteristic
++ School characteristic only used in the mixed-sex, state funded school only sub-analysis

Statistical analyses

To take account of school variability and size, individual coverage was calculated for each school, and the analysis was weighted by the denominator of each school.

Unadjusted regression models were used for each school-level factors (except school size, which was adjusted for by weighting) and region to explore differences in coverage from the baseline for each factor (religious affiliation, school type, urban/rural, single sex/mixed . In addition to school-level factors, the association between ethnicity and deprivation LSOA level factors (proportion of BME in school LSOA, deprivation) and vaccine coverage were explored for mixed-sex state-funded secondary schools, using the same model. To ascertain the effect of school size, we opted to include school size as a variable, rather than weighting, in the mixed-sex state funded only sub-analysis. We restricted the analysis of school size to this subanalysis because all pupil referral units and special schools were small and had less than 400 pupils. An adjusted linear regression model was then used, presenting differences in coverage from the baseline for each factor, adjusting for all other factors.

This analysis was undertaken using aggregated data routinely collected as part of the ongoing monitoring of the vaccination programme. No specific funding was sought and no formal ethical approval was required.

Analyses were undertaken in STATA SE/V.13.1 statistical software.

Patient and Public Involvement

This study used routinely collected aggregated data and patients were not involved.

RESULTS

Representativeness of dataset

HPV vaccine coverage school-level data for Year 9 was received from 41/152 LAs. One LA was excluded because their programme was run in primary care during 2015/16. The final HPV analysis therefore included 1,407 schools in 40/152 (26.3%) LAs (Figure 1a).

MenACWY vaccine coverage school level data for Year 9 was received from 50 LAs. Two were excluded: one ran a selective (males only) vaccination programme and the other delivered their programme through primary care. In total, 48/152 (31.6%) LAs (Figure 1b) representing 1,432 schools were included in the MenACWY analysis.

National HPV vaccine coverage in Year 9 in 2016/17 was 83.1% (6) compared with 82.1% among schools included in the study. National MenACWY vaccine coverage in Year 9 in 2016/17 was 83.6% (9) compared with 83% among schools included in the study.. Schools from each of the four NHS England regions were included, and LAs from all four quartiles of nationally published LA-level HPV vaccine coverage were represented for both HPV and MenACWY.

Compared with the all state funded secondary schools in England, small state-funded secondary schools were under-represented (p=0.03). Distribution was otherwise graphically comparable (Figure 2). London schools were underrepresented, in particular for the HPV dataset where they comprised 3.3% of included schools, whereas 14.6% of all England state funded secondary schools are in London.

School type

In the HPV vaccine coverage dataset, there were 952 state-funded secondary schools, 235 independent schools, 179 special schools and 41 pupil referral units. HPV vaccine coverage was >80% in 67.1% of state-funded secondary schools, 40.4% of independent schools, 33.5% of special schools and 19.5% of pupil referral units (Figure 3).

In the MenACWY vaccine coverage dataset, there were 903 state-funded secondary schools, 263 independent schools, 208 special schools and 58 pupil referral units. MenACWY vaccine coverage was >80% in 68.0% of state-funded secondary schools, 55.1% of independent schools, 26.9% of special schools and 20.7% of pupil referral units (Figure 4).

Factors associated with HPV and MenACWY vaccine uptake

In the adjusted analysis, Muslim and Jewish schools had significantly lower HPV coverage than schools of no religious character (24 and 20.5 percentage points (pp) lower respectively, Table 2) but this was not the case for MenACWY vaccine coverage (Table 3).

Table 2. HPV vaccine coverage and unadjusted/adjusted impact on coverage determined through linear regression, weighted by school size, of school-level predictors, 13-14 year olds, England, 2016/17. *Estimates are in bold if p<0.05. Estimates were adjusted for all variables.*

Variable (significance)	Number of schools	Number of children	Crude vaccine coverage* (%)	Standard deviation of school-level coverage	Unadjusted difference in coverage from baseline (95% confidence interval)	Adjusted difference in coverage from baseline (95% confidence interval)
Denomination of school (p<0.001)						
No religious character	1,140	73,834	82.4	25.4	*Baseline*	*Baseline*
Church of England/Other Christian faith excluding Roman Catholic	164	9,201	79.8	21.8	**-2.5 (-4.7, -0.4)**	-0.7 (-2.9, 1.5)
Roman Catholic	90	6,736	84.3	12.2	2.0 (-0.6, 4.5)	1.9 (-0.6, 4.3)
Islam/Muslim	7	178	56.7	24.7	**-25.6 (-40.5, -10.7)**	**-24 (-38.2, -9.8)**
Jewish	5	356	59.6	33.6	**-22.8 (-33.4, -12.3)**	**-20.5 (-30.7, -10.4)**
Other (Hindu, Sikh, Other)	1	48	93.8	-	11.4 (-17.3, 40.0)	10.4 (-16.9, 37.7)
Type of school (p<0.001)						
State-funded secondary	952	83,741	83.1	13.0	*Baseline*	*Baseline*
Independent school	235	5,693	72.8	30.9	**-10.3 (-12.9, -7.7)**	**-10.3 (-13.0, -7.5)**
Special school	179	819	56.7	35.6	**-26.4 (-33.2, -19.7)**	**-26.1 (-32.7, -19.4)**
Pupil referral unit	41	100	42.0	38.9	**-41.1 (-60.3, -21.8)**	**-41.1 (-60.0, -22.2)**
Urban/rural classification of school (p=0.03)						
Urban	1,165	77,645	82.0	24.4	*Baseline*	
Rural	242	12,708	83.1	25.2	1.1 (-0.8, 3.0)	**2.0 (0.1, 3.9)**
Sex of school pupils (p=0.07)						
Mixed	1,289	78,114	82.2	25.0	*Baseline*	*Baseline*
Males	-	-	-	-	-	-
Females	118	12,239	81.7	19.8	-0.5 (-2.5, 1.4)	1.8 (-0.1, 3.7)
Region (p<0.001)						
South of England	580	36,855	81.0	24.8	*Baseline*	*Baseline*
London	47	3,416	77.0	14.7	**-4.0 (-7.6, -0.4)**	-3.3 (-6.8, 0.1)
Midlands and East of England	572	36,669	82.8	24.0	**1.8 (0.4, 3.3)**	**2.0 (0.6, 3.4)**
North of England	208	13,413	84.6	26.7	**3.6 (1.6, 5.6)**	**3.6 (1.6, 5.5)**
Proportion BME in school LSOA **(p<0.001)						
<5%	243	20,210	85.5	13.3	*Baseline*	
>=5 and <12%	302	25,210	83.7	12.1	-1.8 (-3.7, 0.1)	-1.6 (-3.8, 0.6)
>=12 and <34%	233	19,614	81.8	13.3	**-3.7 (-5.6, -1.7)**	**-4.2 (-6.8, -1.6)**
>=34%	109	8,742	78.0	12.9	**-7.5 (-10.0, -5.0)**	**-7.1 (-10.8, -3.3)**
Deprivation quintile of school LSOA (p<0.001)**						
1 (most deprived)	149	11,295	78.6	15.3	*Baseline*	*Baseline*
2	157	12,318	84.0	11.4	**5.3 (2.8, 7.9)**	**3.2 (0.2, 6.0)**
3	171	14,177	82.3	13.1	**3.7 (1.2, 6.2)**	1.5 (-1.3, 4.4)
4	218	18,892	83.3	13.1	**4.6 (2.3, 7.0)**	2.6 (-0.2, 5.4)
5 (least deprived)	192	17,094	85.5	11.6	**6.9 (4.5, 9.3)**	**3.8 (0.9, 6.8)**
School Size (number of pupils) (p<0.001)**						
>400 to 1000	409	26601	82.7	13.2	*Baseline*	*Baseline*
Up to 400	50	1397	74.9	21.7	**-10.6 (-14.3, -6.8)**	**-10.4 (-14.1, -6.8)**
>1000	428	45778	83.4	10.8	1.3 (-0.4, 3.0)	1.4 (-0.3, 3.1)
Total	***1,407***	***90,353***	***82.1***	***24.6***		

*****Crude coverage calculated as total numerators divided by total denominators*

*** based on subset of mixed-sex state-funded secondary schools (n=887)*

Table 3. MenACWY vaccine coverage and unadjusted/adjusted impact on coverage determined through linear regression, weighted by school size, of school-level predictors, 13-14 year olds, England, 2016/17. *Estimates are in bold if p<0.05. Estimates were adjusted for all variables.*

Variable (significance)	Number of schools	Number of children	Crude vaccine coverage* (%)	Standard deviation of school-level coverage	Unadjusted difference in coverage from baseline (95% confidence interval)	Adjusted difference in coverage from baseline (95% confidence interval)
Denomination of school (p=0.685)						
No religious character	1,170	140,011	83.1	22.4	*Baseline*	*Baseline*
Church of England/Other Christian faith excluding Roman Catholic	158	17,765	82.8	15.8	-0.3 (-2.6, 2.0)	-0.3 (-2.6, 1.9)
Roman Catholic	91	13,374	83.0	14.1	-0.1 (-2.7, 2.5)	-0.3 (-2.7, 2.2)
Islam/Muslim	6	60	56.7	34.2	-26.4 (-63.4, 10.5)	-23.3 (-58.4, 11.8)
Jewish	5	605	79.3	13.4	-3.7 (-15.4, 7.9)	1.2 (-9.9, 12.3)
Other (Hindu, Sikh, Other)	2	153	92.8	30.7	9.7 (-13.4, 32.9)	17.6 (-4.4, 39.6)
Type of school (p<0.001)						
State-funded secondary	903	155,760	83.6	14.3	*Baseline*	*Baseline*
Independent school	263	13,238	81.0	25.4	**-2.6 (-5.1, -0.1)**	**-2.8 (-5.4, -0.2)**
Special school	208	2,402	65.3	25.7	**-18.2 (-23.9, -12.4)**	**-18.0 (-23.6, -12.4)**
Pupil referral unit	58	568	43.7	33.0	**-40.0 (-51.7, -28.3)**	**-39.6 (-51.0, -28.2)**
Urban/rural classification of school (p=0.003)						
Urban	1,162	144,682	82.6	20.7	*Baseline*	
Rural	270	27,286	85.4	24.2	**2.8 (0.9, 4.7)**	**2.0 (0.1, 3.8)**
Sex of school pupils (p=0.599)						
Mixed	1,268	154,500	82.9	21.5	*Baseline*	*Baseline*
Males	63	6,452	83.3	24.2	0.4 (-3.2, 4.0)	**3.7 (0.2, 7.2)**
Females	101	11,016	84.4	18.0	1.4 (-1.4, 4.3)	**4.8 (2.0, 7.6)**
Region (p<0.001)						
South of England	569	66,632	83.2	21.5	*Baseline*	*Baseline*
London	168	21,097	76.2	22.6	**-7.1 (-9.3, -4.8)**	**-7.8 (-10.0, -5.5)**
Midlands and East of England	298	36,382	83.7	19.9	0.5 (-1.4, 2.3)	0.6 (-1.2, 2.4)
North of England	397	47,857	85.3	21.5	**2.1 (0.4, 3.7)**	**2.3 (0.6, 3.9)**
Proportion BME in school LSOA (p<0.001)**						
<5%	274	45,727	84.9	14.9	*Baseline*	*Baseline*
>=5 and <12%	263	47,521	84.9	13.7	0.1 (-2.0, 2.1)	0.4 (-2.1, 2.9)
>=12 and <34%	182	32,394	83.6	13.0	-1.3 (-3.6, 1.0)	1.1 (-1.8, 4.2)
>=34%	100	16,853	75.6	17.4	**-9.3 (-12.1, -6.5)**	-1.1 (-5.9, 3.8)
Deprivation quintile of school LSOA (p<0.001)**						
1 (most deprived)	108	17,574	76.0	15.3	*Baseline*	*Baseline*
2	148	23,107	82.8	16.8	**6.8 (3.7, 9.9)**	**5.2 (1.8, 8.7)**
3	161	26,006	82.0	16.3	**6.0 (3.0, 9.0)**	**3.9 (0.4, 7.3)**
4	206	37,777	83.6	14.3	**7.6 (4.7, 10.4)**	**5.1 (1.7, 8.4)**
5 (least deprived)	196	38,031	88.2	8.8	**12.2 (9.4, 15.0)**	**10.4 (7.0, 13.8)**
School Size (number of pupils) (p<0.001)**						
>400 to 1000	378	51249	82.1	14.2	*Baseline*	*Baseline*
Up to 400	49	2720	76.9	25.5	**-7.5 (-11.9, 3.2)**	**-7.9 (-12, -3.8)**
>1000	392	88526	84.5	12.7	**3.2 (1.1, 5.3)**	**2.6 (0.6, 4.6)**
Total	***1,432***	***171,968***	***83.0***	***21.4***		

