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Examining inequalities in the uptake of the school-based HPV vaccination programme in England: a retrospective cohort study

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Title Page

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Abstract

Background: Although uptake of the Human Papillomavirus (HPV) vaccine is high in the United Kingdom, it is unknown whether the programme has been delivered equitably by ethnicity or deprivation. This study aimed to investigate factors associated with HPV vaccine initiation and completion within the routine HPV vaccination programme in the South West of England.

Methods: Data were retrieved for young women eligible for routine vaccination from 2008/09 to 2010/11 from three Primary Care Trusts/local authorities. Multivariable logistic regression models were developed to examine factors associated with uptake of HPV vaccination.

Results: Of 14,282 eligible young women, 12,658 (88.6%) initiated, of whom 11,725 (92.6%) completed the course. Initiation varied by programme year (86.5 to 89.6%) and Primary Care Trusts/local authorities (84.8 to 91.6%). There was strong evidence for an overall difference of initiation by ethnicity ($p<0.001$), but not deprivation quintile ($p=0.48$). Young women educated in non-mainstream educational settings were less likely to initiate and, if initiated, less likely to complete (both $p<0.001$).

Conclusions: HPV vaccination uptake did not vary markedly by social deprivation. However, associations with ethnicity and substantially lower uptake in non-mainstream educational settings were observed. Research to identify reasons for low vaccine uptake in these population groups is required.

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Introduction

The World Health Organisation recommends primary prevention of Human Papillomavirus (HPV) infection through vaccination of young women before sexual debut.[1] In 2008, a bivalent HPV vaccine was made routinely available for young women aged 12 to 13 years in the United Kingdom (UK).[2] A course of three doses of the vaccine offered protection against HPV 16 and 18[3] which are responsible for approximately 70% of cases of cervical cancer.[4] In England local government areas, organised by Primary Care Trusts (PCTs)/local authorities, were responsible for the design and delivery of their HPV vaccination programme. Most opted for a school-based programme with 'mop-up' sessions for missed appointments organised in general practice.[5]

In the UK, women who are socioeconomically disadvantaged are less likely to attend cervical screening[6] and have a greater risk of developing cervical cancer.[7] High coverage of the HPV vaccine has the potential to substantially reduce cervical cancer incidence and mortality.[4] However, there is also the potential to increase health inequalities if uptake is lower amongst disadvantaged populations.[8] Preliminary ecological findings from UK feasibility programme suggested lower uptake in more deprived areas.[9 10]

The aim of this study was to assess whether the predominantly school-based UK HPV vaccination programme is being delivered equitably, primarily by deprivation and ethnicity, in the three years following vaccine introduction.

Methods

Population

Three PCTs/local authorities responsible for delivery of the vaccination programme (PCT1, PCT2, PCT3), sharing boundaries and covering urban or rural/urban areas in the South West of England, provided data related to the routine HPV vaccination programme. All records related to young women eligible for vaccination (born between 1st September 1995 and 31st August 1998) and who either attended school or were resident within the local authority boundaries were retrieved. As a result, records of young women from other PCTs/local authority areas are included.

Data extraction

Prior to study commencement, written permission was gained from the participating sites. The local ethics committee confirmed that the analysis was conducted as service evaluation and that formal approval was not required. In the UK, the Child Health Information System holds demographic and vaccination related records for each young person registered with a

general practice. Using a computerised search, the following data fields were extracted from records of the eligible population: (i) date of birth; (ii) postcode; (iii) ethnicity; (iv) dates and location HPV vaccination administered; (v) dates of receipt of Measles, Mumps and Rubella (MMR) vaccinations as a proxy for parental vaccination beliefs, and; (vi) name and code of school.

Postcodes from individual records were linked to the corresponding Lower Super Output Area (LSOA). Deprivation score was assigned using the Index of Multiple Deprivation (IMD) 2010[11] and the sample analysed as quintiles. Ethnicity was grouped as follows: (i) White British; (ii) Mixed ethnicity; (iii) Asian or British Asian; (iv) Black or British Black; (v) Chinese and other, and; (vi) not stated.

