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Characteristics of 5-year-olds who catch-up with MMR: findings from the UK Millennium Cohort Study

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ABSTRACT

Objectives: To examine predictors of partial and full measles, mumps and rubella (MMR) vaccination catch-up between 3 and 5 years.

Design: Secondary data analysis of the nationally representative Millennium Cohort Study (MCS).

Setting: Children born in the UK, 2000–2002.

Participants: 751 MCS children who were unimmunised against MMR at age 3, with immunisation information at age 5.

Main outcome measures: Catch-up status: unimmunised (received no MMR), partial catch-up (received one MMR) or full catch-up (received two MMRs).

Results: At age 5, 60.3% (n=440) children remained unvaccinated, 16.1% (n=127) had partially and 23.6% (n=184) had fully caught-up. Children from families who did not speak English at home were five times as likely to partially catch-up than children living in homes where only English was spoken (risk ratio 4.68 (95% CI 3.63 to 6.03)). Full catch-up was also significantly more likely in those did not speak English at home (adjusted risk ratio 1.90 (1.08 to 3.32)). In addition, those from Pakistan/Bangladesh (2.40 (1.38 to 4.18)) or 'other' ethnicities (such as Chinese) (1.88 (1.08 to 3.29)) were more likely to fully catch-up than White British. Those living in socially rented (1.86 (1.34 to 2.56)) or 'Other' (2.52 (1.23 to 5.18)) accommodations were more likely to fully catch-up than home owners, and families were more likely to catch-up if they lived outside London (1.95 (1.32 to 2.89)). Full catch-up was less likely if parents reported medical reasons (0.43 (0.25 to 0.74)), a conscious decision (0.33 (0.23 to 0.48)), or 'other' reasons (0.46 (0.29 to 0.73)) for not immunising at age 3 (compared with 'practical' reasons).

Conclusions: Parents who partially or fully catch-up with MMR experience practical barriers and tend to come from disadvantaged or ethnic minority groups. Families who continue to reject MMR tend to have more advantaged backgrounds and make a conscious decision to not immunise early on. Health professionals should consider these findings in light of the characteristics of their local populations.

ARTICLE SUMMARY

Article focus

- Areas of the UK are currently experiencing measles outbreaks, and a measles, mumps and rubella (MMR) national catch-up programme has just been launched.
- Individual-level predictors of MMR catch-up are unknown.
- We explore a range of risk factors for partial and full catch-up between ages 3 and 5 years in the nationally representative UK Millennium Cohort Study.

Key messages

- Of 751 children who were unimmunised at age 3, 60% remained unimmunised at age 5, 16% had partially caught-up and 24% had fully caught-up.
- Two distinct groups of parents emerged:
  - Those who experienced practical barriers and were from ethnic minority backgrounds—these groups eventually caught-up.
  - Those who consciously rejected MMR and were from more advantaged circumstances—these groups tended to remain unimmunised.
- Health professionals should consider these findings in light of the characteristics of their local populations when designing programmes to increase and maintain uptake.

INTRODUCTION

The combined measles, mumps and rubella (MMR) vaccination has been used routinely in the UK since 1988. Coverage at 2 years of age peaked in England in 1995, at 92%.[1] A two-dose schedule was introduced in 1996, the first dose recommended soon after the age of 12/13 months[2] (affording 90–95% protection against measles), with a second at 3 years 4 months[2] (99% protection). In 1998, a *Lancet* article[3] was widely interpreted as suggesting that MMR was linked with autism and bowel problems. Although the paper was eventually discredited and retracted by the Lancet in 2010,[4] widespread adverse media coverage in the intervening years led to a dramatic fall in MMR uptake, to a low of 80% in England (of the first dose by age 2) in 2003.[1] By 2006–2007, 85% of 2-year-olds had received at least one MMR, although only 73% had received the recommended two doses by age 5, and

ARTICLE SUMMARY

Strengths and limitations of this study

- This is the first study to examine individual-level characteristics of MMR catch-up in the UK; we do this using data from a nationally representative cohort of children who were born at the height of the MMR scare and are currently being targeted by the national catch-up programme.
- Our analyses refer to predictors of catch-up during a period when parental concerns around the safety of the vaccine were relatively high, and the incidence of measles relatively low; predictors of catch-up in families with young children today may be different.
- We were unable to investigate exact timing of vaccination; therefore our analyses focus on children who were unimmunised at age 3 (so approximately 2 years after the recommended age of administration), and we were unable to detect how long children who had partially or fully caught-up by age 5 had been left susceptible.

levels were particularly low in some geographical areas, such as London.[1] Measles cases started to rise and in 2008 the Health Protection Agency announced that measles was again endemic in England and Wales.