******Crude coverage calculated as total numerators divided by total denominators*

*** based on subset of mixed-sex state-funded secondary schools (n=887)*

Independent, special schools and pupil referral units had increasingly lower vaccine coverage than state-funded secondary schools for both HPV and MenACWY. This ranged from 10.3pp lower for independent schools to 41.1pp lower for pupil referral units for HPV (Table 2) and from 2.8pp lower for independent schools to 39.6pp lower for pupil referral units for MenACWY (Table 3).

Rural schools had 2.0pp higher coverage than urban schools for both HPV and MenACWY (Tables 2 and 3).

Single-sex schools had higher coverage than mixed schools for MenACWY (3.7pp higher for males, 4.8pp higher for females, Table 2) but there was no difference between mixed and female-only schools for HPV (Table 2).

There was regional variation in vaccine coverage for both HPV and MenACWY, but this was most marked for MenACWY where coverage in London was 7.8pp lower than in the South of England (Table 3).

Mixed-sex state-funded secondary schools located in LSOAs with the largest BME populations (>=34%) had HPV vaccine coverage 7.1pp below those located in LSOAs with BME populations of <5% (Table 2). In contrast, there was no association between MenACWY vaccine coverage and BME population proportion within the school LSOA (Table 3). There was no clear trend in vaccination coverage by school LSOA deprivation quintiles, though schools located in the least deprived LSOAs had the highest coverage for both HPV and MenACWY (3.8pp and 10.4pp higher than schools located in the most deprived LSOAs for HPV and MenACWY respectively, Tables 2 and 3). Among mixed-sex, state-funded schools, compared with average-sized schools, small schools (up to 400 pupils) had lower coverage for HPV and MenACWY (-10.4pp and -7.9pp respectively) and for MenACWY only, larger schools had higher coverage (2.6pp)

DISCUSSION

Interpretation of key findings

Although national HPV and MenACWY vaccine coverage is high, this first school-level analysis has identified important school-level factors associated with wide variations in vaccine coverage.

The lower coverage in Jewish schools for HPV but not for MenACWY suggests that there are no issues with vaccination acceptance or access in general, but there may be less acceptance of the need for HPV vaccine particularly within this religious community. In Muslim schools, coverage was lower for MenACWY and HPV, the difference was only significantly lower for HPV. In contrast, coverage for both vaccines in Roman Catholic schools was similar or higher than coverage in schools of no religious character. These findings suggest that issues around vaccination may be specific to each religious community and that different vaccines may be perceived differently within a given community. Factors underlying these differences require further investigation.

The vast majority of schools in England participate in the school-based vaccination programmes. A survey of SITs undertaken by Public Health England (PHE)'s national immunisation team highlighted that only a small number of minority faith/anthroposophic (Steiner) schools in specific areas declined to allow immunisation teams access. In these instances, it is sometimes possible for immunisation teams to provide letters and/or leaflets directing pupils to external clinics, although uptake is likely to be lower in these settings than in school-based sessions.

The marked variation in coverage across school types is likely to be multi-factorial. Our analysis has showed that school size is a factor, with smaller schools achieving lower coverage; state-funded secondary schools are the largest, followed by independent, special schools and pupil referral units. Identifying and reaching eligible pupils in referral units, where pupil numbers are likely to be small and change throughout the year, with possibly only one eligible child in a particular year, is more challenging than in larger schools. Immunisation teams may also find it more resource-efficient to visit and offer mop-up sessions in larger schools where a greater number of pupils can be reached at any one visit. Pupils in special schools in particular may have specific health needs that are typically managed by their general or specialist practitioner, and children with medical conditions are less likely to be immunised(20). Information about vaccines given by other health practitioners may not always get back to the immunisation teams responsible for providing vaccine coverage data to PHE. In addition, the independent school category may include some small schools that cater for children with special educational or health needs so there could be some overlap between categories. Steiner schools, identified by several SITs as not offering vaccination, are typically independent schools and could not be identified separately in our analysis (they are categorised as having no religious character).

There was no difference in HPV coverage between mixed and female-only schools. The reason behind the higher Men ACWY coverage in single-sex schools is unclear, though in the case of female-only schools it may partly be because MenACWY can be offered alongside the existing HPV programme. It could also be that in mixed schools, boys have lower coverage than girls, although this cannot be verified because gender specific coverage is not collected.

Coverage was lower for London compared with other areas, as seen across other childhood immunisation programmes (21). Participation from London was low in this study particularly for HPV. Lack of statistical power with the London HPV sample may partly explain why HPV coverage for London was not lower than the baseline after adjusting for other factors.

The ability to study school-specific factors was a major strength of this study. Although we did a restricted, mixed-sex state-funded secondary schools only sub-analysis (i.e. schools most likely to have pupil catchment areas in the immediate locality) to determine the association between coverage and deprivation and ethnicity factors, the influence of these factors on vaccine coverage is less clear. However, the fact that schools in the most deprived areas had lowest coverage across both programmes suggests that even within a school-based programme, deprivation has an influence on coverage. These findings may be less reliable in London as students may travel in other parts of the city to attend school.

The lower HPV coverage in schools located in areas with the highest BME proportion, could relate to the school-level finding of particular religious schools having lower coverage for HPV. These results suggest some religious and possibly ethnic groups have objections to offering or receiving the HPV vaccine in particular. These results were not observed for the MenACWY vaccination programme.

Limitations of the data

This dataset relied on voluntary submissions of school-level data. Although the dataset contained schools from only 26% and 32% of LAs for HPV and MenACWY respectively, overall coverage aligned well with national coverage, and the distribution of school size in the sample was broadly similar to the national distribution, with a slight over-representation of small schools. Overall, the dataset appeared to be representative. Because the schools census does not allow to easily distinguish primary and secondary schools, we could not ascertain whether the proportion of religious, independent, and special schools were similar in our sample compared with all schools in England. This may affect the precision of the findings and may lead to failing to detect associations between particular characteristics and uptake for school types that are underrepresented.

Although the numerator for each school should include any vaccine given up to and including 31 August 2017, it could be underestimated as some schools/areas may only include vaccines given in the particular academic year, which ends in July in most schools. The extent to which this is an issue is unclear, but likely small as only a limited number of individuals in these age groups receive HPV and MenACWY through general practice.

Similarity/difference to results of other studies

HPV vaccine uptake by school denomination has previously been studied in Scotland though no difference in uptake was found between denominational and non-denominational schools(22). This may be because the denomination category did not allow the detail of individual types of denominational schools to be explored, and because the number of non-Christian faith schools is small. Similar to our findings, the Scottish study found that those in schools with the highest deprivation quintile (as measured by the percentage of pupils eligible for free school meals) had a significantly lower uptake than those in schools with the lowest percentage of pupils eligible for free school meals(22), deprivation was also significantly associated with lower vaccine coverage for the

influenza programme(15). A previous study in South West England found no evidence of an association of HPV vaccination and deprivation (assigned by LSOA of residence), but did find an association by ethnicity (individual-level), and that young women attending non-mainstream educational settings were less likely to initiate vaccination(23). A systematic review of factors associated with HPV vaccine initiation and completion in teenage girls found that having a Caucasian ethnic background was associated with higher rates vaccine initiation and completion(24). Another systematic review mainly including studies from the USA also found inequalities with regards to ethnicity, and more specifically that compared with White women, Black women were less likely to be vaccinated against HPV (25). Although these findings are not directly comparable to our ecological analysis of the role of ethnicity, the results are nonetheless compatible.

Vaccine uptake for the school-based influenza programme by area (LSOA) level factors has identified variation by religious beliefs with adjusted uptake in 4-11 year olds in the highest Muslim population tertile 8% lower than the lowest Muslim population tertile, but this could be specific to the influenza vaccine because of the porcine origin gelatine component(13). Similarly to MenACWY and HPV, Influenza vaccine uptake in schools was higher in rural areas than in urban areas, and similarly to HPV coverage decreased with increasing proportion of BME population in the LSOA, although the association was stronger with the influenza vaccine(13). The school-based influenza vaccine programme targets a much younger age group, and there may be other factors influencing uptake such as perceptions and attitudes to each disease.(26)

Finally, in addition to school-based programmes, variation in uptake by ethnicity, deprivation and geography is also found in primary care-based programme(10,11) and while some factors influencing uptake are school specific, others may be more closely related to characteristics of the population attending these schools.