Individual records were classed as 'initiated' if there was a record of at least one HPV vaccine dose administered, and 'completed' if all three doses were recorded as administered. If the record indicated that the first and third dose had been administered, but the second was missing, the record was classified as initiated but not completed, to avoid potential overestimation of uptake. The effect of this assumption was tested in a sensitivity analysis. Individuals were categorised as receiving the MMR vaccine if there was a record of timely course completion (2 doses by age 5 years).

A school code was used to assign PCT/local authority responsible for delivery of the HPV vaccine. Publicly available school-level characteristics were obtained to supplement the dataset (school type and proportion of students obtaining five or more A* to C grades in the General Certificate of Secondary Education (GCSE) examinations).[12] Schools were categorised as: (i) comprehensive, non fee-paying; (ii) private, fee-paying; and (iii) non-mainstream educational settings, which included pupil referral units, young offender units, hospital education service, specialist schools for students with significant additional needs, and young women educated at home.

Parents of individuals born within the participating PCT/local authority boundaries are routinely asked antenatally to provide information on ethnicity. Parents may not state the ethnic group for their child because they choose not to, or because they do not understand what they are being asked. Further, children with missing ethnicity data may have been born outside local authority boundaries, such as immigrant populations, and therefore data were not available from antenatal sources.

Exclusion criteria

The records of young women were excluded from analyses if: the record indicated they were deceased or still-born; an invalid postcode was present, or; the relevant school code was either missing, or invalid.

Statistical analyses

Error checking was implemented prior to analysis. Publicly available LSOA[11] and school data[12] were obtained to cross check the accuracy of deprivation score, LSOA, school name, and PCT/local authority.

Initially, a descriptive analysis comprising counts, percentages, medians, and interquartile ranges (IQR) was performed. Logistic univariable analyses and Likelihood Ratio Tests (LRT) were undertaken to identify associations between HPV vaccination initiation and: (i) ethnicity; (ii) deprivation quintile; (iii) PCT/local authority responsible for delivery; (iv) programme year; (v) MMR vaccination receipt, and; (vi) school-level characteristics (school type and educational attainment tertile). Results were presented as Odds Ratios (OR) and 95% Confidence Intervals (CIs) with corresponding p-values.

A multivariable logistic regression model was developed for HPV vaccination initiation. The main determinants were ethnic group and deprivation quintile. Potential confounders (programme year, PCT/local authority, MMR vaccination receipt, and school category) were included a priori. MMR vaccination receipt was associated with HPV uptake but not included in the multivariable model as we considered this was likely to be causally related, rather than a confounder. A separate model was developed with MMR vaccination receipt as the outcome. School-level category 'educational attainment' was not incorporated into the final model due to inconsistency of reporting and correlation with school category.

Potential clustering by school was adjusted for using robust standard errors approach allowing for school-level random effects in the final model. Results were presented as adjusted Odds Ratios (aORs), 95% CIs, and corresponding p-values. Using the same methods, we undertook an analysis of factors associated with HPV vaccination completion for young women who had initiated HPV vaccination. Analyses were performed with STATA statistical package, release 12.1 (STATA Corp, College Station, TX).

Results

Records related to 15,745 young women registered with a general practice and eligible for routine HPV vaccination were extracted. All records had a valid date of birth. Individual records were excluded if they indicated that they were deceased or still-born (n=146, 0.9%),

school code was absent or invalid (n=1,297, 8.2%), or postcode was invalid (n=20, 0.1%). The characteristics of records excluded were similar to those retained by PCT/local authority, programme year and deprivation quintile, but differences were observed by ethnicity (Supplemental Table 1).

