

Factors associated with uptake of measles, mumps, and rubella vaccine (MMR) and use of single antigen vaccines in a contemporary UK cohort: prospective cohort study

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ABSTRACT

Objectives To estimate uptake of the combined measles, mumps, and rubella vaccine (MMR) and single antigen vaccines and explore factors associated with uptake and reasons for not using MMR.

Design Nationally representative cohort study.

Setting Children born in the UK, 2000-2.

Participants 14 578 children for whom data on immunisation were available.

Main outcome measures Immunisation status at 3 years defined as "immunised with MMR," "immunised with at least one single antigen vaccine," and "unimmunised."

Results 88.6% (13 013) were immunised with MMR and 5.2% (634) had received at least one single antigen vaccine. Children were more likely to be unimmunised if they lived in a household with other children (risk ratio 1.74, 95% confidence interval 1.35 to 2.25, for those living with three or more) or a lone parent (1.31, 1.07 to 1.60) or if their mother was under 20 (1.41, 1.08 to 1.85) or over 34 at cohort child's birth (reaching 2.34, 1.20 to 3.23, for ≥ 40), more highly educated (1.41, 1.05 to 1.89, for a degree), not employed (1.43, 1.12 to 1.82), or self employed (1.71, 1.18 to 2.47). Use of single vaccines increased with household income (reaching 2.98, 2.05 to 4.32, for incomes of $\geq \text{£}52\ 000$ ($\text{€}69\ 750$, $\text{\$}102\ 190$)), maternal age (reaching 3.04, 2.05 to 4.50, for ≥ 40), and education (reaching 3.15, 1.78 to 5.58, for a degree).

Children were less likely to have received single vaccines if they lived with other children (reaching 0.14, 0.07 to 0.29, for three or more), had mothers who were Indian (0.50, 0.25 to 0.99), Pakistani or Bangladeshi (0.13, 0.04 to 0.39), or black (0.31, 0.14 to 0.64), or aged under 25 (reaching 0.14, 0.05 to 0.36, for 14-19). Nearly three quarters (74.4%, 1110) of parents who did not immunise with MMR made a "conscious decision" not to immunise.

Conclusions Although MMR uptake in this cohort is high, a substantial proportion of children remain susceptible to avoidable infection, largely because parents consciously decide not to immunise. Social differentials in uptake could be used to inform targeted interventions to promote uptake.

INTRODUCTION

The combined measles, mumps, and rubella vaccine (MMR) was introduced in the United Kingdom in 1988 and is recommended for children at 13 months with a second dose shortly before they start school.¹ In 1995 uptake of MMR among 2 year olds living in the UK reached its peak at 92%.² After publication of research in 1998 that was widely interpreted as suggesting a link between the vaccine and autism and bowel disease,³ uptake declined to a low of 79% in 2003.⁴ Current uptake, based on data from July-September 2007, is estimated to be 85%,⁵ so while the rate is recovering, it is still below levels achieved before 1998. The 1998 publication³ was accompanied by one researcher calling for single antigen measles, mumps, and rubella vaccines to be given separately at intervals of at least a year.⁶ Despite the lack of evidence to support this, and subsequent research showing no link between MMR and autism and bowel disorders,^{7,8} some parents have sought single vaccines for their children. These are available only at a cost on a private basis and information about their administration is not routinely transferred into the NHS child health information systems. There are no routine data on use of single antigen vaccines in the UK, and estimates derived from local level studies⁹⁻¹¹ and a national survey of providers¹² range from around 2% to 21%.

Before 1998, MMR uptake was lower among single parent families and larger families and in more socially deprived areas.¹³⁻¹⁷ Since 1998, however, the decline in uptake has been faster in more affluent areas^{15,18} and slower in areas with less highly educated residents,¹⁵ although this faster decline in more affluent groups has not been sufficient to eliminate the unequal social distribution of uptake. Reasons why parents choose not to immunise their children with MMR include concerns about the safety of the vaccine, the potential risks of the vaccine outweighing the risks of contracting the disease, negative publicity, and not trusting the advice given by health professionals and the government.^{10,19} We are unaware of research on the

Table 1 | Weighted percentage (and number) of cohort children vaccinated against measles, mumps, and rubella at age 3 across four UK countries, English regions, and UK overall*