Conclusions

Although school delivery programmes achieve high coverage for adolescent vaccine programmes overall, there are particular types of schools that have lower coverage and where alternative approaches to improve coverage might be beneficial. This includes particular religious schools, where further understanding of acceptance of particular vaccinations would be helpful. Tailored approaches, such as the World health Organization's "Tailoring immunization programmes" (TIP), that aim to understand barriers that are context specific(27) , could help improve uptake in these schools. Because factors influencing uptake are likely to be a mix of school based and community-based factors, tailored strategies addressing both aspects are most likely to succeed. In addition, it could be helpful to share best practice regarding the best ways of reaching pupils in small specialist schools and pupil referral centres. It is important to bear in mind that as well as considering school-level factors, the individual relationship between a school and immunisation nursing teams must be mutually supportive for successful vaccine delivery(28). It is hoped that, given these findings, submission of school-level data returns will improve to enable continued monitoring of these influences on vaccine coverage.

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Author contributions:

KT, JW, ME and MR designed the study. KT, ME and NA designed the analytical plan. KT and ET managed and analysed the data. All authors contributed to writing the manuscript.

Data Sharing

The school level dataset (anonymised to prevent school-level disclosure) can be requested by emailing the corresponding author .

Competing interests: none

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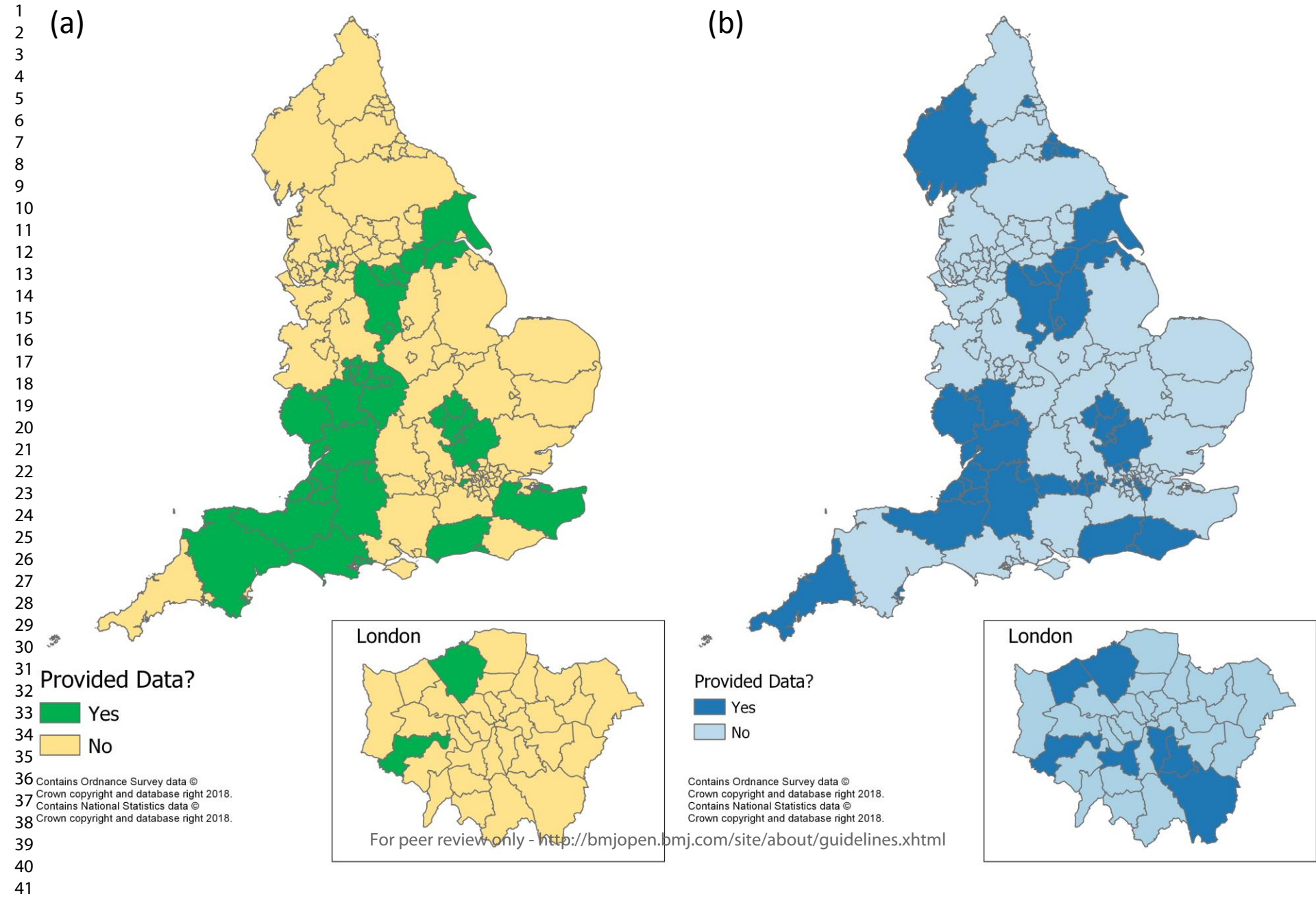
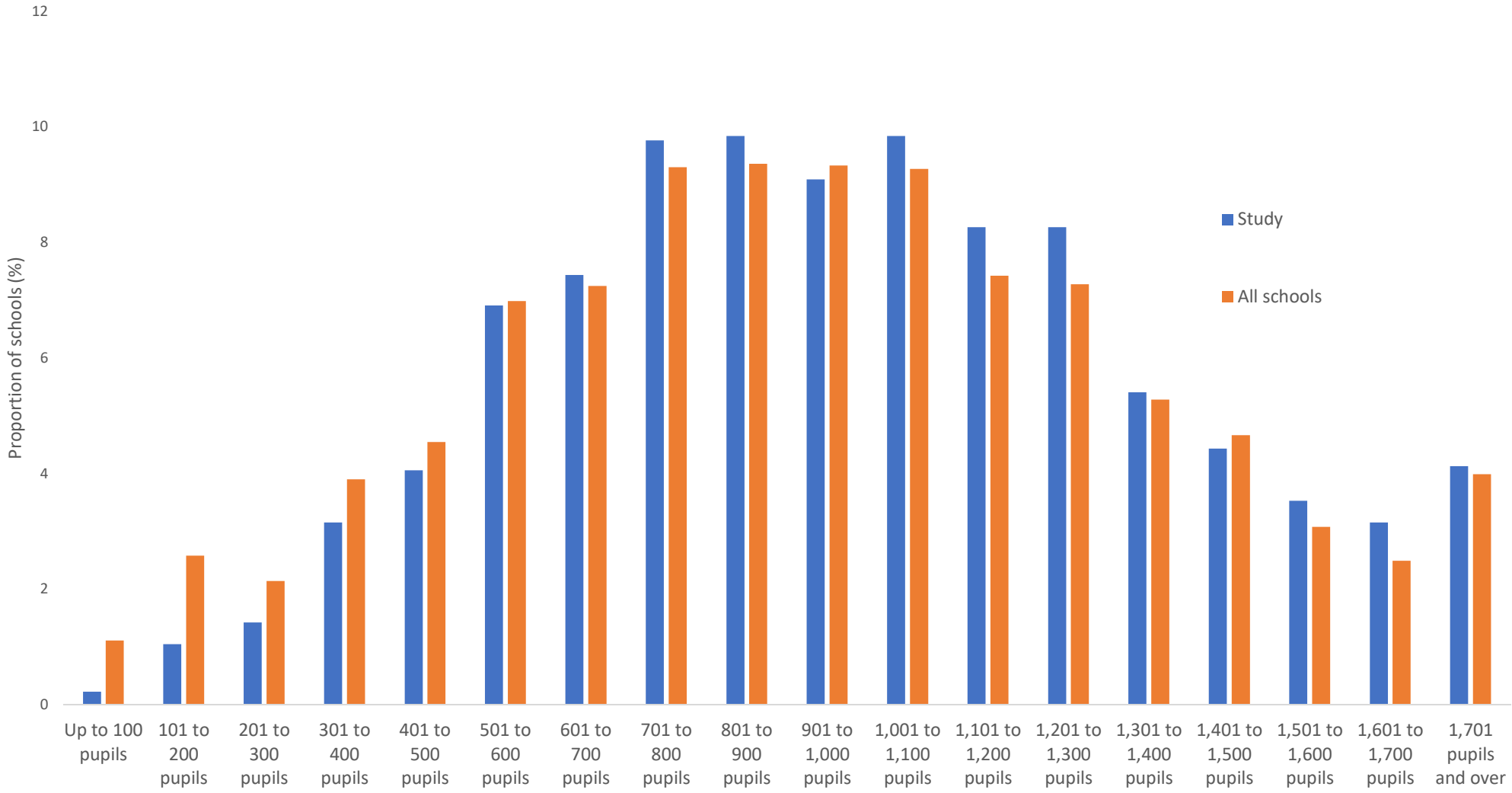
Figure 1. Local Authorities providing school-level (a) HPV vaccine coverage data (n=40), and (b) MenACWY vaccine coverage data (n=48) included in the analysis in 2016/17