Descriptive statistics

Overall, data related to 14,282 young women eligible for routine HPV vaccination were retained for analysis, of whom 12,658 (88.6%) initiated vaccination (Table 1). Of those initiated, 11,725 (92.6%) completed the three dose course. The majority of young women were White British (N=11,070, 77.5%), followed by Asian or British Asian (335, 2.3%). The vaccine eligible population was approximately equal by programme year. Most young women attended non fee-paying schools (13,105, 91.8%).

Univariable analysis of HPV vaccination initiation

There was evidence for an overall association of HPV vaccination initiation by ethnicity, deprivation, PCT/local authority, programme year, and school category variables (all p<0.001) (Table 2). In comparison to White British young women, those belonging to Mixed ethnicity, Asian or British Asian, Black or British Black, 'Chinese and other' and 'not stated' categories were less likely to initiate HPV vaccination (p<0.001). Young women belonging to the third and fourth most deprived quintile were less likely to initiate compared to the least deprived (both p<0.01). Young women eligible in the 2009/10 programme year were less likely to initiate HPV vaccination in comparison to the 2008/09 programme year (p<0.001). Young women attending fee-paying or non-mainstream educational settings were less likely to initiate in comparison to non fee-paying educational settings (both p<0.001).

Multivariable analysis of HPV vaccination initiation

After adjustment for ethnicity, deprivation quintile, PCT/local authority, programme year, and educational setting, there was no evidence of an association of HPV vaccination and deprivation (p=0.48). There was evidence for an overall association of HPV vaccination initiation by ethnicity, PCT/local authority, programme year, and school category variables (all p<0.01) (Table 2). Young women classified as Asian or British Asian (aOR=0.59, 95% CI: 0.44-0.80), Black or British Black (aOR=0.50, 95% CI: 0.32-0.79), Chinese or other (aOR=0.48, 95% CI: 0.33-0.71), and 'not stated' (aOR=0.44, 95% CI: 0.39-0.50) were less likely to initiate HPV vaccination in comparison to White British young women. There was evidence for higher initiation by PCT/local authority in comparison to the reference group (PCT/local authority 2 aOR=1.70, 95% CI: 1.18-2.44 and PCT/local authority 3 aOR=1.75, 95% CI: 1.26-2.43). Young women eligible for HPV vaccination during 2009/10 were less

likely to initiate in comparison to the 2008/09 programme year (aOR=0.76, 95% CI: 0.66-0.86). Young women attending non-mainstream educational settings were less likely to initiate the vaccine in comparison to those attending non fee-paying settings (aOR=0.16, 95% CI: 0.11-0.24).

Univariable and multivariable analysis of HPV vaccination completion following initiation

There was evidence for an overall association between completion by ethnicity, deprivation quintile, PCT/local authority, and school category variables (all p<0.01), but not programme year (p=0.77) (Table 3). Young women with ethnicity category 'not stated' were less likely to complete the vaccination course (p<0.001), but no evidence for a difference was observed across other ethnicity categories. There was some evidence for a difference by deprivation quintile, with young women belonging to the third most deprived quintile appearing less likely to complete the HPV vaccination course (p=0.008). Differences were observed by PCT/local authority (all p<0.001) and young women attending a non-mainstream educational setting (p<0.001). There was no evidence for differences in completion by programme year.

After adjustment for ethnicity, deprivation quintile, PCT/local authority, programme year, and educational setting, there was evidence for an overall association for completion by PCT/local authority and school category variables (both p<0.001). However, there was no strong evidence by ethnicity (p=0.08), deprivation quintile (p=0.104), or programme year variables (p=0.71) (Table 3). There was strong evidence that being eligible for vaccination in PCT/local authority 3 was associated with higher HPV vaccination completion in comparison to PCT/local authority 1 (aOR=1.85, 95% CI: 1.43-2.41). Attending a non-mainstream educational setting was associated with lower odds of completion in comparison to non fee-paying setting (aOR=0.27, 95% CI: 0.17-0.44).

Testing the assumption that vaccination doses which appeared to be missing were actually administered resulted in similar aORs and 95% CIs in the final models.