	MMR	Unimmunised	Single antigen vaccines	Total
Scotland	91.4 (1624)	5.8 (105)	2.8 (51)	1780
Northern Ireland	94.3 (1338)	4.1 (60)	1.6 (25)	1423
Wales	88.8 (1960)	7.9 (186)	3.4 (76)	2222
England	88.0 (8091)	6.2 (580)	5.8 (482)	9153
England by region:				
North east	93.0 (387)	3.6 (16)	3.5 (14)	417
North west	92.2 (1056)	4.7 (58)	3.1 (33)	1147
Yorkshire and Humberside	89.5 (954)	7.2 (70)	3.3 (28)	1052
East Midlands	93.2 (675)	3.7 (27)	3.1 (24)	726
West Midlands	88.8 (977)	5.3 (57)	5.9 (46)	1080
East	87.7 (808)	4.7 (50)	7.7 (67)	925
London	83.1 (1457)	19.0 (151)	8.0 (123)	1731
South east	86.2 (1170)	6.9 (100)	6.9 (93)	1363
South west	85.4 (607)	6.9 (51)	7.6 (54)	712
United Kingdom	88.6 (13 013)	6.1 (931)	5.2 (634)	14 578

*Information on MMR uptake not available for 52 (0.4%) children in second sweep.

social distribution of use of single antigen vaccine nor any that explores differences in the reasons given for declining MMR vaccine by parents whose children have had single antigen vaccines and those who remain unimmunised.

We estimated MMR coverage and the uptake of single vaccines across the UK and explored the geographic, socioeconomic, and cultural risk factors, as well as parents' reasons, for not accepting MMR, differentiating between parents who did not immunise their child against measles, mumps, and rubella at all and those who chose to use single vaccines.

METHODS

Participants

We examined data from the millennium cohort study, a longitudinal study of children born in the UK from September 2000 to January 2002. The sample was taken from a random sample of electoral wards that were disproportionately stratified to ensure an adequate representation of all four UK countries, deprived areas, and areas with high proportions of families from ethnic minorities.²⁰ Families eligible for child benefit and resident in England, Wales, Scotland, or Northern Ireland were invited to participate. The first contact with the cohort was when the children were aged about 9 months, when information was collected on 72% of those approached, giving 18 819 babies, of whom 18 296 were singletons. Children who had not died or permanently emigrated were eligible to participate in the second sweep of data collection, which took place when they were about 3 years old.²¹ Of the original 18 296 singleton babies, 80% (14 630) participated in the second sweep. Trained researchers interviewed the main care giver, usually the mother, at home. At both sweeps information collected included various socioeconomic characteristics. At three years, researchers determined MMR uptake (confirmed by consulting the

personal child health record if available) and parents' reasons for not opting for MMR. We obtained data from both surveys from the UK Data Archive at the University of Essex.

Our analysis included 14 578 children at age 3 for whom information was available on MMR uptake (99.6% of the 14 630 included in the second sweep). Children's immunisation status was classified into three groups: immunised with MMR, immunised with at least one of the single antigen vaccines, and unimmunised. We used data on socioeconomic and cultural factors gathered at the age of 9 months as this was closest in time to the recommended age for receipt of MMR (13 months). Children who were not included in the second sweep were more likely to be from an ethnic minority background or a more disadvantaged socioeconomic household.²¹ They were also less likely to be immunised with primary vaccinations. All analyses were conducted in Stata/SE 9.2 (Stata Corporation, TX, USA), with sampling and non-response weights to take account of the initial sampling design and non-response at the first and second sweeps.

Analysis

Firstly, we calculated the uptake of MMR for the UK overall for each of the four countries and for the English regions. We then looked at the combinations of single antigen vaccines used in those children immunised with at least one antigen. Confidence intervals (95%) were calculated and analyses of variance used to determine whether differences were significant.