Although coverage has continued to rise (in England in 2011–2012, 91% of 2-year-olds had received one and 86% of 5-year-olds had received two doses of MMR[5]), levels remain below those needed for herd immunity, particularly in some geographical areas and in children who were born in the late 1990s and early 2000s. Consequently, measles outbreaks are currently occurring across some areas of the UK, with young teenagers disproportionately affected (one-quarter of measles cases in 2011–2012 were in 10-year-olds to 14-year-olds[6]). In response to this, Public Health England, National Health Service England and the Department of Health announced a national MMR catch-up programme to vaccinate as many partially or unimmunised 10-year-olds to 16-year-olds as possible by the start of the next school year (September 2013).[7] The catch-up programme outlines aims to strengthen current routine immunisation strategies and in particular to target hard to reach populations; general practitioners (GPs) and schools will play a central role. A better understanding of the social and demographic characteristics associated with catching up (or not), and the reasons reported by parents for their child's immunisation status, is essential if the aims of the new framework are to be achieved and maintained. Cross-sectional evidence indicates that, at age 3, being unimmunised against MMR, or receiving the single antigen vaccines, was socially distributed.[8] However, little is known about the factors which influence the propensity of families with unimmunised children to catch-up. We examine the social correlates of partial and full catch-up with MMR between the age of 3 and 5 years, in a nationally representative cohort of children born at the height of the MMR scare.

METHODS

Participants

We analysed data from the Millennium Cohort Study (MCS), a longitudinal study of children eligible for Child Benefit and born in the UK between September 2000 and January 2002. The sample was derived from a random sample of electoral wards which were disproportionately stratified to ensure an adequate representation of all four UK countries, deprived areas and, in the case of England, areas with high proportions of families from ethnic minority groups.[9] At the first contact, when the MCS children were aged 9 months, data were collected on 18 296 singleton babies (72% of those approached); with subsequent data collections at 3 and 5 years. Seventy-one per cent of the initial cohort responded to all three sweeps (n=12 989). Participants in the second and third sweeps were less likely to be from ethnic or deprived wards,[10 11] although due to the sampling design these proportions remained higher than the general population.

Our analyses focus on the subsample of MCS singleton children who were unimmunised against MMR at age 3 years. Of the 804 children who were unimmunised at age 3 years, 777 (96.6%) had a recorded MMR outcome at 5 years, and 26 (3.3%) of them were excluded because they were reported to have received at least one single antigen vaccine by age 5, leaving 751 eligible participants in our analyses. Compared with the unimmunised children (who are the focus of this analysis), children who had been immunised against MMR at age 3 were: less likely to have a mother with a degree or A-levels, and more likely to have a mother in her 20s or early 30s or who did not smoke during pregnancy; they were also less likely to be living in a lone parent family and more likely to be an only child. The socioeconomic and demographic characteristics of children according to MMR status at age 3 is described in greater detail elsewhere.[8]

Measures

Measures were reported by the main respondent (usually the mother) during survey interviews, which were carried out by trained interviewers in the home.

Outcome measure: MMR status at age 5 was classified as unimmunised (received no combined MMR vaccine), partially caught-up (received one combined MMR) or fully caught-up (received two combined MMRs).

Covariates: We explored socioeconomic and demographic factors that were found to be associated with immunisation status in earlier sweeps of the MCS,[8 12 13] or that were pertinent to immunisation policy. We examined maternal social class (based on National Statistics Socio-economic Classification), ethnicity, maternal age at birth (in 5-year age bands), maternal education and child gender. These measures were all captured at age 9 months because they were unlikely to have changed in later sweeps. In addition, we explored the following time-variant measures, captured at age 3 (the beginning of the potential catch-up period): UK country of residence, ward type ('advantaged', 'disadvantaged',

'ethnic'), number of children in the household, maternal employment status, lone parenthood, household income, housing tenure, whether resident in London, whether the family had changed residential address since age 3, and whether the parents reported the child having natural measles infection. Income data were missing for 14% (122) children at age 3; we supplemented this with information captured at age 9 months, reducing the level of missingness to 24. Missing data were very low for all other measures (listed at the foot of table 1).

We also investigated reasons given for not having had MMR at age 3, classified in a previous analysis[10] as 'practical' (such as missing an appointment), 'medical' (eg, child had asthma), 'conscious decision' (including fear of links with autism) or 'other' (which included don't know). The mean age of the MCS children at the third survey was 61 months, with a range between 52 and 72 months, meaning that some children had more time to catch-up than others. We therefore explored age as a potential confounder, but as it was not found to be associated with immunisation status (p=0.28) we did not include it in our models. There were no a priori hypotheses for interactions so none were explored.