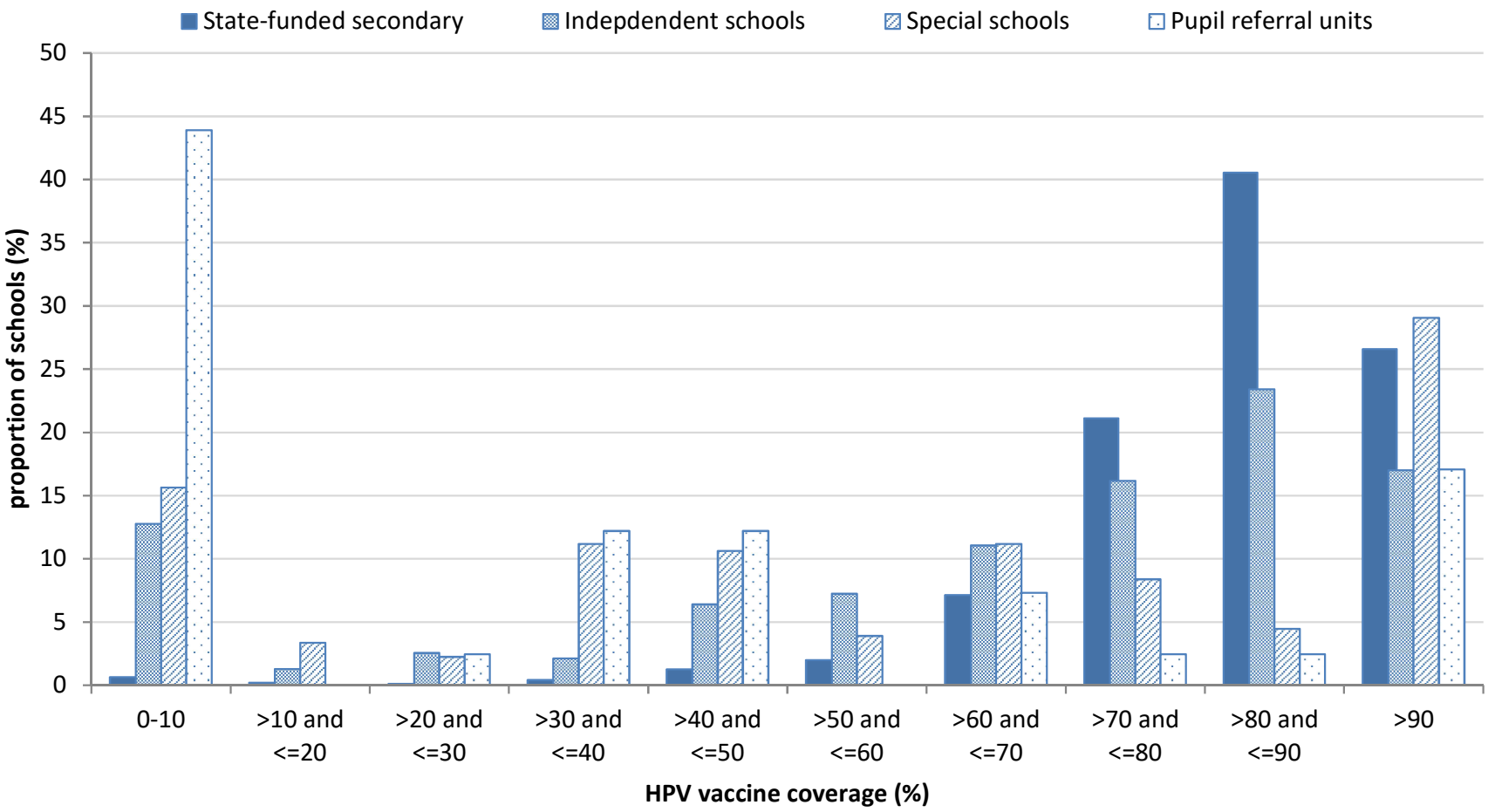
Figure 2. Distribution of state funded secondary schools by pupil numbers, England, 2017

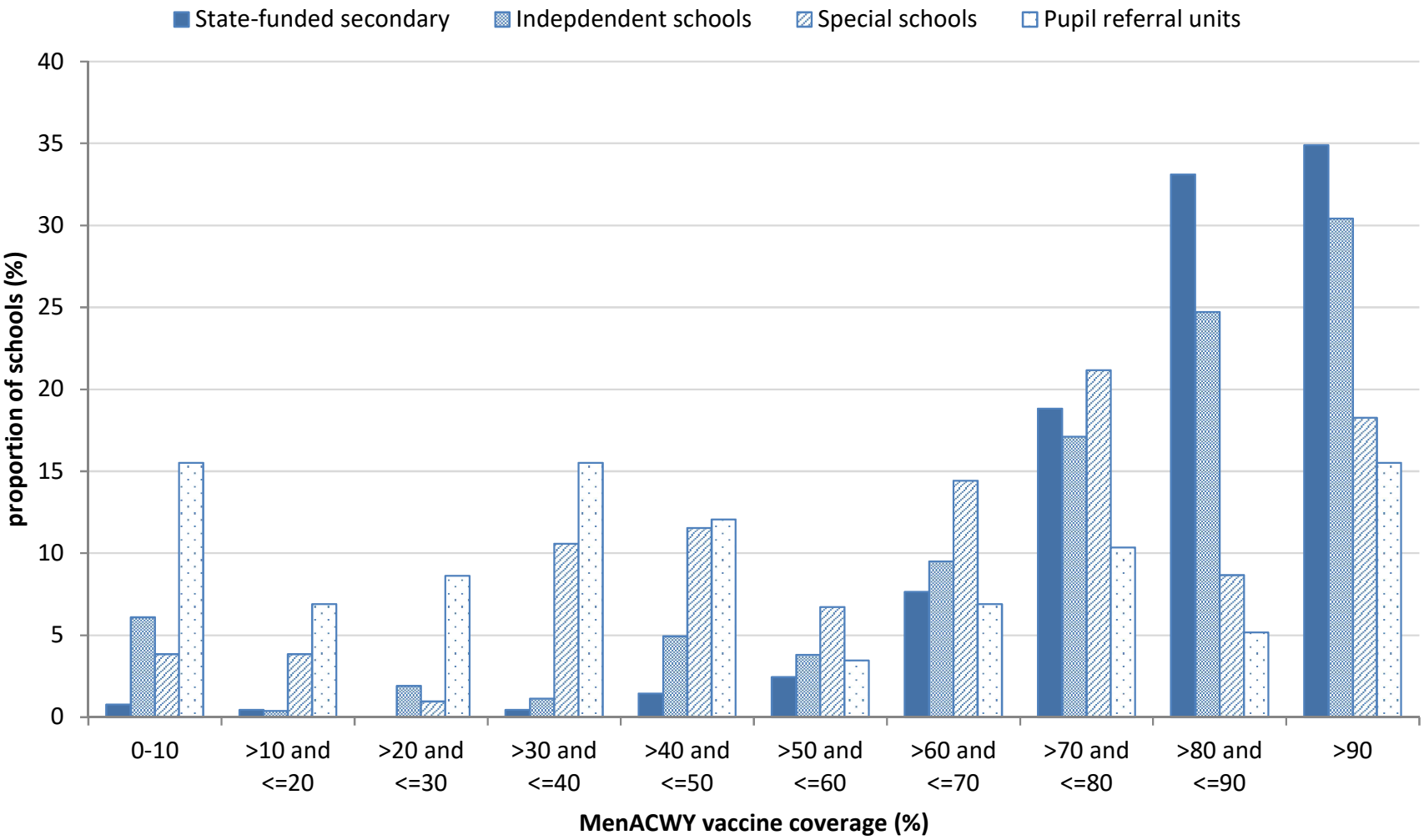
Figure 3. HPV vaccine coverage distribution by school type 2016/17

Figure 4. MenACWY vaccine coverage distribution by school type 2016/17




12
10
8
6
4
2
0
Proportion of schools (%)
Study
All schools
Up to 100 pupils
101 to 200 pupils
201 to 300 pupils
301 to 400 pupils
401 to 500 pupils
501 to 600 pupils
601 to 700 pupils
701 to 800 pupils
801 to 900 pupils
901 to 1,000 pupils
1,001 to 1,100 pupils
1,101 to 1,200 pupils
1,201 to 1,300 pupils
1,301 to 1,400 pupils
1,401 to 1,500 pupils
1,501 to 1,600 pupils
1,601 to 1,700 pupils
1,701 pupils and over


State-funded secondary
Indepdendent schools
Special schools
Pupil referral units
proportion of schools (%)
50
45
40
35
30
25
20
15
10
5
0
0-10
>10 and <=20
>20 and <=30
>30 and <=40
>40 and <=50
>50 and <=60
>60 and <=70
>70 and <=80
>80 and <=90
>90
HPV vaccine coverage (%)


State-funded secondary
Indepdendent schools
Special schools
Pupil referral units
proportion of schools (%)
40
35
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>10 and <=20
>20 and <=30
>30 and <=40
>40 and <=50
>50 and <=60
>60 and <=70
>70 and <=80
>80 and <=90
>90
MenACWY vaccine coverage (%)

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page found
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	4-7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4-5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4-7
Bias	9	Describe any efforts to address potential sources of bias	7-8
Study size	10	Explain how the study size was arrived at	4-5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	7-8
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	n/a
		(*e*) Describe any sensitivity analyses	n/a
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	n/a
		(b) Give reasons for non-participation at each stage	n/a
		(c) Consider use of a flow diagram	n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8-9
		(b) Indicate number of participants with missing data for each variable of interest	n/a
Outcome data	15*	Report numbers of outcome events or summary measures	8-9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-9

		(*b*) Report category boundaries when continuous variables were categorized	8-9
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	8-9
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8-10
Discussion			
Key results	18	Summarise key results with reference to study objectives	11-12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	12-13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	n/a

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

What school and area level factors influenced HPV and MenACWY vaccine coverage in England in 2016/17? An ecological study

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What school and area level factors influenced HPV and MenACWY vaccine coverage in England in 2016/17? An ecological study

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ABSTRACT

objectives: To describe school and area-level factors that influence coverage of the school-delivered HPV and MenACWY programmes among adolescents.

design: Ecological study

setting and participants: Aggregated 2016/17 data from year 9 pupils were received from 1,407 schools for HPV and 1,432 schools for MenACWY. The unit of analysis was the school.

primary and secondary outcome measures: Percentage points difference in vaccine coverage by school religious affiliation, school type, urban/rural, single sex/mixed and region. A sub-analysis of mixed-sex state-funded secondary schools also included deprivation, proportion of population from black and ethnic minorities, and school size.

results: Muslim and Jewish schools had significantly lower coverage than schools of no religious character for HPV (24.0 (95%CI -38.2, -9.8) and 20.5 (95%CI -30.7, -10.4) percentage points (pp) lower respectively) but not for MenACWY. Independent, special schools and pupil referral units had increasingly lower vaccine coverage compared with state-funded secondary schools for both HPV and MenACWY. For both vaccines, Coverage was 2 pp higher in rural schools than urban schools and lowest in London. Compared with mixed schools, HPV coverage was higher in male-only (3.7pp, 95%CI 0.2, 7.2)) and female-only (4.8 pp, 95%CI 2, 7.6) schools. In the sub-analysis, schools located in least deprived areas had the highest coverage for both vaccines (3.8 (0.9, 6.8) and 10.4 (7.0, 13.8) percentage points for HPV and MenACWY respectively), and the smallest schools had the lowest coverage (-10.4 (-14.1, -6.8) and -7.9 (-12, -3.8) for HPV and MenACWY, respectively).

conclusions: Tailored approaches are required to improve HPV vaccine coverage in Muslim and Jewish schools. In addition, better ways of reaching pupils in smaller specialist schools are needed.

Strengths and limitations of this study

- This study is the first school-level analysis of factors influencing the coverage of school-delivered vaccines among adolescents in England
- The data set includes a large number of schools across the country and the school level variables collected allow determination of associations between vaccine coverage and previously unstudied factors such as school type or faith affiliation
- The voluntary nature of the school-level data return means the dataset is not complete
- For some types of schools, the dataset only includes a small number of schools, limiting the precision of some of the results
- The analysis of socio economic factors was restricted to mixed-sex state-funded secondary schools only, based on the assumption that they were more likely to represent pupils from their immediate geographical area

INTRODUCTION

Offering vaccination at school enables large numbers of children to be vaccinated without requiring individual appointments. School vaccination achieves higher coverage than primary care for adolescent vaccines(1,2). There are four school-based vaccination programmes in the UK which protect against human papillomavirus (HPV vaccine, females only), meningococcal A, C, W and Y (MenACWY vaccine), diphtheria, tetanus and polio (Td/IPV vaccine), and seasonal influenza(3).