We used forward stepwise Poisson regression analysis to identify socioeconomic and cultural characteristics associated with vaccination uptake in two models. The first examined the risk of being unimmunised against measles, mumps, and rubella (that is, having received no vaccine at all), and the second examined the risk of being vaccinated with at least one of the single antigen vaccines. To simplify interpretation, and as MMR is the recommended vaccination policy,¹ we excluded children who were immunised with at least one of the single antigen vaccines from the first model and children who were unimmunised from the second. Potential explanatory factors explored were the number of children in the household, mother's employment status, single parenthood, maternal age at birth of cohort child, maternal age at first live birth, ever smoked during pregnancy, maternal education, household income, mother's ethnicity, household language, interview language, sex of the child, type of electoral ward (disadvantaged, advantaged, or ethnic minority), and country. Univariable analyses assessed the strength of the association between the outcome and each of these characteristics. Characteristics that had a significant or borderline significant ($P < 0.1$) univariate association with the outcome were entered into the relevant model, one at a time; those with the strongest association were added first. Variables that did not significantly add to the model ($P > 0.05$) were not retained. There were no a priori hypotheses for interaction terms so these were

not explored. We used backward stepwise regression to check the validity of the models and several sensitivity analyses to check the validity of the findings.

Finally, we reported parents' reasons for not having their child immunised with MMR. The open question was asked "Why has the *cohort child* not had the combined vaccination against measles, mumps, and rubella?" Parents were allowed to provide more than one reason; 96.4% (1508) of parents who did not opt for MMR gave at least one reason, with 19% (282) providing two or more reasons, and 1% (22) three or more. As these additional reasons were usually an elaboration on the first we explored only the first reason given. The data were available in 33 categories of reasons from the free text, ranging from fears over possible links with autism, siblings having adverse reactions, negative media attention, lack of information, perceived contraindications, "not getting around to it," and "don't know." We further divided these 33 categories into "medical" (which included responses such as "the child has asthma" or "had a cold at the time of appointment"); "practical" (such as missing an appointment); "conscious decision" (which included reasons such as "links with autism" or "mistrust in the government"), and "other" (which included "don't know" or "no reason").

RESULTS

Table 1 shows the weighted percentage and frequency of cohort children by immunisation status for the four UK countries and the English regions. Of the total cohort, 88.6% (87.5% to 89.7%, n=13 013) had been immunised with MMR by age 3, 5.2% (4.6% to 5.9%, n=634) had received at least one of the single antigen vaccines, and 6.1% (5.5% to 6.9%, n=931) were unimmunised. MMR uptake varied by country ($P<0.001$) and was highest in Northern Ireland and lowest in England. Uptake of single antigen vaccines was highest in England, and children living in Wales were most likely to be unimmunised. Uptake also varied significantly across the English regions: MMR

coverage was highest in the northern regions while in the south a relatively high proportion of children were unimmunised or had received single antigen vaccines ($P<0.001$).

Table 2 shows the frequency and weighted percentage of the various combinations of single antigen vaccines administered to the 634 children who received at least one. Of these, 52% (47.1% to 56.6%, n=335) had received all three and 37% (31.8% to 42.1%, n=227) had received measles and rubella. Some 7.4% (5.6% to 9.8%, n=48) of children had received only one of the vaccines, of which measles was the most common and mumps the least. Overall, 98.3% (96.8% to 99.1%) of children who received single antigen vaccines and 93.8% (93.0% to 94.5%) of all children had received a vaccine containing measles (n=13 638). Single antigen vaccine use did not vary by sex ($P>0.2$).

In the univariable analyses (data not shown) number of children in the household, mother's employment status, single parenthood, maternal age at birth of cohort child, ever smoked during pregnancy, maternal education, household income, household language, sex of the child, and country were significantly associated with being unimmunised and with being immunised with at least one single antigen vaccine. In addition, use of single antigen vaccine was significantly associated with maternal age at first live birth, mother's ethnicity, interview language, and electoral ward type (disadvantaged, advantaged, or ethnic minority).

Table 3 shows risk ratios for children being unimmunised, adjusted for all other characteristics that significantly added to the model and were therefore retained. The model excludes children who were immunised with single antigen vaccines and results are therefore independent of those shown in table 4. Children were significantly less likely to be unimmunised if they lived in Northern Ireland. They were more likely to be unimmunised if they lived in families with other children, if their mother was over 34 or under 20 when she gave birth to the cohort child, or if they lived in a single parent household. Children were also at increased risk of being unimmunised if their mother was not employed or was self employed, if her highest educational qualifications were AS/A level or a degree or above, or if she had ever smoked during pregnancy. Girls were significantly less likely to be unimmunised than boys.