Analysis

We estimated the prevalence of MMR status (unimmunised, partially caught-up and fully caught-up) at age 5, overall and according to the potential explanatory factors. We then fitted Poisson regression models to estimate risk ratios (RRs) and 95% CIs for partial and full catch-up (in two separate models, because previous research indicates that the social correlates of partial and full immunisation are likely to differ[12]). The models were built as follows: first we explored univariable associations between the outcome and each of the explanatory variables. Variables, which were associated with the outcome (p<0.10) using Wald tests for trend, were entered into a multivariable model using a forward stepwise model selection strategy. Residence in London was forced into the multivariable models, due to its potential significance for policy. Only measures which remained significantly associated with the outcome after adjustment were retained.

Data were downloaded from the UK Data Archive, University of Essex in May 2010. Analyses were carried out in Stata V.12 (Stata Corporation, Texas, USA) using survey and response weights to allow for the sample design and attrition between sweeps.[10 14]

RESULTS

Of the 751 MCS children who were unimmunised at age 3, 60.3% (440) remained unvaccinated, 16.1% (127) had partially caught-up and 23.6% (184) had fully caught-up. Table 1 presents the proportion of children who were partially, fully or unimmunised, according to the various predictor measures.

Partial catch-up (compared with remaining unimmunised)

Table 2 (column A) shows unadjusted RRs for partial catch-up, according to each of the predictor measures. Partial catch-up was more likely in families who spoke a language other than English at home (particularly if English was not spoken at home at all), compared with those who only spoke English at home and in those who lived in a ward classified as 'disadvantaged' or 'ethnic', compared with advantaged wards. No significant associations were seen with any of the other variables. When language, ward type and London residence (due to its policy significance) were entered into the multivariable model, only language remained significantly associated with the likelihood of being partially immunised, with a RR of 4.68 (3.63 to 6.03) in families who did not speak English at home (table 2, column B).

Full catch-up (compared with remaining unimmunised)

Table 2 also presents unadjusted and adjusted RRs for fully catching up. In the univariable analyses (column C), children whose parents spoke a language other than English at home (as opposed to only speaking English), who were from ethnic minority groups (compared with White British), or lived in 'ethnic' wards (compared with 'advantaged' wards) were more likely to fully catch-up. Catch-up was also significantly more likely in children whose mother had no educational qualifications (compared with a degree), in lone parent families (compared with two parent families) and in those living in 'socially rented' or 'other' tenure types (compared with own/mortgage). Catch-up was significantly less likely in children with a mother in her 30s (compared with 24–29 years), and in children living in higher income households. Children whose parents had reported a non-practical reason ('medical', 'conscious decision' or 'other') for not having their child immunised with the combined MMR at age 3 were also less likely to have fully caught-up than those reporting practical reasons. Living in London was not associated with immunisation status, although due to its policy significance was included in the multivariable model reported below.

In the multivariable analysis (column D), full catch-up remained significantly more likely in those who only spoke a non-English language at home (1.90 (1.08 to 3.32)), when compared with those who only spoke English. Those from Pakistani or Bangladeshi (2.40 (1.38 to 4.18)), and 'Other' (1.88 (1.08 to 3.29)) ethnic groups were more likely to have caught-up than white British groups, as were those living in 'socially rented' (1.86 (1.34 to 2.56)) or 'Other' (2.52 (1.23 to 5.18)) tenure types (compared with own/mortgage). Full catch-up was also more likely in families living outside London (1.95 (1.32 to 2.89)). Compared with those reporting practical reasons for not having been immunised at age 3, children whose parents reported medical reasons (0.43 (0.25 to 0.74)), a conscious decision (0.33 (0.23 to 0.48)) or 'Other' reasons (0.46 (0.29 to 0.73)) were considerably less likely to have fully caught-up.