MMR receipt in relation to ethnicity and deprivation

Young women who had received MMR vaccination were more likely to initiate HPV vaccination (OR=3.64, 95% CI: 3.27-4.04) (Table 4). In addition, there was evidence for an overall association between MMR vaccination receipt with ethnicity, deprivation quintile, PCT/local authority (all p<0.001), and cohort (p=0.012) variables. In comparison to White British young women, young women belonging to all other ethnic categories were less likely to have received the MMR vaccine (all p<0.001). In comparison to the least deprived, young

women belonging to the third, fourth, and fifth quintile were less likely to have a record of timely MMR vaccine receipt (p<0.001).

Discussion

Main finding of this study

Overall, this study supports the national available data[13] that the UK HPV vaccination programme, delivered predominantly through school settings and free at the point of delivery, is achieving high uptake. Using aggregated PCT/local authority level data, variation of uptake has been previously explained by deprivation, ethnic composition of the population and childhood vaccination uptake.[14] Our richer data does not indicate a clear association of uptake by deprivation. However, variation of uptake of the HPV vaccine by ethnicity, PCT/local authority responsible for delivery, and category of educational setting was apparent. These are evidence of inequalities that should be addressed.

What is already known on this topic

Organisational and contextual issues

Our analyses reveal differences at the level of the PCT/local authority (p<0.001) which may, in part, be explained by organisational differences between the participating sites. For example, PCT/local authority 2 with higher uptake funded an additional member of staff to encourage young women to receive missed scheduled doses in community health clinics, rather than general practice. Lower initiation was observed in young women who were eligible for vaccination in programme year 2009/10 during the catch-up campaign and when HPV vaccination was subject to adverse media publicity.[15] More detailed understanding could be beneficial for the development of interventions to address disparities and to inform policy for future school-based health initiatives. This is an important consideration as adolescent vaccinations in the UK schedule are likely to increase.[16]

Deprivation

In this study, which examined HPV vaccination uptake over three years, we were unable to detect differences by deprivation. This finding is reassuring given the known cervical cancer related inequalities.[6 7] There was evidence for socioeconomic patterning in relation to uptake of MMR vaccination. School-based delivery may facilitate equity in access by overcoming logistical barriers, such as maternal work schedule or childcare commitments identified in relation to childhood vaccinations delivered within the general practice.[17-19]

However, young women attending non-mainstream educational settings were less likely to receive protection from the HPV vaccine (p<0.001). Given the nature of these institutions,

these young women may be particularly vulnerable. For example, young women with specialist educational needs have been shown to be less likely to receive other childhood vaccinations.[20] Other vulnerable population groups have been reported to be at higher risk of acquiring sexually transmitted infections.[21 22] Targeting these young women and their parents/carers by improving the provision of accessible information and offering flexible services, such as home visits, may help to address these differences. School nurses have reported that these methods to vaccinate 'hard-to-reach' young women can be effective, albeit resource intensive.[23]

Ethnicity

Ethnic differences related to HPV vaccine acceptability[24] and poorer uptake[9 10] prior to the general availability of the HPV vaccine appear to have been translated to lower initiation in the context of the UK national programme ($p<0.001$). Cultural or religious beliefs may play a part in parents' decisions regarding vaccination against a sexually transmitted infection. Religious beliefs regarding sexual abstinence before marriage[25] and fewer lifetime partners reported by some ethnic minority populations in the UK[26] may result in differing perceptions of risk for acquisition of HPV.[25 27] This could subsequently reduce perceived need. However, as MMR vaccination receipt was also patterned by ethnicity ($p<0.001$), this suggests that parental barriers related to the vaccination of young children, for example vaccination beliefs and perceptions of side effects,[17-19] could also be relevant. Additional language barriers may delay or prevent parental vaccination consent for this population. Further research is required to identify the reasons for lower uptake of both childhood and HPV vaccination amongst these young women, and provide culturally sensitive services if required.