Table 4 shows risk ratios for children receiving at least one of the single antigen vaccines, adjusted for all other characteristics in the model. This model excludes children who were unimmunised and results are therefore independent of those shown in table 3. Children were less likely to have received single antigen vaccines if they lived in Wales, Scotland, or Northern Ireland or in families with other children. Use of single antigen vaccine increased with maternal age at birth of the cohort child and also with household income. Mothers who were not employed or educated to GCSE (grades A*-C) level or above were also more likely to use single antigen vaccines. Children were less

Table 2 | Frequency and weighted percentage of combinations of single antigen vaccines administered to children who received at least one

Single vaccines	No of children	Proportion of total receiving at least one single antigen vaccine (%)	Proportion of all 14 578 children (%)
Measles, mumps, rubella	335	52	2.7
Measles, mumps	19	3.1	0.2
Mumps, rubella	5	0.8	0.04
Measles, rubella	227	37	1.9
Measles only	44	6.6	0.4
Mumps only	1	0.2	0.01
Rubella only	3	0.6	0.03
Total	634	100	5.2
At least measles	625	98	94*
At least mumps	360	56	92*
At least rubella	570	90	93*

*Includes children who received MMR.

Table 3 | Adjusted risk ratios for children being unimmunised against measles, mumps, and rubella by age 3*

Social characteristics†	%‡ (No)	Adjusted risk ratios‡ for being unimmunised against MMR	P value
Country:			
England	57 (8595)	1	0.001
Wales	16 (2125)	1.24 (0.99 to 1.54)	
Scotland	14 (1716)	0.88 (0.68 to 1.15)	
N Ireland	13 (1390)	0.60 (0.43 to 0.84)	
No of children in household:			
1	41 (5587)	1	0.001
2-3	52 (7121)	1.18 (1.02 to 1.38)	
≥4	7 (1118)	1.74 (1.35 to 2.25)	
Maternal age at cohort birth:			
14-19	8 (1101)	1.41 (1.08 to 1.85)	<0.001
20-24	17 (2544)	1.07 (0.86 to 1.31)	
25-29	28 (3874)	1	
30-34	30 (4175)	1.11 (0.91 to 1.34)	
35-39	15 (1991)	1.60 (1.32 to 1.95)	
≥40	2 (293)	2.34 (1.70 to 3.23)	
Single parent:			
No	85 (11 678)	1	<0.001
Yes	15 (2148)	1.31 (1.07 to 1.60)	
Mother's employment status:			
Full time	11 (1643)	1	<0.001
Part time	31 (4033)	1.07 (0.82 to 1.39)	
Not employed	49 (6933)	1.43 (1.12 to 1.82)	
Self employed	3 (432)	1.71 (1.18 to 2.47)	
On leave	5 (664)	0.94 (0.61 to 1.45)	
Full time student	1 (121)	1.85 (0.98 to 3.47)	
Maternal education:			
None	16 (2477)	1	0.01
Other	2 (361)	1.06 (0.68 to 1.66)	
GCSE grades D-G	11 (1502)	0.81 (0.62 to 1.06)	
O level/GCSE grades A*-C	35 (4664)	0.98 (0.81 to 1.19)	
A/AS level	9 (1323)	1.35 (1.01 to 1.80)	
Diploma	9 (1222)	1.15 (0.87 to 1.54)	
Degree	17 (2277)	1.41 (1.05 to 1.89)	
Ever smoked in pregnancy:			
No	65 (9004)	1	0.02
Yes	35 (4822)	1.22 (1.04 to 1.43)	
Sex of child:			
Male	51 (7016)	1	0.005
Female	49 (6810)	0.84 (0.75 to 0.95)	

*Total No of observations=13 826; data missing for 18 for maternal age, 40 for mother's employment status, 30 for educational qualification, 60 for ever smoked during pregnancy.

†Variables not significantly adding to model and therefore omitted: household income, household language.

‡Percentages and risk ratios calculated with sample and non-response weights.

likely to have received single antigen vaccines if their mother was Pakistani or Bangladeshi, Indian, or black.

Re-analysis with backward stepwise regression led to the same two models (that is, with all the same variables). Sensitivity analyses were conducted without the non-response weights and, in the case of the single antigen vaccines model, in children of white mothers only. The size of the associations changed little.