Table 1 Weighted percentage (n) of children who remained unimmunised or who partially for fully caught-up with measles, mumps and rubella vaccination, according to social, demographic and other characteristics

	Total	Full catch-up (two doses)	Partial catch-up (one dose)	Unimmunised
Language spoken at home				
English only	91.6 (658)	20.4 (130)	15.8 (115)	63.8 (413)
English and other language(s)	5.7 (64)	53.0 (29)	15.0 (9)	32.0 (26)
No—other language(s) only	2.7 (29)	70.2 (25)	27.7 (3)	2.1 (1)
Ward type				
Advantaged	56.5 (290)	20.3 (60)	13.6 (43)	66.1 (187)
Disadvantaged	38.5 (50)	24.1 (79)	20.1 (73)	55.8 (227)
Ethnic	5.0 (82)	57.6 (45)	13.3 (11)	29.2 (26)
Ethnicity				
British white	87.5 (644)	20.3 (126)	15.8 (111)	63.9 (407)
Other white	2.2 (13)	10.3 (2)	15.6 (2)	74.1 (9)
Mixed	1.4 (10)	33.5 (3)	15.1 (2)	51.4 (5)
Indian	1.0 (12)	76.9 (9)	5.5 (1)	17.5 (2)
Pakistani or Bangladeshi	3.8 (39)	74.7 (28)	9.8 (3)	15.5 (8)
Black or Black British	2.7 (18)	24.7 (7)	35.1 (5)	40.2 (6)
Other	1.4 (14)	65.2 (9)	19.6 (2)	15.2 (3)
Lone parent/carer				
Two parents/carers	79.2 (597)	21.9 (142)	15.3 (97)	62.9 (358)
One parent/carer	20.8 (154)	30.2 (42)	19.3 (30)	50.5 (82)
Maternal age at birth of cohort child (years)				
14–19	8.1 (60)	37.7 (21)	21.8 (14)	40.6 (25)
20–24	15.9 (130)	34.3 (40)	19.4 (27)	46.3 (63)
25–29	23.5 (174)	25.8 (52)	18.2 (27)	55.9 (95)
30–34	27.6 (205)	17.0 (36)	13.0 (30)	70.0 (139)
35–39	20.4 (145)	15.8 (25)	14.3 (24)	70.0 (96)
40+	4.5 (36)	24.2 (9)	10.6 (5)	65.1 (22)
Maternal education				
Degree	20.8 (152)	18.8 (32)	10.4 (15)	70.7 (105)
Diploma	8.9 (64)	13.9 (9)	14.9 (9)	71.1 (46)
A or AS levels	11.3 (85)	22.7 (19)	17.0 (20)	60.2 (46)
GCSE A*–C	32.2 (238)	20.4 (48)	19.6 (50)	60.0 (140)
GCSE D–G	8.4 (64)	18.1 (13)	23.9 (16)	58.0 (35)
Other	1.9 (15)	25.1 (6)	7.7 (1)	67.2 (8)
None	16.4 (133)	44.5 (57)	13.4 (16)	42.1 (60)
Housing tenure age 3				
Owned	58.7 (451)	18.1 (92)	15.6 (77)	66.3 (282)
Privately rented	9.8 (71)	29.8 (18)	11.5 (8)	58.6 (45)
Socially rented	27.7 (199)	30.4 (65)	19.8 (37)	49.8 (97)
Other	3.8 (30)	43.4 (9)	8.1 (5)	48.6 (16)
Household income (£ per annum)				
0–11 000	23.7 (186)	32.1 (57)	18.7 (34)	49.2 (95)
11 000–22 000	30.4 (228)	23.4 (56)	18.2 (41)	58.4 (131)
22 000–33 000	19.9 (142)	12.6 (21)	18.3 (34)	69.1 (87)
33 000–55 000	17.4 (123)	20.6 (28)	6.8 (8)	72.6 (87)
55 000+	8.9 (48)	23.5 (11)	15.9 (8)	60.6 (29)
Social class (9 months)				
Managerial and professional	30.2 (222)	20.8 (42)	12.7 (34)	66.5 (14.6)
Intermediate	16.7 (119)	17.5 (22)	17.6 (18)	65.0 (79)
Small employer/self-employed	8.0 (53)	10.1 (10)	11.9 (8)	78.0 (35)
Lower supervisory and technical	4.0 (33)	33.4 (10)	9.6 (4)	57.1 (19)
Semiroutine and routine	32.0 (248)	24.4 (61)	20.6 (53)	54.9 (134)
Never worked/unemployed	9.2 (73)	47.8 (37)	15.6 (10)	36.6 (26)
Number of children in household (age 3)				
One child	22.5 (180)	26.2 (43)	20.0 (38)	53.8 (99)
Two or three children	63.1 (459)	21.3 (104)	15.5 (73)	63.2 (282)
Four or more children	14.4 (112)	29.9 (37)	12.6 (16)	57.6 (59)