Strengths and limitations of this study

Our study utilised routinely collected data eliminating the risk of recall and selection bias. The data relates to vaccinations delivered in school and community settings to all young women registered with a general practice eligible for routine HPV vaccination during the study period. As such, our results correspond to an almost complete population and, although limited to a geographical area, our findings may be generalisable to other parts of the UK.

Ethnicity is routinely collected at birth by each of the participating PCTs/local authorities. As a result, we were able to examine and show influence of ethnicity in a multivariable model. Local population profiles show that the recorded non-White British population of the combined local authorities are lower than the national average (9.1%) reported in the 2001 Census (non-White British population PCT/local authority 1: 8.2%; PCT/local authority 2:

1.4%; PCT/local authority 3 3; 2.5%).[28] Future research in other populations is required to establish whether these patterns are occurring elsewhere.

There were missing ethnicity data (17%) relating to young women who were born outside the local authority boundaries which could change the direction or quantity of aORs corresponding to ethnicity. An issue, common to all routinely collected data, is the possibility of data input errors and missing data. Missing school codes maybe due to movements into and out of schools. However, we were unable to ascertain this. In circumstances where an individual missed a dose given by one organisation (e.g. change of school), the dose could be over or undercounted, if administered by another organisation. The extent of this is unknown.

As the study relied on routinely collected information, we did not have access to individual-level measures of socioeconomic status and relied on area-based measures of deprivation. Our study findings may therefore be subject to ecological fallacy. We were unable to control for other potential predictors of vaccination coverage, including cultural norms, religious beliefs or preventative health beliefs. This could be important as elsewhere daughters of mothers who are not engaged with cervical cancer screening are less likely to be vaccinated.[29] Further, we were unable to include young women not registered with a general practitioner or identify some vulnerable groups, such as young women who are looked after by the local authority, those registered homeless or those in asylum-seeking families. Although we adjusted for school category and clustering by school, other school-level characteristics, such as attitudes of school staff, could affect uptake of the HPV vaccine. This was beyond the remit of this study.

Conclusions

Inequalities in HPV vaccine coverage related to cost and access to healthcare are less likely to apply in countries, such as the UK, where there is a national health service and HPV vaccination is provided free at the point of delivery, primarily through the universal schooling system. This study examining equity in delivery of the HPV vaccination programme by ethnicity and deprivation suggests that a school-based vaccination programme may help to address barriers to vaccination experienced in other settings. However, some groups for whom there appear to be barriers to uptake were identified where further work to reduce inequalities is required.

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Contributors: HF, MH, CT and SA conceived and designed the study. JM facilitated data acquisition. HF analysed the data and drafted the manuscript. All authors have made substantial contributions to interpreting the data, revising it critically for important intellectual content and have given approval of the final version to be submitted.

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Table 1. Descriptive statistics of HPV initiation and completion

		Initiated		Completed	
	N	N	%	N	%
Overall	14,282	12,658	88.6	11,725	92.6
Ethnicity category					
White British*	11,070	10,079	91.1	9,385	93.1
Mixed Ethnicity	143	127	88.8	119	93.7
Asian or British Asian	335	273	81.5	252	92.3
Black or British Black	122	94	77.1	85	90.4
Chinese and other	179	141	78.8	127	90.1
Not stated	2,433	1,944	79.9	1,757	90.4
Deprivation quintile					
1*	2,842	2,567	90.3	2,391	93.1
2	2,863	2,562	89.5	2,403	93.7
3	2,862	2,518	88.0	2,295	91.1
4	2,858	2,469	86.4	2,268	91.9
5	2,857	2,542	89.0	2,368	93.2
PCT responsible for delivery					
1	5,596	4,746	84.8	4,349	91.6
2	3,243	2,934	90.5	2,624	89.4
3	4,371	4,004	91.6	3,813	95.2
Other	1,072	974	90.9	939	96.4
Programme year					
2008/09*	4,780	4,284	89.6	3,968	92.6
2009/10	4,758	4,116	86.5	3,804	92.4
2010/11	4,744	4,258	89.8	3,953	92.9
Complete record of MMR vaccination					
Yes	10,918	10,077	92.3	9,442	93.7
No	3,364	2,581	76.7	2,283	88.5
Educational setting					
Non fee-paying	13,105	11,709	89.4	10,853	92.7
Fee-paying	981	836	85.2	785	93.9
Non-mainstream	196	113	57.7	87	77.0
School educational attainment tertile					
High*	4,738	4,211	88.9	3,989	94.7
Medium	4,858	4,370	90.0	4,063	93.0
Low	4,535	3,992	88.0	3,608	90.4
Not reported	151	85	56.3	65	76.5