HPV vaccine was introduced for females only in the UK in 2008, initially as a three-dose schedule offered in Year 8 (children aged 12-13 years). In September 2014 this changed to a two-dose schedule(4). The recommendation, for operational ease, is for the first (priming) dose to be offered in Year 8 and the second (completing) dose in Year 9 (age 13-14 years) but NHS England (the agency responsible for commissioning the services) can choose to offer both doses in Year 8. In 2015/16, 85/152 (56%) local authorities (LAs) offered both doses within Year 8(5). HPV vaccine coverage by the end of Year 9 is the final year of assessment for both delivery models. In 2016/17, national Year 9 coverage for HPV was 83.1%(6). MenACWY vaccine was introduced in August 2015 in response to the rising number of meningococcal W (MenW) cases(7). From autumn 2013 adolescent MenC booster had been offered in school years Year 9 or 10 (age 14-15 years) but increasingly LAs were aligning to all offer MenC vaccine in Year 9(8). In 2016/17 82% (124/152) of LAs offered MenACWY routinely in Year 9 through the schools-based programme(9). The Td/IPV ('school leaver booster') vaccine is usually offered alongside MenACWY vaccine. In 2016/17, MenACWY vaccine coverage nationally by the end of Year 9 was 83.6%(9).

Previous studies of the national immunisation programme in England have identified inequalities in terms of geography, ethnicity and deprivation for vaccines delivered in primary care (10,11). A previous analysis of vaccine coverage data for the primary school-based seasonal influenza programme in England, using population-level characteristics at the Lower Super Output Area level (LSOA, small areas with an average of approximately 1,500 residents or 650 households(12)) in which the school was located identified deprivation, non-white ethnicity, religious beliefs and urban areas to be associated with lower coverage(13,14,15). 2016/17 is the first year that school-level data were available nationally for the adolescent vaccination programmes, delivered in secondary schools. This study aims to determine whether school-level and other local area factors are associated with vaccine coverage for those adolescent programmes.

METHODS

In England, school-based vaccination is delivered by a variety of public and private healthcare providers and commissioned and coordinated through Screening and Immunisation Teams (SITs). Data are routinely collected in each school through tally sheets, aggregated at local LA level and submitted to PHE. Therefore prior to 2016/17 school-level data, although collected, were not routinely available at national level. In September 2017, the 14 SITs in England were asked to voluntarily submit school-level vaccine coverage data for 2016/17 for all schools in their area using a standardised MS Excel data collection tool. Reminders to submit school-level data were sent out as each submission of LA-level data was received and validated.

School level data for the 2016/17 academic year includes vaccines given up to and including 31 August 2017. For HPV the data will have included some doses given in the previous academic year (2015/16))

Queries on data were sent back to providers if:

- Denominators or numerators were missing for particular schools. For the small number of schools where denominators were unavailable from the provider, nationally published school roll data were used instead(16).
- A numerator was greater than a denominator (coverage >100%).
- Coverage was 100% for schools with >20 pupils in the denominator.
- All schools in an LA were queried if substantial changes were made to any individual schools queried above, and/or if total numerators, denominators or coverage differed by more than 5% from published statistics for LA coverage(9,6).

School delivery of the MenACWY and Td/IPV vaccines are generally organised concurrently and given on the same day, so only MenACWY data were used and the findings relating to MenACWY should be generalisable to Td/IPV.

Data were analysed for school year 9 pupils (13-14 year olds), born 1 September 2002 to 31 August 2003. Vaccine coverage of a completed course was calculated by dividing the number of year 9 females receiving two doses of HPV vaccine and the number of year 9 pupils receiving one dose of MenACWY vaccine by the total number of females and adolescents respectively in the school year.

School characteristics (table 1) were obtained from the Department for Education 2017 school census and were linked to vaccine coverage using each school' unique reference number. The LSOA-level geographical factors (Table 1), based on the location of each school were assigned to mixed-sex state-funded secondary schools only, as these schools were considered most likely to represent pupils from their immediate geographical area. All schools were assigned an NHS commissioning region (South of England, London, Midlands and East of England, North of England) based on their geographical location. We described the geographical distribution of schools included in the study and compared state-funded secondary schools in the study with all state-funded secondary schools in terms of distribution by school size, graphically and using chi-square test. It was not possible to compare the distribution of the sample with all schools in England because the Department of Education's school dataset does not report the number of independent and special schools or pupil referral units separately between primary and secondary education.

Table 1. School and geographical characteristics included in the analysis		
Type of characteristics	**Categories**	**notes**
Religious affiliation*	No religious character	
	Church of England/Other Christian faith excluding Roman Catholic	includes Anglican, Free Church, Methodist, Other Anglican Faith, Other Christian Faith, Plymouth Brethren Christian Church
	Roman Catholic	
	Jewish	
	Islam/Muslim	
	Other	includes Hindu, Sikh and other
School type*	State-funded secondary	
	Independent	
	Special school	combines state-funded and non-maintained, schools for children with special educational needs
	Pupil referral unit	schools for children excluded from mainstream education because of behaviour, sickness, or other reasons
Urban/rural*	Urban	
	Rural	
Single sex/mixed*	Mixed	
	Female	
	Male	
School Size (number of pupils)++	Up to 400 (small)	Mean headcount was 728 pupils (range 1-2945)
	>400 to 1000 (average)	
	>1000 (large)	
% of population classifying themselves as black or minority ethnic (BME)**	<5%,	Includes any ethnic group other than 'White: English/Welsh/Scottish/Northern Irish/British, based on 2011 census categories (17). The thresholds are aligned with those used for influenza vaccine coverage school-level analyses in England (13,18).
	>=5% and <12%	
	>=12% and <34%	
	>=34%	
Index of multiple deprivation 2015**	quintiles	1 represents the most deprived, 5 the least deprived. Quintiles were obtained by combining published deciles which rank the 32,844 LSOAs in England from most deprived to least deprived and dividing them into ten equal groups (19).

*School characteristic
** Lower super output (LSOA) characteristic
++ School characteristic only used in the mixed-sex, state funded school only sub-analysis

Statistical analyses

To take account of school variability and size, individual coverage was calculated for each school, and the analysis was weighted by the denominator of each school.

Unadjusted regression models were used for each school-level factors (except school size, which was adjusted for by weighting) and region to explore differences in coverage from the baseline for each factor (religious affiliation, school type, urban/rural, single sex/mixed . In addition to school-level factors, the association between ethnicity and deprivation LSOA level factors (proportion of BME in school LSOA, deprivation) and vaccine coverage were explored for mixed-sex state-funded secondary schools, using the same model. To ascertain the effect of school size, we opted to include school size as a variable, rather than weighting, in the mixed-sex state funded only sub-analysis. We restricted the analysis of school size to this subanalysis because all pupil referral units and special schools were small and had less than 400 pupils. An adjusted linear regression model was then used, presenting differences in coverage from the baseline for each factor, adjusting for all other school-level factors. Area level factors (proportion of BME in school LSOA, deprivation) were adjusted for all other factors in the subanalysis restricted to mixed-sex state-funded secondary schools

This analysis was undertaken using aggregated data routinely collected as part of the ongoing monitoring of the vaccination programme. No specific funding was sought and no formal ethical approval was required.

Analyses were undertaken in STATA SE/V.13.1 statistical software.

Patient and Public Involvement

This study used routinely collected aggregated data and patients were not involved.

RESULTS

Representativeness of dataset

HPV vaccine coverage school-level data for Year 9 was received from 41/152 LAs. One LA was excluded because their programme was run in primary care during 2015/16. The final HPV analysis therefore included 40/152 (26.3%) LAsand 1,407 schools.

MenACWY vaccine coverage school level data for Year 9 was received from 50 LAs. Two were excluded: one ran a selective (males only) vaccination programme and the other delivered their programme through primary care. In total, 48/152 (31.6%) LAs representing 1,432 schools were included in the MenACWY analysis.

National HPV vaccine coverage in year 9 in 2016/17 was 83.1% (6) compared with 82.1% among schools included in the study. National MenACWY vaccine coverage in year 9 in 2016/17 was 83.6% (9) compared with 83% among schools included in the study.. Schools from each of the four NHS England regions were included, and LAs from all four quartiles of nationally published LA-level HPV vaccine coverage were represented for both HPV and MenACWY.

Compared with the all state funded secondary schools in England, small state-funded secondary schools were under-represented (p=0.03). Distribution was otherwise graphically comparable (figure 1). London schools were underrepresented, in particular for HPV where they comprised 3.3% of included schools, whereas 14.6% of all England state funded secondary schools are in London.

School type

In the HPV vaccine coverage dataset, there were 952 state-funded secondary schools, 235 independent schools, 179 special schools and 41 pupil referral units. HPV vaccine coverage was >80% in 67.1% of state-funded secondary schools, 40.4% of independent schools, 33.5% of special schools and 19.5% of pupil referral units (Figure 2).

In the MenACWY vaccine coverage dataset, there were 903 state-funded secondary schools, 263 independent schools, 208 special schools and 58 pupil referral units. MenACWY vaccine coverage was >80% in 68.0% of state-funded secondary schools, 55.1% of independent schools, 26.9% of special schools and 20.7% of pupil referral units (Figure 3).

Factors associated with HPV and MenACWY vaccine uptake

In the adjusted analysis, Muslim and Jewish schools had significantly lower HPV coverage than schools of no religious character (24 and 20.5 percentage points (pp) lower respectively, Table 2) but this was not the case for MenACWY vaccine coverage (Table 3).