Continued

Table 1 Continued

	Total	Full catch-up (two doses)	Partial catch-up (one dose)	Unimmunised
Maternal employment (age 3)				
Full-time	11.2 (93)	23.8 (21)	11.5 (17)	64.7 (55)
Part-time	25.2 (191)	22.1 (41)	19.6 (37)	58.3 (113)
On leave	3.9 (28)	26.8 (8)	3.9 (1)	69.4 (19)
Self-employed	9.3 (60)	17.1 (13)	13.0 (10)	69.9 (37)
Not employed/student	50.4 (379)	25.3 (101)	16.9 (62)	57.8 (216)
Sex of child				
Male	55.1 (404)	20.6 (95)	17.7 (70)	61.7 (239)
Female	44.9 (347)	27.3 (89)	14.1 (57)	58.6 (201)
Parental report of measles disease by age 3				
Yes	3.5 (22)	19.2 (5)	13.2 (3)	67.6 (14)
No	96.5 (721)	23.7 (176)	16.1 (123)	60.2 (422)
Residence in London				
London	16.2 (102)	17.7 (23)	20.0 (19)	62.3 (60)
Not London	83.8 (649)	24.8 (161)	15.3 (108)	60.0 (380)
Country of residence				
England	58.6 (462)	23.3 (122)	15.7 (74)	61.0 (266)
Wales	21.6 (160)	22.1 (31)	20.1 (31)	57.7 (98)
Scotland	12.9 (87)	26.7 (21)	15.6 (14)	57.5 (52)
Northern Ireland	6.9 (42)	25.3 (10)	17.8 (8)	60.0 (24)
Smoked during pregnancy				
No	63.2 (465)	23.4 (121)	15.1 (76)	61.6 (268)
Yes	36.8 (283)	23.8 (62)	18.0 (51)	58.2 (170)
Changed address since 3				
No	85.6 (647)	23.8 (161)	16.6 (112)	59.6 (374)
Yes	14.4 (104)	22.4 (23)	13.1 (15)	64.5 (66)
Reasons given for not having had MMR (aged 3)				
Practical	6.2 (51)	54.5 (30)	15.3 (7)	30.3 (14)
Medical	15.2 (107)	17.9 (24)	25.5 (26)	56.7 (57)
Conscious decision	66.7 (486)	17.8 (82)	16.0 (85)	66.2 (31.9)
Other	11.7 (76)	35.3 (26)	9.9 (9)	54.9 (41)

Missing: social class 3, smoked during pregnancy 3, income 24, ethnicity 1, reason 31, age at birth 1.

Parents from Asian and 'other White' backgrounds were 2–3 times more likely to experience practical barriers to immunisation than those from White British, Mixed or Black backgrounds. Similarly, families who spoke a non-English language in the home were 2–3 times as likely to experience practical barriers as families who only spoke English at home (although these differences did not reach statistical significance, data not shown).

DISCUSSION

Just over 40% of children who were unimmunised with MMR vaccine at age 3 had either partially or fully caught-up by age 5. The likelihood of catching up varied markedly with a number of social factors, and more so for full than partial catch-up. Some families, particularly those from ethnic minority groups, appear to have difficulty accessing vaccination in a timely fashion. Advantaged families and those citing non-practical reasons for non-vaccination at age 3 are more likely to persist in not immunising their child against MMR.

We used sample and response weights to account for the survey design and attrition between the first, second and third sweeps of the MCS. However, the non-response weights are unlikely to have entirely accounted for differential response; for example, 95.7% children who were included in the ages 3 and 5 surveys were fully immunised with the primary vaccines (at age 9 months) compared with 92.7% in children who did not take part in both of the later surveys ($p<0.001$). We used data from a large national cohort; however since just 6% of MCS children were not immunised by age three, numbers were very small in some cells. We may have therefore lacked statistical power to detect some associations. A limitation of the study is that we utilised parental report of immunisation status, and it was not possible to validate report of immunisation status against health system records. However, there is no gold standard measure of immunisation status and studies have found disagreement between parental report and health records to be low[15] and not socially distributed.[16] Parents were given the opportunity to consult the Personal Child Health Record (or 'red book'). Of the 751 families included in our analysis, 19% (137) consulted the book and found the relevant information, 2% (11) checked the book and did not find the relevant information and 79% (603) chose not to consult the book and relied on their memory. There was no association between catch-up status and whether the parent

Table 2 Unadjusted and adjusted ORs for partial catch-up with the combined MMR vaccine (baseline unimmunised) by age 5