* Reference category

Deprivation quintile: 1= Least Deprived

School specialist 'non-mainstream' includes: schools for students with special educational needs; pupil referral unit; educated at home; & hospital education service

HPV: Human Papillomavirus; PCT: Primary Care Trust; MMR: Measles, Mumps and Rubella

Table 2. Univariable and multivariable model of predictors of initiation of HPV vaccination course

		Unadjusted			Adjusted		
Covariate	**N**	**OR**	**95% CI**	**p-value**	**OR**	**95% CI**	**p-value**
Ethnicity							
White British*	11,070	1.00	-	-	1.00	-	-
Mixed Ethnicity	143	0.78	(0.46-1.32)	0.35	0.94	(0.55-1.61)	0.84
Asian or British Asian	335	0.43	(0.33-0.57)	<0.001	0.59	(0.44-0.80)	0.001
Black or British Black	122	0.33	(0.22-0.51)	<0.001	0.50	(0.32-0.79)	0.003
Chinese and other	179	0.36	(0.25-0.53)	<0.001	0.48	(0.33-0.71)	<0.001
Not stated	2,433	0.39	(0.35-0.44)	<0.001	0.44	(0.39-0.50)	<0.001
				<0.001**			**<0.001****
Deprivation quintile							
1*	2,842	1.00	-	-	1.00	-	-
2	2,863	0.92	(0.77-1.08)	0.29	0.92	(0.77-1.10)	0.35
3	2,862	0.79	(0.66-0.93)	0.005	0.95	(0.79-1.14)	0.56
4	2,858	0.68	(0.58-0.80)	<0.001	0.85	(0.71-1.02)	0.077
5	2,857	0.87	(0.73-1.03)	0.095	0.91	(0.76-1.09)	0.29
				<0.001**			**0.48****
PCT responsible for delivery							
1*	5,596	1.00	-	-	1.00	-	-
2	3,243	1.70	(1.48-1.95)	<0.001	1.70	(1.18-2.44)	0.004
3	4,371	1.95	(1.72-2.22)	<0.001	1.75	(1.26-2.43)	0.001
Other	1,072	1.77	(1.43-2.22)	<0.001	1.69	(1.13-2.53)	0.011
				<0.001**			**<0.002****
Programme year							
2008/09*	4,780	1.00	-	-	1.00	-	-
2009/10	4,758	0.74	(0.66-0.84)	<0.001	0.76	(0.66-0.86)	<0.001
2010/11	4,744	1.01	(0.89-1.16)	0.83	1.00	(0.87-1.14)	0.98
				<0.001**			**<0.001****
School-level variables							
Educational setting							
Non fee-paying*	13,105	1.00	-	-	1.00	-	-
Fee-paying	981	0.69	(0.57-0.83)	<0.001	0.74	(0.51-1.09)	0.13
Non-mainstream	196	0.16	(0.12-0.22)	<0.001	0.16	(0.11-0.24)	<0.001
				<0.001**			**<0.001****
Educational attainment							
High*	4,738	1.00	-	-	-	-	-
Medium	4,858	1.12	(0.98-1.28)	0.086	-	-	-
Low	4,535	0.92	(0.81-1.05)	0.20	-	-	-
Unknown	151	0.16	(0.12-0.23)	<0.001	-	-	-