Table 5 shows parents' reasons for not immunising their child with the combined MMR vaccine for

children who were unimmunised and for those who received single antigen vaccines. Overall, 74.4% (71.3% to 77.0%, n=1110) of the parents made a "conscious decision" not to have their child immunised with MMR. Of all the reasons given by parents that fell into the "conscious decision" category, the most common were being too scared or thinking the vaccine was too dangerous (24.1%, 21.2% to 27.2%, n=277), not wanting to their child to receive MMR (18.6%, 16.1% to 21.3%, n=211), fears over possible links with autism (14.1%, 12.1% to 16.4%, n=168), and negative media attention (9.5%, 7.4% to 12.0%, n=105). Six per cent of parents (4.7% to 8.2%, n=65) of unimmunised children reported practical issues as the reason for their child not receiving MMR compared with only 0.1% (0.03% to 0.3%, n=3) of those whose children had received single antigen vaccines.

DISCUSSION

In this large cohort study we found that around 88.6% of children were immunised with MMR, 5.2% had received one or more single vaccines, and 6.1% were unimmunised. Parents often made a conscious decision not to immunise.

Strengths and limitations

The data collected in the millennium cohort study allowed us to differentiate between children who had been immunised with at least one of the single antigen vaccines and those who remained unimmunised. The breadth of information collected in this study, the large sample size, and the oversampling of ethnic minorities and people living in disadvantaged areas enabled precise estimation of vaccine uptake across the UK and its variation in different socioeconomic, cultural, demographic, and ethnic groups. Our findings supplement current knowledge on the social distribution of MMR uptake and regional differences in coverage, particularly in relation to use of single antigen vaccines on which there is little published research.

We were able to adjust our estimated proportions for the initial oversampling of ethnic minorities and lower socioeconomic groups in the sampling frame and differential response to both the first and second sweeps. The non-response weights, however, were not able to fully take into account the fact that children in the second sweep were more likely to have been immunised with primary vaccinations (96%, ascertained at the first sweep) than those who were not included (93%). Children who received the primary vaccinations were more likely to have been immunised with MMR (data not shown), and these findings are consistent with other research.^{17,22} Therefore it is possible that our estimates of MMR uptake are slightly inflated. The sensitivity analyses, however, indicate that the social, demographic, and cultural patterns found are less likely to be affected.

Immunisation status was based on maternal report. Parents were encouraged to check the immunisation record in the personal child health record, although only a fifth actually did so. There is no agreed standard

Table 4 | Adjusted risk ratios for children being immunised with at least one single antigen vaccine by age 3*

Social characteristics†	%‡ (No)	Adjusted risk ratios‡ for being immunised with at least one single antigen vaccine	P value
Country:			
England	59 (7817)	1	<0.001
Wales	16 (1931)	0.65 (0.51 to 0.84)	
Scotland	13 (1537)	0.45 (0.34 to 0.59)	
N Ireland	12 (1208)	0.33 (0.22 to 0.50)	
No of children in household:			
1	43 (5298)	1	<0.001
2-3	51 (6306)	0.31 (0.26 to 0.38)	
≥4	6 (889)	0.14 (0.07 to 0.29)	
Maternal age at cohort birth (years):			
14-19	7 (1021)	0.14 (0.05 to 0.36)	<0.001
20-24	17 (2431)	0.63 (0.45 to 0.87)	
25-29	28 (3826)	1	
30-34	31 (4186)	1.36 (1.11 to 1.66)	
35-39	15 (1933)	1.40 (1.10 to 1.77)	
≥40	2 (284)	3.04 (2.05 to 4.50)	
Household income (£):			
<10 400	22 (3068)	1	<0.001
10 400-20 800	32 (4118)	1.20 (0.86 to 1.69)	
20 800-31 200	22 (2639)	1.88 (1.33 to 2.66)	
31 200-52 000	17 (1974)	2.05 (1.42 to 2.95)	
≥52 000	7 (694)	2.98 (2.05 to 4.32)	
Mother's employment status:			
Full time	11 (1580)	1	0.003
Part time	32 (3773)	1.23 (0.96 to 1.59)	
Not employed	48 (6067)	1.60 (1.26 to 2.04)	
Self employed	3 (360)	1.46 (0.97 to 2.18)	
On leave	5 (614)	1.16 (0.78 to 1.72)	
Full time student	1 (99)	0.47 (0.07 to 3.24)	
Maternal education:			
None	15 (2043)	1	<0.001
Other	2 (293)	1.76 (0.66 to 4.66)	
GCSE grades D-G	11 (1343)	1.48 (0.74 to 2.97)	
O level/GCSE A*-C	35 (4258)	2.66 (1.52 to 4.66)	
A/AS level	10 (1230)	3.37 (1.85 to 6.13)	
Diploma	10 (1161)	3.31 (1.92 to 5.69)	
Degree	18 (2165)	3.15 (1.78 to 5.58)	
Mother's ethnicity:			
White	90 (10 847)	1	<0.001
Mixed	1 (109)	1.94 (0.85 to 4.41)	
Indian	2 (302)	0.50 (0.25 to 0.99)	
Pakistani or Bangladeshi	4 (695)	0.13 (0.04 to 0.39)	
Black or black British	3 (343)	0.31 (0.14 to 0.64)	
Other	1 (197)	0.56 (0.23 to 1.36)	