	Partial catch-up (one dose)		Full catch-up (two doses)	
	A: uRR (95% CI)	B: aRR (95% CI)	C: uRR (95% CI)	D: aRR (95% CI)
Language spoken at home				
English only	1	1	1	1
English and other language(s)	1.61 (0.96 to 2.70)	1.61 (0.96 to 2.70)	2.57 (2.00 to 3.32)*	1.54 (0.91 to 2.63)
Other language(s) only	4.68 (3.63 to 6.03)*	4.68 (3.63 to 6.03)*	4.00 (3.37 to 4.76)*	1.90 (1.08 to 3.32)*
p Value	<0.001	<0.001	<0.001	0.0811
Ward type				
Advantaged	1		1	
Disadvantaged	1.55 (1.05 to 2.27)*		1.29 (0.92 to 1.80)	
Ethnic	1.83 (1.18 to 2.83)*		2.83 (2.19 to 3.65)*	
p Value	0.0146		<0.001	
Ethnicity				
British white	1		1	1
Other white	0.88 (0.22 to 3.54)		0.51 (0.13 to 2.06)	0.37 (0.10 to 1.34)
Mixed	1.15 (0.29 to 4.59)		1.64 (0.57 to 4.74)	1.83 (0.65 to 5.17)
Indian	1.21 (0.19 to 7.82)		3.38 (2.40 to 4.76)*	2.01 (0.75 to 5.41)
Pakistani or Bangladeshi	1.96 (0.84 to 4.54)		3.44 (2.79 to 4.23)*	2.40 (1.38 to 4.18)*
Black or Black British	2.35 (0.99 to 5.57)		1.58 (0.73 to 3.43)	1.12 (0.35 to 3.63)
Other	2.84 (1.12 to 7.22)*		3.36 (2.42 to 4.67)*	1.88 (1.08 to 3.29)*
p Value	0.0126		<0.001	0.0950
Lone parent/carer				
Two parents/carers	1		1	
One parent/carer	1.42 (0.92 to 2.17)		1.45 (1.06 to 1.99)*	
p Value	0.1110		0.0208	
Maternal age at birth of cohort child (years)				
14–19	1.42 (0.80 to 2.51)		1.52 (0.98 to 2.37)	
20–24	1.20 (0.68 to 2.12)		1.35 (0.89 to 2.03)	
25–29	1		1	
30–34	0.63 (0.37 to 1.08)		0.62 (0.40 to 0.97)*	
35–39	0.69 (0.40 to 1.20)		0.58 (0.37 to 0.92)*	
40+	0.57 (0.23 to 1.43)		0.86 (0.42 to 1.74)	
p Value	0.0259		<0.001	
Maternal education				
Degree	1		1	
Diploma	1.35 (0.54 to 3.36)		0.78 (0.35 to 1.72)	
A or AS levels	1.72 (0.79 to 3.74)		1.30 (0.71 to 2.38)	
GCSE A*–C	1.91 (1.05 to 3.49)*		1.21 (0.75 to 1.96)	
GCSE D–G	2.27 (1.07 to 4.80)*		1.13 (0.55 to 2.34)	
Other	0.80 (0.11 to 5.93)		1.29 (0.49 to 3.39)	
None	1.88 (0.87 to 4.03)		2.44 (1.63 to 3.66)*	
p Value	0.2420		<0.001	
Housing tenure age 3				
Owned	1		1	1
Privately rented	0.86 (0.32 to 2.34)		1.57 (0.96 to 2.59)	1.51 (0.91 to 2.48)
Socially rented	1.49 (0.96 to 2.32)		1.77 (1.29 to 2.43)*	1.86 (1.34 to 2.56)*
Other	0.75 (0.27 to 2.09)		2.20 (1.27 to 3.79)*	2.52 (1.23 to 5.18)*
p Value	0.0936		0.0014	<0.001
Household income (£ per annum)				
0–11 000	1		1	
11 000–22 000	0.86 (0.53 to 1.41)		0.72 (0.52 to 1.02)	
22 000–33 000	0.76 (0.44 to 1.31)		0.39 (0.23 to 0.66)	
33 000–55 000	0.31 (0.14 to 0.70)*		0.56 (0.36 to 0.87)	
55 000+	0.76 (0.36 to 1.61)		0.71 (0.39 to 1.29)	
p Value	0.0816		0.0028	
Social class (9 months)				
Managerial and professional	1		1	
Intermediate	1.33 (0.73 to 2.42)		0.89 (0.52 to 1.53)	
Small employer/self-employed	0.83 (0.38 to 1.79)		0.48 (0.20 to 1.16)	