Table 2. HPV vaccine coverage and unadjusted/adjusted impact on coverage determined through linear regression,

weighted by school size, of school-level predictors, 13-14 year olds, England, 2016/17. *Estimates are in bold if p<0.05. Estimates were adjusted for all variables.*

Variable (significance)	Number of schools	Number of children	Crude vaccine coverage* (%)	Standard deviation of school-level coverage	Unadjusted difference in coverage from baseline (95% confidence interval)	Adjusted difference in coverage from baseline (95% confidence interval)‡
Denomination of school (p<0.001)						
No religious character	1,140	73,834	82.4	25.4	*Baseline*	*Baseline*
Church of England/Other Christian faith excluding Roman Catholic	164	9,201	79.8	21.8	**-2.5 (-4.7, -0.4)**	-0.7 (-2.9, 1.5)
Roman Catholic	90	6,736	84.3	12.2	2.0 (-0.6, 4.5)	1.9 (-0.6, 4.3)
Islam/Muslim	7	178	56.7	24.7	**-25.6 (-40.5, -10.7)**	**-24 (-38.2, -9.8)**
Jewish	5	356	59.6	33.6	**-22.8 (-33.4, -12.3)**	**-20.5 (-30.7, -10.4)**
Other (Hindu, Sikh, Other)	1	48	93.8	-	11.4 (-17.3, 40.0)	10.4 (-16.9, 37.7)
Type of school (p<0.001)						
State-funded secondary	952	83,741	83.1	13.0	*Baseline*	*Baseline*
Independent school	235	5,693	72.8	30.9	**-10.3 (-12.9, -7.7)**	**-10.3 (-13.0, -7.5)**
Special school	179	819	56.7	35.6	**-26.4 (-33.2, -19.7)**	**-26.1 (-32.7, -19.4)**
Pupil referral unit	41	100	42.0	38.9	**-41.1 (-60.3, -21.8)**	**-41.1 (-60.0, -22.2)**
Urban/rural classification of school (p=0.03)						
Urban	1,165	77,645	82.0	24.4	*Baseline*	
Rural	242	12,708	83.1	25.2	1.1 (-0.8, 3.0)	**2.0 (0.1, 3.9)**
Sex of school pupils (p=0.07)						
Mixed	1,289	78,114	82.2	25.0	*Baseline*	*Baseline*
Males	-	-	-	-	-	-
Females	118	12,239	81.7	19.8	-0.5 (-2.5, 1.4)	1.8 (-0.1, 3.7)
Region (p<0.001)						
South of England	580	36,855	81.0	24.8	*Baseline*	*Baseline*
London	47	3,416	77.0	14.7	**-4.0 (-7.6, -0.4)**	-3.3 (-6.8, 0.1)
Midlands and East of England	572	36,669	82.8	24.0	**1.8 (0.4, 3.3)**	**2.0 (0.6, 3.4)**
North of England	208	13,413	84.6	26.7	**3.6 (1.6, 5.6)**	**3.6 (1.6, 5.5)**
Proportion BME in school LSOA **(p<0.001)						
<5%	243	20,210	85.5	13.3	*Baseline*	
>=5 and <12%	302	25,210	83.7	12.1	-1.8 (-3.7, 0.1)	-1.6 (-3.8, 0.6)
>=12 and <34%	233	19,614	81.8	13.3	**-3.7 (-5.6, -1.7)**	**-4.2 (-6.8, -1.6)**
>=34%	109	8,742	78.0	12.9	**-7.5 (-10.0, -5.0)**	**-7.1 (-10.8, -3.3)**
Deprivation quintile of school LSOA (p<0.001)**						
1 (most deprived)	149	11,295	78.6	15.3	*Baseline*	*Baseline*
2	157	12,318	84.0	11.4	**5.3 (2.8, 7.9)**	**3.2 (0.2, 6.0)**
3	171	14,177	82.3	13.1	**3.7 (1.2, 6.2)**	1.5 (-1.3, 4.4)
4	218	18,892	83.3	13.1	**4.6 (2.3, 7.0)**	2.6 (-0.2, 5.4)
5 (least deprived)	192	17,094	85.5	11.6	**6.9 (4.5, 9.3)**	**3.8 (0.9, 6.8)**
School Size (number of pupils) (p<0.001)**						
>400 to 1000	409	26601	82.7	13.2	*Baseline*	*Baseline*
Up to 400	50	1397	74.9	21.7	**-10.6 (-14.3, -6.8)**	**-10.4 (-14.1, -6.8)**
>1000	428	45778	83.4	10.8	1.3 (-0.4, 3.0)	1.4 (-0.3, 3.1)
Total	***1,407***	***90,353***	***82.1***	***24.6***		

**Crude coverage calculated as total numerators divided by total denominators*

*** based on subset of mixed-sex state-funded secondary schools (n=887)*

‡School-level factors (denomination, type of school, urban/rural, sex of school pupils, region) are adjusted for other school-level factors only

Table 3. MenACWY vaccine coverage and unadjusted/adjusted impact on coverage determined through linear regression, weighted by school size, of school-level predictors, 13-14 year olds, England, 2016/17. *Estimates are in bold if p<0.05. Estimates were adjusted for all variables.*

Variable (significance)	Number of schools	Number of children	Crude vaccine coverage* (%)	Standard deviation of school-level coverage	Unadjusted difference in coverage from baseline (95% confidence interval)	Adjusted difference in coverage from baseline (95% confidence interval)‡
Denomination of school (p=0.685)						
No religious character	1,170	140,011	83.1	22.4	*Baseline*	*Baseline*
Church of England/Other Christian faith excluding Roman Catholic	158	17,765	82.8	15.8	-0.3 (-2.6, 2.0)	-0.3 (-2.6, 1.9)
Roman Catholic	91	13,374	83.0	14.1	-0.1 (-2.7, 2.5)	-0.3 (-2.7, 2.2)
Islam/Muslim	6	60	56.7	34.2	-26.4 (-63.4, 10.5)	-23.3 (-58.4, 11.8)
Jewish	5	605	79.3	13.4	-3.7 (-15.4, 7.9)	1.2 (-9.9, 12.3)
Other (Hindu, Sikh, Other)	2	153	92.8	30.7	9.7 (-13.4, 32.9)	17.6 (-4.4, 39.6)
Type of school (p<0.001)						
State-funded secondary	903	155,760	83.6	14.3	*Baseline*	*Baseline*
Independent school	263	13,238	81.0	25.4	**-2.6 (-5.1, -0.1)**	**-2.8 (-5.4, -0.2)**
Special school	208	2,402	65.3	25.7	**-18.2 (-23.9, -12.4)**	**-18.0 (-23.6, -12.4)**
Pupil referral unit	58	568	43.7	33.0	**-40.0 (-51.7, -28.3)**	**-39.6 (-51.0, -28.2)**
Urban/rural classification of school (p=0.003)						
Urban	1,162	144,682	82.6	20.7	*Baseline*	
Rural	270	27,286	85.4	24.2	**2.8 (0.9, 4.7)**	**2.0 (0.1, 3.8)**
Sex of school pupils (p=0.599)						
Mixed	1,268	154,500	82.9	21.5	*Baseline*	*Baseline*
Males	63	6,452	83.3	24.2	0.4 (-3.2, 4.0)	**3.7 (0.2, 7.2)**
Females	101	11,016	84.4	18.0	1.4 (-1.4, 4.3)	**4.8 (2.0, 7.6)**
Region (p<0.001)						
South of England	569	66,632	83.2	21.5	*Baseline*	*Baseline*
London	168	21,097	76.2	22.6	**-7.1 (-9.3, -4.8)**	**-7.8 (-10.0, -5.5)**
Midlands and East of England	298	36,382	83.7	19.9	0.5 (-1.4, 2.3)	0.6 (-1.2, 2.4)
North of England	397	47,857	85.3	21.5	**2.1 (0.4, 3.7)**	**2.3 (0.6, 3.9)**
Proportion BME in school LSOA (p<0.001)**						
<5%	274	45,727	84.9	14.9	*Baseline*	*Baseline*
>=5 and <12%	263	47,521	84.9	13.7	0.1 (-2.0, 2.1)	0.4 (-2.1, 2.9)
>=12 and <34%	182	32,394	83.6	13.0	-1.3 (-3.6, 1.0)	1.1 (-1.8, 4.2)
>=34%	100	16,853	75.6	17.4	**-9.3 (-12.1, -6.5)**	-1.1 (-5.9, 3.8)
Deprivation quintile of school LSOA (p<0.001)**						
1 (most deprived)	108	17,574	76.0	15.3	*Baseline*	*Baseline*
2	148	23,107	82.8	16.8	**6.8 (3.7, 9.9)**	**5.2 (1.8, 8.7)**
3	161	26,006	82.0	16.3	**6.0 (3.0, 9.0)**	**3.9 (0.4, 7.3)**
4	206	37,777	83.6	14.3	**7.6 (4.7, 10.4)**	**5.1 (1.7, 8.4)**
5 (least deprived)	196	38,031	88.2	8.8	**12.2 (9.4, 15.0)**	**10.4 (7.0, 13.8)**
School Size (number of pupils) (p<0.001)**						
>400 to 1000	378	51249	82.1	14.2	*Baseline*	*Baseline*
Up to 400	49	2720	76.9	25.5	**-7.5 (-11.9, 3.2)**	**-7.9 (-12, -3.8)**
>1000	392	88526	84.5	12.7	**3.2 (1.1, 5.3)**	**2.6 (0.6, 4.6)**
Total	***1,432***	***171,968***	***83.0***	***21.4***		

******Crude coverage calculated as total numerators divided by total denominators*

*** based on subset of mixed-sex state-funded secondary schools (n=887)*

‡School-level factors (denomination, type of school, urban/rural, sex of school pupils, region) are adjusted for other school-level factors only

Independent, special schools and pupil referral units had increasingly lower vaccine coverage than state-funded secondary schools for both HPV and MenACWY. This ranged from 10.3pp lower for independent schools to 41.1pp lower for pupil referral units for HPV (Table 2) and from 2.8pp lower for independent schools to 39.6% lower for pupil referral units for MenACWY (Table 3).

Rural schools had 2.0pp higher coverage than urban schools for both HPV and MenACWY (Tables 2 and 3).

Single-sex schools had higher coverage than mixed schools for MenACWY (3.7pp higher for males, 4.8pp higher for females, Table 2) but there was no difference between mixed and female-only schools for HPV (Table 2).

There was regional variation in vaccine coverage for both HPV and MenACWY, but this was most marked for MenACWY where coverage in London was 7.8pp lower than in the South of England (Table 3).

Mixed-sex state-funded secondary schools located in LSOAs with the largest BME populations (>=34%) had HPV vaccine coverage 7.1pp below those located in LSOAs with BME populations of <5% (Table 2). In contrast, there was no association between MenACWY vaccine coverage and BME population proportion within the school LSOA (Table 3). There was no clear trend in vaccination coverage by school LSOA deprivation quintiles, though schools located in the least deprived LSOAs had the highest coverage for both HPV and MenACWY (3.8pp and 10.4pp higher than schools located in the most deprived LSOAs for HPV and MenACWY respectively, Tables 2 and 3). Among mixed-sex, state-funded schools, compared with average-sized schools, small schools (up to 400 pupils) had lower coverage for HPV and MenACWY (-10.4pp and -7.9pp respectively) and for MenACWY only, larger schools had higher coverage (2.6pp)

DISCUSSION

Interpretation of key findings

Although national HPV and MenACWY vaccine coverage is high, this first school-level analysis has identified important school-level factors associated with wide variations in vaccine coverage.