*Total No of observations=12 493; data missing for 18 for maternal age, 1095 for household income, 40 for mother's employment status, 31 for educational qualification, 30 for ethnicity.

†Variables not significantly adding to the model and therefore omitted: maternal age at first live birth, ward type, interview language, household language, lone parenthood, sex of child, ever smoked in pregnancy.

‡Percentages and risk ratios calculated with sample and non-response weights.

for reporting immunisation status and conflicting evidence about the reliability of computerised immunisation records and primary care records compared with parents' reports.^{23,24} Some studies have found that parents tend to overestimate childhood immunisation

status,²⁵⁻²⁷ although more recent studies looking at MMR in particular have found the level of disagreement to be low²⁸ and not socially distributed.²⁷ Parents reporting non-uptake of MMR in the cohort study would probably accurately recall this information as for most their decision was made consciously and in the case of those deciding to use single antigen vaccines one that required special arrangements.

We were unable to take into account the timing of vaccination. A study of over a million children born in Scotland from 1987 to 2004 found that late MMR vaccination was associated with deprivation, whereas children of more affluent parents tended to be vaccinated either on time or not at all.¹⁸ In addition, our study did not allow a more detailed exploration of parents' reasons for not immunising their child with MMR. Such reasons are likely to be complex and might be more appropriately investigated with qualitative methods.

Our findings relate to children who were born in 2000-2. From 1998 considerable media attention was given to the safety of MMR vaccine with a peak of negative coverage around the time when cohort parents were likely to be making decisions about their child's vaccinations. It is therefore possible that our results are unique to this cohort.²⁹ Recent research suggests that since 2004 mothers of a higher social class are no longer less likely to regard the MMR vaccine as being completely safe or just a slight risk than mothers from lower social strata,³⁰ although this is based on attitudes alone and not on immunisation status. While our findings relate to children born in 2000-2, they might also indicate a more general differential response to health messages. Furthermore, it is possible that negative media attention around MMR will recur.³¹

Comparison with other findings

We found the reported uptake of MMR at 3 years to be higher than that in published routine statistics for a similar UK birth cohort at 2 years (80.7%)³² and in COVER reports of children aged 36 months born in England at a similar time to the children in this cohort (82.1% to 84.2%).³³⁻³⁶ This may be because of under-reporting, which is known to occur in routine data, or selection or recall bias in the cohort study. The pattern of uptake between countries in the cohort study, however, is consistent with routine data.⁴ There are no routine data on use of single antigen vaccines and only a limited number of small studies with which to compare our findings. One study estimated uptake of single vaccines in England and Wales based on the number of applications for importation and the number of vaccines actually administered by a proportion of providers.¹² It calculated that 1.7-5.6% of children born in 2001 and 2.1-5.6% of children born in 2002 would have received the single measles vaccine. For the mumps vaccine estimates were 0.3-4.0% and 0.02-4.0%, respectively. It was not possible to estimate coverage of the rubella vaccine because it was also licensed and available through the NHS at the time. The estimates, while not at odds with ours (5.2%),

Table 5 | Weighted percentage* (and number) of categorised reasons† provided by mothers for not immunising their child with combined MMR vaccine

	Unimmunised	Single antigen vaccines	Total
Practical	6% (65)	0.1% (3)	3% (68)
Medical	15% (128)	9% (53)	12% (181)
Conscious decision	67% (588)	82% (522)	74% (1110)
Other	12% (98)	8% (51)	10% (149)
Total	879	629	1508

*Percentages may not add to 100 because of rounding.