* Reference category

** Corresponds to p-value derived from Likelihood Ratio Test

Variables adjusted by all variables listed in multivariable model

Deprivation quintile: 1=Least deprived

School specialist 'non-mainstream' includes: schools for students with special educational needs, pupil referral unit, educated at home & hospital education service

HPV: Human Papillomavirus; OR: Odds Ratio; CI: Confidence Interval; PCT: Primary Care Trust

Model adjusted variables by the following: ethnicity; deprivation quintile; PCT/local authority responsible for delivery; programme year; educational setting

Table 3. Univariable and multivariable model of predictors of completion of HPV vaccination course

		Unadjusted			Adjusted		
Covariate	**N**	**OR**	**95% CI**	**p-value**	**OR**	**95% CI**	**p-value**
Ethnicity							
White British*	10,079	1.00	-	-	1.00	-	-
Mixed Ethnicity	127	1.10	(0.54-2.26)	0.80	1.08	(0.52-2.25)	0.83
Asian or British Asian	273	0.89	(0.56-1.39)	0.60	0.94	(0.59-1.49)	0.79
Black or British Black	94	0.70	(0.35-1.39)	0.31	0.79	(0.39-1.60)	0.51
Chinese and other	141	0.67	(0.38-1.17)	0.16	0.68	(0.38-1.19)	0.18
Not stated	1,944	0.70	(0.59-0.82)	<0.001	0.77	(0.65-0.92)	0.004
				0.002**			**0.08****
Deprivation quintile							
1*	2,567	1.00	-	-	1.00	-	-
2	2,562	1.11	(0.89-1.39)	0.35	1.04	(0.83-1.31)	0.71
3	2,518	0.76	(0.62-0.93)	0.008	0.84	(0.68-1.05)	0.12
4	2,469	0.83	(0.67-1.03)	0.084	0.88	(0.70-1.09)	0.24
5	2,542	1.00	(0.81-1.24)	0.99	1.08	(0.87-1.35)	0.48
				0.002**			**0.104****
PCT/local authority responsible for delivery							
1*	4,746	1.00	-	-	1.00	-	-
2	2,934	0.77	(0.66-0.90)	0.001	0.83	(0.63-1.08)	0.16
3	4,004	1.82	(1.53-2.18)	<0.001	1.85	(1.43-2.41)	<0.001
Other	974	2.45	(1.72-3.48)	<0.001	2.30	(1.50-3.53)	<0.001
				<0.001**			**<0.001****
Programme year							
2008/09*	4,284	1.00	-	-	1.00	-	-
2009/10	4,116	0.97	(0.83-1.14)	0.72	0.96	(0.81-1.13)	0.61
2010/11	4,258	1.03	(0.88-1.22)	0.704	1.03	(0.87-1.21)	0.75
				0.77**			**0.71****
School-level variables							
Educational setting							
Non fee-paying*	11,709	1.00	-	-	1.00	-	-
Fee-paying	836	1.21	(0.91-1.63)	0.19	1.36	(0.94-1.98)	0.11
Non-mainstream	113	0.26	(0.17-0.41)	<0.001	0.27	(0.17-0.44)	<0.001
				<0.001**			**<0.001****
Educational attainment							
High*	4,211	1.00	-	-	-	-	-
Medium	4,370	0.74	(0.62-0.88)	0.001	-	-	-
Low	3,992	0.52	(0.44-0.62)	<0.001	-	-	-
Unknown	85	0.18	(0.11-0.30)	<0.001	-	-	-

* Reference category

** Corresponds to p-values derived from Likelihood Ratio Test

Variables adjusted by all variables listed in multivariable model

Deprivation quintile: 1=Least deprived

School specialist 'non-mainstream' includes: schools for students with special educational needs, pupil referral unit, educated at home & hospital education service

HPV: Human Papillomavirus; OR: Odds Ratio; CI: Confidence Interval; PCT: Primary Care Trust