The lower coverage in Jewish schools for HPV but not for MenACWY suggests that there are no issues with vaccination acceptance or access in general, but there may be less acceptance of the need for HPV vaccine particularly within this religious community. In Muslim schools, coverage was lower for MenACWY and HPV, the difference was only significantly lower for HPV. In contrast, coverage for both vaccines in Roman Catholic schools was similar or higher than coverage in schools of no religious character. These findings suggest that issues around vaccination may be specific to each religious community and that different vaccines may be perceived differently within a given community. Factors underlying these differences require further investigation.

The vast majority of schools in England participate in the school-based vaccination programmes. A survey of SITs undertaken by Public Health England (PHE)'s national immunisation team highlighted that only a small number of minority faith/anthroposophic (Steiner) schools in specific areas declined to allow immunisation teams access. In these instances, it is sometimes possible for immunisation teams to provide letters and/or leaflets directing pupils to external clinics, although uptake is likely to be lower in these settings than in school-based sessions.

The marked variation in coverage across school types is likely to be multi-factorial. Our analysis has showed that school size is a factor, with smaller schools achieving lower coverage; state-funded secondary schools are the largest, followed by independent, special schools and pupil referral units. Identifying and reaching eligible pupils in referral units, where pupil numbers are likely to be small and change throughout the year, with possibly only one eligible child in a particular year, is more challenging than in larger schools. Immunisation teams may also find it more resource-efficient to visit and offer mop-up sessions in larger schools where a greater number of pupils can be reached at any one visit. Pupils in special schools in particular may have specific health needs that are typically managed by their general or specialist practitioner, and children with medical conditions are less likely to be immunised(20). Information about vaccines given by other health practitioners may not always get back to the immunisation teams responsible for providing vaccine coverage data to PHE. In addition, the independent school category may include some small schools that cater for children with special educational or health needs so there could be some overlap between categories. Steiner schools, identified by several SITs as not offering vaccination, are typically independent schools and could not be identified separately in our analysis (they are categorised as having no religious character).

There was no difference in HPV coverage between mixed and female-only schools. The reason behind the higher Men ACWY coverage in single-sex schools is unclear, though in the case of female-only schools it may partly be because MenACWY can be offered alongside the existing HPV programme. It could also be that in mixed schools, boys have lower coverage than girls, although this cannot be verified because gender specific coverage is not collected.

Coverage was lower for London compared with other areas, as seen across other childhood immunisation programmes (21). Participation from London was low in this study particularly for HPV. Lack of statistical power with the London HPV sample may partly explain why HPV coverage for London was not lower than the baseline after adjusting for other factors.

The ability to study school-specific factors was a major strength of this study. Although we did a restricted, mixed-sex state-funded secondary schools only sub-analysis (i.e. schools most likely to have pupil catchment areas in the immediate locality) to determine the association between coverage and deprivation and ethnicity factors, the influence of these factors on vaccine coverage is less clear. However, the fact that schools in the most deprived areas had lowest coverage across both programmes suggests that even within a school-based programme, deprivation has an influence on coverage. These findings may be less reliable in London as students may travel in other parts of the city to attend school.

The lower HPV coverage in schools located in areas with the highest BME proportion, could relate to the school-level finding of particular religious schools having lower coverage for HPV. These results suggest some religious and possibly ethnic groups have objections to offering or receiving the HPV vaccine in particular. These results were not observed for the MenACWY vaccination programme.

Limitations of the data

This dataset relied on voluntary submissions of school-level data. Although the dataset contained schools from only 26% and 32% of LAs for HPV and MenACWY respectively, overall coverage aligned well with national coverage so the dataset appeared to be broadly representative. Because the schools census does not allow to easily distinguish primary and secondary schools, we could not ascertain whether the proportion of religious, independent, and special schools were similar in our sample compared with all schools in England. This may affect the precision of the findings and may lead to failing to detect associations between particular characteristics and uptake for school types that are underrepresented.

Although the numerator for each school should include any vaccine given up to and including 31 August 2017, it could be underestimated as some schools/areas may only include vaccines given in the particular academic year, which ends in July in most schools. The extent to which this is an issue is unclear, but likely small as only a limited number of individuals in these age groups receive HPV and MenACWY through general practice.

Similarity/difference to results of other studies

HPV vaccine uptake by school denomination has previously been studied in Scotland though no difference in uptake was found between denominational and non-denominational schools(22). This may be because the denomination category did not allow the detail of individual types of denominational schools to be explored, and because the number of non-Christian faith schools is small. Similar to our findings, the Scottish study found that those in schools with the highest deprivation quintile (as measured by the percentage of pupils eligible for free school meals) had a significantly lower uptake than those in schools with the lowest percentage of pupils eligible for free school meals(22), deprivation was also significantly associated with lower vaccine coverage for the influenza programme(15). A previous study in South West England found no evidence of an

association of HPV vaccination and deprivation (assigned by LSOA of residence), but did find an association by ethnicity (individual-level), and that young women attending non-mainstream educational settings were less likely to initiate vaccination(23). A systematic review of factors associated with HPV vaccine initiation and completion in teenage girls found that having a Caucasian ethnic background was associated with higher rates vaccine initiation and completion(24). Another systematic review mainly including studies from the USA also found inequalities with regards to ethnicity, and more specifically that compared with White women, Black women were less likely to be vaccinated against HPV (25). Although these findings are not directly comparable to our ecological analysis of the role of ethnicity, the results are nonetheless compatible.

Vaccine uptake for the school-based influenza programme by area (LSOA) level factors has identified variation by religious beliefs with adjusted uptake in 4-11 year olds in the highest Muslim population tertile 8% lower than the lowest Muslim population tertile, but this could be specific to the influenza vaccine because of the porcine origin gelatine component(13). Similarly to MenACWY and HPV, Influenza vaccine uptake in schools was higher in rural areas than in urban areas, and similarly to HPV coverage decreased with increasing proportion of BME population in the LSOA, although the association was stronger with the influenza vaccine(13). The school-based influenza vaccine programme targets a much younger age group, and there may be other factors influencing uptake such as perceptions and attitudes to each disease.(26)

Finally, in addition to school-based programmes, variation in uptake by ethnicity, deprivation and geography is also found in primary care-based programme(10,11) and while some factors influencing uptake are school specific, others may be more closely related to characteristics of the population attending these schools.

Conclusions

Although school delivery programmes achieve high coverage for adolescent vaccine programmes overall, there are particular types of schools that have lower coverage and where alternative approaches to improve coverage might be beneficial. This includes particular religious schools, where further understanding of acceptance of particular vaccinations would be helpful. Tailored approaches, such as the World health Organization's "Tailoring immunization programmes" (TIP), that aim to understand barriers that are context specific(27) , could help improve uptake in these schools. Because factors influencing uptake are likely to be a mix of school based and community-based factors, tailored strategies addressing both aspects are most likely to succeed. In addition, it could be helpful to share best practice regarding the best ways of reaching pupils in small specialist schools and pupil referral centres. It is important to bear in mind that as well as considering school-level factors, the individual relationship between a school and immunisation nursing teams must be mutually supportive for successful vaccine delivery(28). It is hoped that, given these findings, submission of school-level data returns will improve to enable continued monitoring of these influences on vaccine coverage.

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Author contributions:

KT, JW, ME and MR designed the study. KT, ME and NA designed the analytical plan. KT and ET managed and analysed the data. All authors contributed to writing the manuscript.

Data Sharing

The school level dataset (anonymised to prevent school-level disclosure) can be requested by emailing the corresponding author .