†Reported reasons were missing for 3.6% (57) of 1565 children who did not receive MMR.

were based on a series of assumptions about the link between supply and uptake rather than using the more direct information from parents that we used. Three local investigations of uptake of single vaccines all reported higher estimates,⁹⁻¹¹ although this could have been because of local circumstances, unrepresentative samples, or publication bias.

Previous research has shown that single parenthood, area deprivation, and high birth order and family size are associated with lower uptake of MMR,¹³⁻¹⁶ although since concerns over the safety of MMR were raised in 1998, uptake has declined more among parents living in more affluent areas and those with more highly educated residents.^{15, 18} Our study also found that children who remained unimmunised were more likely to live in a household with greater numbers of children or be living with a single parent (table 3), after adjustment for other socioeconomic characteristics. Type of ward (disadvantaged, advantaged, or ethnic) was not significantly associated with uptake. This categorisation, however, is not directly comparable with measures of area deprivation and, unlike many of the studies that found an association between area deprivation and immunisation, we were able to take into account individual and household level socioeconomic measures that might have been confounding the association between area deprivation and immunisation status. The adjusted associations of individual and household characteristics with use of single antigen vaccines (see table 4) have not previously been reported. Use of single antigen vaccine increased with household income, after adjustment for other socioeconomic characteristics. Similar positive relations between household income and healthcare expenditure, such as health insurance, prescriptions, and optician fees, have been found in the United States.^{37, 38}

In previous research, fears over safety, negative publicity, the belief that the risk of side effects outweighs the risk of contracting the disease, and mistrust in professional and government advice were given as reasons by parents choosing not to immunise their child with MMR.^{10, 19, 39} Our findings are consistent with these for parents who chose to use single antigen vaccines as well as for those who chose not to have their child immunised at all. In addition, practical and medical reasons were important for parents who did not immunise their child at all.

Implications for policy, practice, and research

We estimate that 88.6% of children born in 2000-2 had received MMR by the age of 3 and a further 2.7% had received all three of the single antigen vaccines. Although coverage is relatively high, it remains lower than the estimated level required to ensure herd immunity (over 95%), leaving a substantial proportion of children susceptible to avoidable infection. Reports of confirmed cases of measles in England and Wales in 2006 exceeded those in any year for the past decade,⁴⁰ and the potential for large outbreaks of measles will continue while so many children remain susceptible. Although the efficacy of MMR is well established,⁷ we know little about the nature and handling and therefore effectiveness of the unlicensed single antigen vaccines. Furthermore, because of the intervals between doses of single antigen vaccines, children are left unprotected for a longer period of time than if they had received MMR. In addition, as our data show, a significant proportion of children whose parents choose single vaccines do not receive all three antigens (48%).

We have shown social inequalities in uptake of different vaccines and suggest that a range of interventions might be required to address these inequalities and therefore increase uptake. For some parents who do not immunise their child at all, reminders of immunisation appointments and more accessible opportunities for immunisation might be successful. For most parents who declined MMR, however, it was a conscious decision and it is therefore important to ensure ready access to evidence based information about MMR vaccine, tailored to respond to particular concerns, questions, and beliefs of different groups. For those parents who opted for single antigen vaccines, it is important to ensure that they have received information about the research looking at the safety of MMR vaccine⁷ and discussion of the disadvantages of opting for a course of single antigen vaccines might also be appropriate. Further research into the reasons given by

WHAT IS ALREADY KNOWN ON THIS TOPIC

In the UK, MMR uptake has declined and its social patterning is changing

There is no comparable information on the use of single antigen vaccines

Current estimated coverage of 85% is below the level required for herd immunity

WHAT THIS STUDY ADDS

Many parents make a conscious decision not to have their child immunised with MMR, with a substantial proportion opting to use single antigen vaccines

Socioeconomic and cultural patterns in uptake differ for parents choosing the single antigen vaccines and those not immunising at all

Interventions to improve uptake should be designed to meet the needs of different groups

parents for not having their child immunised with MMR could help to inform policy and practice further.

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Competing interests: HB and DE have been reimbursed in the past (not in the past five years) by several vaccine manufacturers, for attending and speaking at conferences and conducting research. DE has also provided expert reports for potential litigants in court cases involving vaccines.

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