Continued

Table 2 Continued

	Partial catch-up (one dose)		Full catch-up (two doses)	
	A: uRR (95% CI)	B: aRR (95% CI)	C: uRR (95% CI)	D: aRR (95% CI)
Lower supervisory and technical	0.90 (0.30 to 2.67)		1.55 (0.80 to 3.00)	
Semiroutine and routine	1.71 (1.11 to 2.64)*		1.29 (0.87 to 1.92)	
Never worked/unemployed	1.87 (0.96 to 3.64)		2.38 (1.62 to 3.49)*	
p Value	0.0989		<0.001	
Number of children in household (age 3)				
One child	1		1	
Two or three children	0.73 (0.47 to 1.12)		0.77 (0.52 to 1.14)	
Four or more children	0.66 (0.34 to 1.29)		1.04 (0.67 to 1.63)	
p Value	0.2807		0.1832	
Maternal employment (age 3)				
Full-time	1		1	
Part-time	1.67 (0.84 to 3.33)		1.02 (0.58 to 1.79)	
On leave	0.35 (0.05 to 2.48)		1.04 (0.46 to 2.33)	
Self-employed	1.04 (0.41 to 2.66)		0.73 (0.37 to 1.45)	
Not employed/student	1.50 (0.88 to 2.57)		1.13 (0.71 to 1.80)	
p Value	0.1836		0.6517	
Sex of child				
Male	1		1	
Female	0.87 (0.60 to 1.27)		1.27 (0.94 to 1.71)	
p Value	0.4755		0.1171	
Parental report of measles disease by age 3				
Yes	1		1	
No	1.29 (0.48 to 3.49)		1.28 (0.52 to 3.16)	
p Value	0.6163		0.5970	
Residence in London				
London	1		1	1
Not London	0.84 (0.50 to 1.41)		1.32 (0.86 to 2.02)	1.95 (1.32 to 2.89)*
p Value	0.5078		0.2012	<0.001
Country of residence				
England	1		1	
Wales	1.26 (0.86 to 1.84)		1.00 (0.69 to 1.46)	
Scotland	1.04 (0.60 to 1.83)		1.16 (0.71 to 1.88)	
Northern Ireland	1.16 (0.55 to 2.44)		1.11 (0.66 to 1.88)	
p Value	0.6802		0.9272	
Smoked during pregnancy				
No	1		1	
Yes	1.20 (0.83 to 1.74)		1.05 (0.76 to 1.46)	
p Value	0.3202		0.7481	
Changed address since 3				
No	1			
Yes	0.77 (0.42 to 1.43)		0.90 (0.62 to 1.32)	
p Value	0.4112		0.6031	
Reasons given for not having had MMR (aged 3)				
Practical	1		1	
Medical	0.93 (0.44 to 1.93)		0.37 (0.20 to 0.68)*	0.43 (0.25 to 0.74)*
Conscious decision	0.58 (0.27 to 1.22)		0.33 (0.23 to 0.47)*	0.33 (0.23 to 0.48)*
Other	0.45 (0.16 to 1.30)		0.61 (0.40 to 0.93)*	0.46 (0.29 to 0.73)*
p Value	0.1357		<0.001	<0.001

*p=<0.05.
aRR, adjusted risk ratio; MMR, measles, mumps and rubella; uRR, unadjusted risk ratio.

consulted the red book (p=0.18), and the associations reported in this paper remained the same when analyses were repeated excluding children where the parent had looked but not found information (data not shown). A small number (26) of children who were unimmunised at age 3 had received at least one single antigen vaccine by age 5. Owing to low numbers we were unable to explore the characteristics of this group.

The intense negative media attention around the safety of the MMR vaccine peaked in 2002/2003 when the MCS children were toddlers. These findings therefore provide important information on the barriers to

catch-up, in a cohort of children who are currently experiencing measles outbreaks throughout the UK,[6] and are a central focus of the newly launched national catch-up programme. However, we measured catch-up across the period 2003/2005 to 2006/2007, when the MMR scare was at its height and the incidence of measles was relatively low (although with some indications of a rise). Concerns around the safety of the MMR have diminished over recent years and therefore the characteristics of families who catch-up with the vaccine today may be different. It is also likely that some of the barriers we report for more advantaged families are reduced during times of measles outbreaks, as the perceived risk–benefit balance of the vaccine shifts. Nonetheless, this paper provides important information on the barriers experienced by advantaged families during times of no outbreak to improve and sustain the current MMR programme, which is also a central aim of the catch-up programme. The recommended age of the first dose of MMR is 12/13 months; however, information on uptake was not collected in the MCS until the children were 3 years of age. Our analysis is unable to address those children who were immunised by the age of 3 but who had not been immunised on time. Similarly, we were unable to investigate the timing of catch-up between the ages of 3 and 5, and therefore how long children who partially or fully caught-up were left susceptible. Finally, the MCS consists only of children who were born in the UK. The barriers experienced by families from ethnic minority groups or who speak other may be different and/or greater in families where the child was born outside the UK.