Competing interests: none

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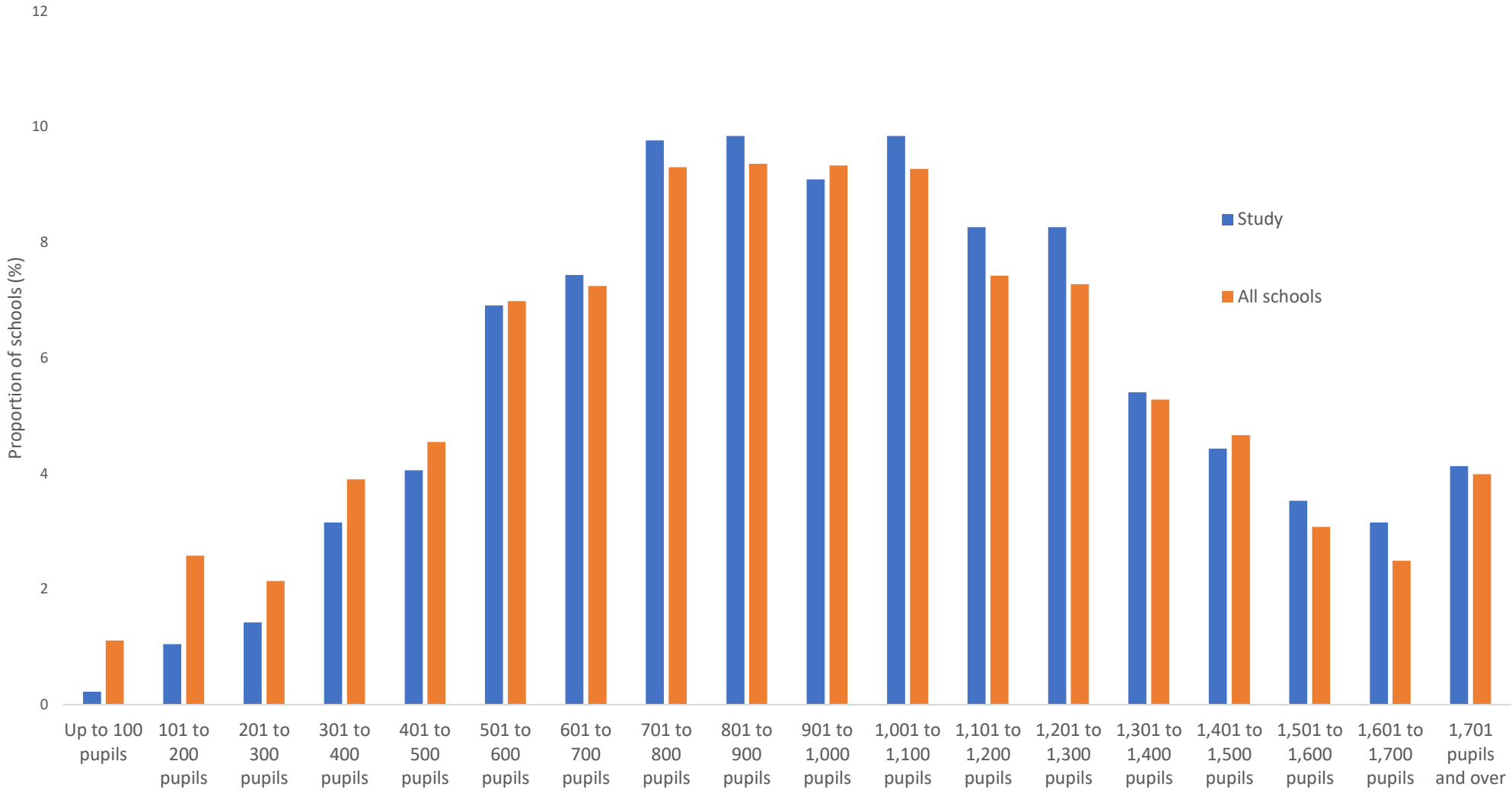
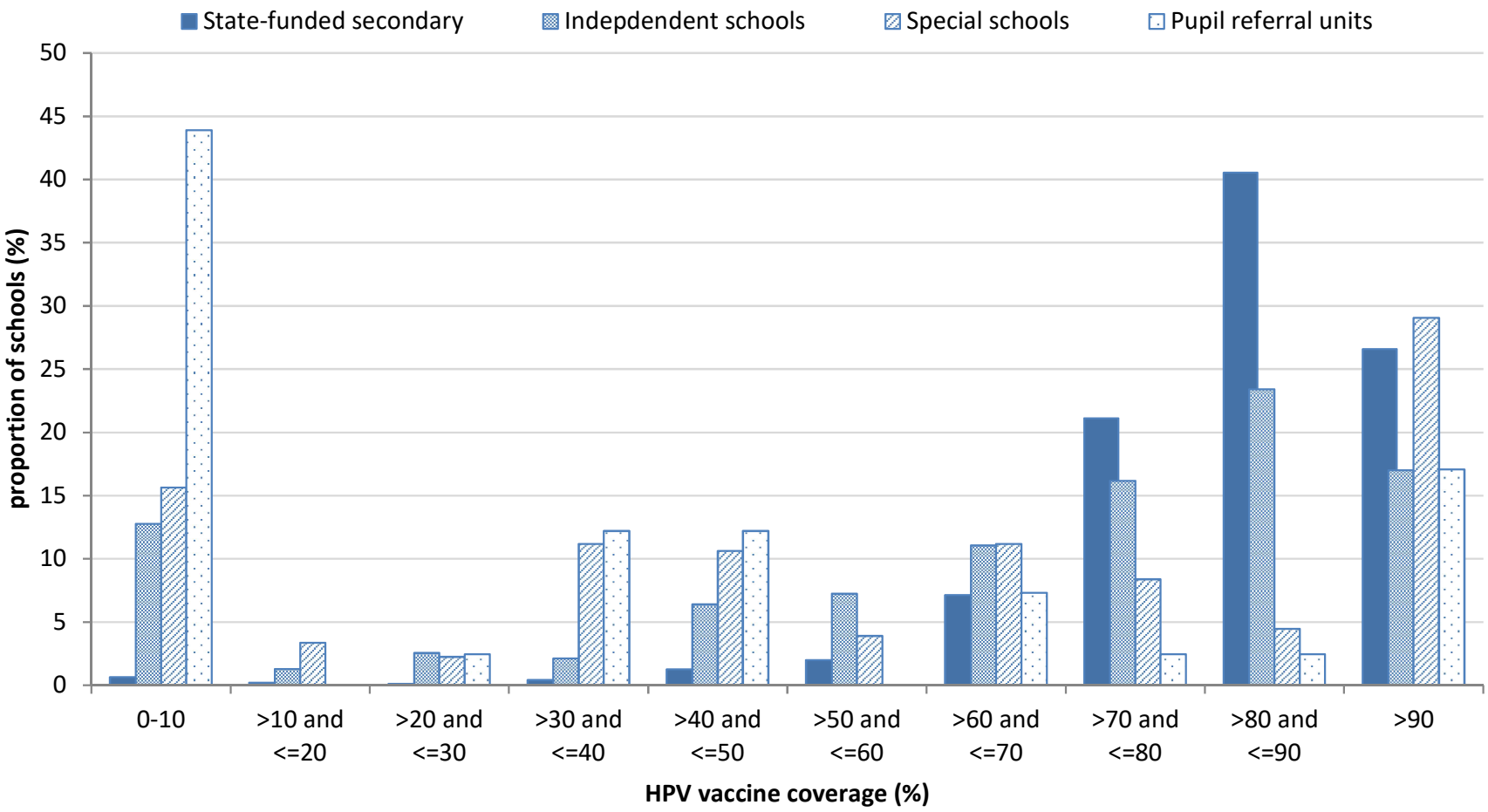
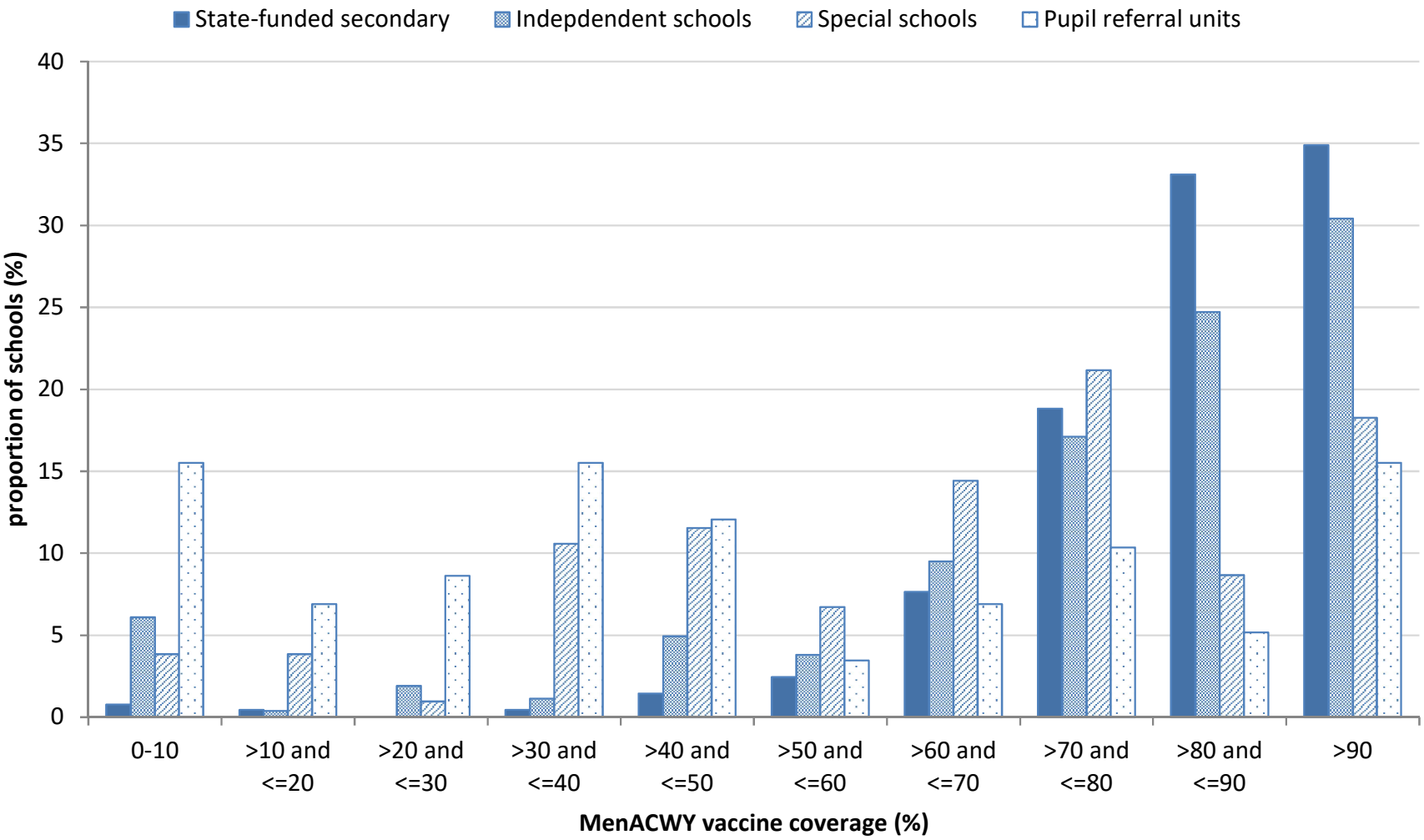
Figure 1. Distribution of state funded secondary schools by pupil numbers, England, 2017

Figure 2. HPV vaccine coverage distribution by school type 2016/17

Figure 3. MenACWY vaccine coverage distribution by school type 2016/17


12
10
8
6
4
2
0
Proportion of schools (%)
Study
All schools
Up to 100 pupils
101 to 200 pupils
201 to 300 pupils
301 to 400 pupils
401 to 500 pupils
501 to 600 pupils
601 to 700 pupils
701 to 800 pupils
801 to 900 pupils
901 to 1,000 pupils
1,001 to 1,100 pupils
1,101 to 1,200 pupils
1,201 to 1,300 pupils
1,301 to 1,400 pupils
1,401 to 1,500 pupils
1,501 to 1,600 pupils
1,601 to 1,700 pupils
1,701 pupils and over


State-funded secondary
Indepdendent schools
Special schools
Pupil referral units
proportion of schools (%)
50
45
40
35
30
25
20
15
10
5
0
0-10
>10 and <=20
>20 and <=30
>30 and <=40
>40 and <=50
>50 and <=60
>60 and <=70
>70 and <=80
>80 and <=90
>90
HPV vaccine coverage (%)


State-funded secondary
Indepdendent schools
Special schools
Pupil referral units
proportion of schools (%)
40
35
30
25
20
15
10
5
0
0-10
>10 and <=20
>20 and <=30
>30 and <=40
>40 and <=50
>50 and <=60
>60 and <=70
>70 and <=80
>80 and <=90
>90
MenACWY vaccine coverage (%)

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page found
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3
Objectives	3	State specific objectives, including any prespecified hypotheses	3
Methods			
Study design	4	Present key elements of study design early in the paper	4-7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4-5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	4-5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	5-6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	4-7
Bias	9	Describe any efforts to address potential sources of bias	7-8
Study size	10	Explain how the study size was arrived at	4-5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	6
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	6
		(*b*) Describe any methods used to examine subgroups and interactions	6
		(*c*) Explain how missing data were addressed	7-8
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	n/a
		(*e*) Describe any sensitivity analyses	n/a
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	n/a
		(b) Give reasons for non-participation at each stage	n/a
		(c) Consider use of a flow diagram	n/a
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	8-9
		(b) Indicate number of participants with missing data for each variable of interest	n/a
Outcome data	15*	Report numbers of outcome events or summary measures	8-9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	8-9

		(*b*) Report category boundaries when continuous variables were categorized	8-9
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	8-9
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	8-10
Discussion			
Key results	18	Summarise key results with reference to study objectives	11-12
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	12
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-13
Generalisability	21	Discuss the generalisability (external validity) of the study results	12-13
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	n/a

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.