Model adjusted variables by the following: ethnicity; deprivation quintile; PCT/local authority responsible for delivery; programme year; educational setting

Table 4. Univariable and multivariable model of in relation to timely receipt of MMR

		Unadjusted			Adjusted		
Covariate	**N**	**OR**	**95% CI**	**p-value**	**OR**	**95% CI**	**p-value**
HPV vaccine							
Initiation	14,282	3.64	(3.27-4.04)	<0.001	-	-	-
Completion of initiated	12,658	1.94	(1.68-2.24)	<0.001	-	-	-
Ethnicity							
White British*	11,070	1.00	-	-	1.00	-	-
Mixed Ethnicity	143	0.39	(0.27-0.56)	<0.001	0.45	(0.32-0.65)	<0.001
Asian or Asian British	335	0.34	(0.27-0.43)	<0.001	0.40	(0.32-0.51)	<0.001
Black or Black British	122	0.06	(0.04-0.09)	<0.001	0.08	(0.05-0.12)	<0.001
Chinese and other	179	0.34	(0.25-0.46)	<0.001	0.36	(0.26-0.49)	<0.001
Not stated	2,433	0.18	(0.16-0.20)	<0.001	0.18	(0.16-0.20)	<0.001
				<0.001**			**<0.001****
Deprivation quintile							
1*	2,842	1.00	-	-	1.00	-	-
2	2,863	1.00	(0.88-1.14)	0.98	0.95	(0.82-1.09)	0.43
3	2,862	0.73	(0.64-0.82)	<0.001	0.85	(0.74-0.97)	0.015
4	2,858	0.69	(0.61-0.78)	<0.001	0.78	(0.68-0.89)	<0.001
5	2,857	0.87	(0.77-0.99)	0.038	0.84	(0.73-0.96)	0.009
				<0.001**			**<0.001****
PCT/Local authority responsible for delivery							
PCT 1*	6,318	1.00	-	-	1.00	-	-
PCT 2	3,237	1.39	(1.26-1.53)	<0.001	1.41	(1.26-1.57)	<0.001
PCT 3	4,381	2.19	(1.98-2.41)	<0.001	1.97	(1.78-2.19)	<0.001
Other	346	0.85	(0.68-1.07)	0.18	1.03	(0.80-1.33)	0.81
				<0.001**			**<0.001****
HPV vaccination programme year							
2008/09*	4,780	1.00	-	-	1.00	-	-
2009/10	4,758	1.12	(1.02-1.24)	0.01	1.16	(1.05-1.29)	0.004
2010/11	4,744	1.11	(1.01-1.22)	0.03	1.10	(1.00-1.22)	0.059
				0.027**			**0.012**

* Reference category
** Corresponds to p-value derived from Likelihood Ratio Test
Deprivation quintile: 1=Least deprived
Model adjusted variables by the following: ethnicity; deprivation quintile; PCT/local authority responsible for delivery; HPV vaccination programme year

Supplemental Table 1. Characteristics of records excluded and retained from analysis

	Excluded		Retained	
Ethnicity category	**n**	**%**	**n**	**%**
White British*	585	40.0	11,655	74.0
Mixed Ethnicity	3	0.2	146	0.9
Asian or British Asian	46	3.1	381	2.4
Black or British Black	7	0.5	129	0.8
Chinese and other	25	1.7	204	1.3
Not stated	797	54.5	3,230	20.5
Deprivation quintile				
1*	273	19.0	2,809	19.7
2	249	17.3	2,896	20.3
3	310	21.5	2,845	19.9
4	336	23.3	2,842	19.9
5	272	18.9	2,890	20.2
PCT/local authority				
1	297	48.1	5,596	39.2
2	142	23.0	3,243	22.7
3	157	25.5	4,371	30.6
Other	21	3.4	1,072	7.5
Programme year				
2008/09*	438	29.9	4,780	33.5
2009/10	515	35.2	4,758	33.3
2010/11	510	34.9	4,744	33.2

Appendix 1. Flow diagram of record exclusions