Before the scare, MMR uptake was generally lower in more deprived areas and households.[17 18] Since 1998, rates declined faster in more advantaged areas[19 20] and more slowly in areas with lower proportions of highly educated residents[20] and in minority ethnic groups.[21] Earlier cross-sectional findings from the MCS demonstrated that the likelihood of being unimmunised against MMR tended to be greater in more disadvantaged families, while children living in more affluent households were more likely to receive single antigen vaccines (indicating conscious rejection of combined MMR).[8] However there is a dearth of longitudinal research exploring the social correlates of catch-up with MMR. The only study, to our knowledge, which has explored the social correlates of MMR catch-up was an ecological study of one million children born between 1987 and 2004 in Scotland. The authors found that children living in more affluent areas were either immunised against MMR on time or not at all, whereas children living in deprived areas were more likely to be immunised late.[20] Our findings not only reflect this, but add to the evidence base by demonstrating that individual-level predictors are strongly related to catch-up. We have also found that remaining unvaccinated against MMR at age 5 was associated with non-practical reasons for not immunising with MMR at 3, reflecting other research which has shown that more affluent families are more likely to consciously reject MMR.[20 22]

Outbreaks of measles are currently being experienced across the UK, leading to the launch of a national catch programme in April 2013. Approaches to optimise uptake of MMR will need to be tailored to the needs of local populations, both now and in the future. Our study has identified two distinct groups of families that do not immunise their child against MMR in a timely fashion (during periods of low measles incidence). The first comprises those who partially or fully catch-up, amounting to 40% of those who were unimmunised at age 3. These families tend to experience practical barriers to immunisation, and are socially disadvantaged or from ethnic minority groups. The second group, which continues to reject MMR and makes up the remaining 60%, consists of parents who consciously reject MMR from the start, and are from more advantaged backgrounds.

Steps are required to minimise time to uptake in those families who do eventually catch-up, through the reduction of practical barriers. National Institute for Health and Care Excellence (NICE) guidance outlines actions to reduce inequalities in immunisation,[23] including provision of information in multiple languages, offering immunisation checks and administration in alternative settings and sending out reminder invitations from GPs.[24] In addition, alleviating any lingering fears and concerns of families who consciously reject MMR is essential. This should include discussion of concerns about 'medical' reasons for not giving MMR. Mythical contraindications to MMR have circulated among the health professional community and parents for some time[25] despite there being few true contraindications for MMR vaccination. 'Medical reasons' reported by parent for not immunising in the MCS (at age 5) included: 'child is not able to have it for health reasons' and 'other medical problems or bad reactions'. It is not possible to ascertain whether any of these were true contraindications, although there are very few genuine contraindications to MMR[2] and these tend to be very rare. It was possible to look at longstanding illness however, and children who had not been immunised for 'medical reasons' had a higher prevalence of longstanding illness (37%) than overall prevalence in the cohort (17%). Conditions reported for children who had not been immunised and who had a long-standing illness included asthma, epilepsy, dermatitis/eczema and cerebral palsy, and although none appeared to be true contraindications, some may have been incorrectly considered to be at that time, either by the health professional or the parents themselves. NICE recommends offering parents opportunities to discuss their concerns about vaccines or vaccine safety with health professionals; receiving such information from health professionals has been found to be the decisive factor for parents who have changed their minds about previously rejected or delayed vaccines.[26] In addition training is recommended for healthcare professionals to equip

them with the skills and information needed to communicate effectively with parents about immunisation, to allay any fears over the safety of the vaccine and any misinformation about medical contraindications. Finally, joint working between the health sector and childcare providers, nurseries and schools is essential.[23]

CONCLUSIONS

Children born at the height of the MMR scare are being disproportionately affected by current measles outbreaks and are the target of a newly launched national catch-up programme. Our findings refer to children of this age and have identified the characteristics of two distinct groups of parents who do not immunise their children with MMR on time. Health professionals should consider their local populations in light of our findings, and tailor the local roll-out of the catch-up programme accordingly.

The new national immunisation framework not only aims to facilitate catch-up but also to strengthen routine approaches to immunisation.[7] Findings from this study should be used to inform longer term local and national planning to improve and maintain timely uptake. While uptake of the first dose of MMR in younger age groups has increased, levels remain below those required for herd immunity and uptake of the second dose is lower still. Measles outbreaks remain a risk, particularly in areas of the country with low uptake.

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