Public Health England

Evaluation of vaccine uptake during the 2013 MMR catch-up campaign in England
Report for the national measles oversight group

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List of abbreviations

CHIS   Child Health Information System

LA   Local Authority outside of London

LB   London Borough

MMR   Measles, mumps and rubella vaccine

SMV   Single measles antigen vaccine

List of definitions

Baseline

The beginning of the catch-up campaign, 31 March 2013

Mid-point

The point in time where information on vaccination with measles-containing vaccine during the catch-up campaign was collected from GP records, approximately 20 August 2013 (but this varied between areas and was between 10-30 August depending on the timeliness of responses of GP practices)

Target population

Children unvaccinated with measles-containing vaccine aged 10-16 years in England

Population of interest

Children aged 10-16 years in England

Measles-containing vaccine

Either measles-mumps-rubella or single measles vaccine

Unvaccinated

Individual with no record of having received any dose of measles-containing vaccine

Vaccinated

Individual with record of having received at least one dose of measles-containing vaccine

Vaccine coverage

Proportion vaccinated with at least one dose of measles-containing vaccine

Executive summary

Background

In the first three months of 2013 there was an increase in number of cases of measles in England compared to previous years which was most marked among 10-16 year-olds. A national catch-up campaign was launched in April 2013 with the objective of ensuring that 95% of children aged 10-16 years received at least one dose of MMR vaccine by 30 September 2013.

The objectives of this evaluation of outcomes were:

1. To estimate, for children aged ten to 16 years at 1 April 2013 in England (and separately for London and the rest of England), the proportion that were vaccinated for measles at baseline.

2. To estimate, for all children aged ten to 16 years at 1 April 2013 in England (and separately for London and the rest of England), the proportion receiving at least one dose of MMR and the number of children who remained unvaccinated by the mid-point of the campaign.

Methods

We used Child Health Information Systems (CHISes) as our sampling frame. We first randomly selected 13 of the 33 London Boroughs (LBs) and 24 of the 116 Local Authorities outside of London (LAs). For each selected LB/LA, we then randomly selected 200 children from the list of those children aged ten, 12, 14 and 16 who were reported to be unvaccinated with MMR in CHIS.

We then used the Patient Demographic Service and GP records to determine, as far as possible: (1) whether these children were still resident in the area; (2) their MMR and/or single measles vaccine (SMV) vaccination status; and (3), if vaccinated, whether they had been vaccinated before or during the campaign.

For each LB / LA, we collected baseline data on the proportion of vaccinated children aged ten, 12, 14 and 16 years.

We used the data collected from the sample to calculate a corrected proportion of vaccinated children assuming that those children "lost to follow up" were as likely to be unvaccinated as those for whom vaccination status was known. We undertook a sensitivity analysis where we assumed that the children "lost to follow up" were all unvaccinated.

For the overall proportion of vaccinated children in England we used a weighted average of the proportion vaccinated in the different LBs / LAs. We estimated the number of children who remain unvaccinated at baseline and mid-point applying these proportions to 2011 census data.

Results

Table 1 shows, for all children aged 10-16 who are resident in England and registered in CHIS: the percentage vaccinated at baseline; the percentage vaccinated at the mid-point of the campaign; the percentage point change in vaccination coverage between baseline and mid-point of the campaign; and the percentage of the target population receiving the vaccine between baseline and the mid-point of the campaign.

Table 1: Estimate of the percentage of unvaccinated children (baseline and mid-point) resident in England and registered in CHIS; evaluation of the 2013 MMR catch-up campaign in England.

	% vaccinated at baseline (95% confidence interval)	% vaccinated at mid-point (95%CI)	% vaccinated from baseline to mid-point (95% CI)	% of previously unvaccinated children who were vaccinated from baseline to mid-point (95% CI)
	%Vbase	%Vmid	%Vmid-%Vbase	(%Vmid-%Vbase)/ (100-%Vbase)
England	**94.73 (93.48-95.98)**	**95.25 (94.07-96.43)**	**0.52 (0.34-0.71)**	**10.77 (6.97-14.57)**
London	86.91 (82.97-90.85)	87.84 (84.11-91.57)	0.93 (0.54-1.32)	7.10 (4.9-9.3)
Outside London	96.12 (95.47-96.77)	96.57 (95.99-97.16)	0.45 (0.25-0.65)	11.42 (7.00-15.85)

Applying these percentages to census data, we estimated that there were approximately 230,000 unvaccinated children aged 10-16 years in England at the beginning of the catch-up campaign (~85,000 in London and ~145,000 outside London). At the mid-point in the campaign, this number can be estimated to have decreased to approximately 210,000 (~80,000 in London and ~130,000 outside London). The baseline and mid-point estimates from the sensitivity analysis are consistent with our findings from the main analysis.

Discussion

This is the first time an attempt has been made to estimate MMR vaccine coverage in England outside the routine data collection systems at age two and five years. There are, however, some limitations to be considered:

- the collection of data from GP practices spanned through the month of August (median: 20 August). We therefore did not include a proportion of children who were immunised in August/September, after the GP practices had provided the data, hence underestimating our final figures of vaccinated children. This proportion is likely to be small

- CHIS lists often include those who migrate into an area but fail to exclude those who have moved elsewhere. We were unable to exclude children migrating out of each LB / LA from all parts of the calculation. Thus we estimated percentages of vaccinated children, for each LB / LA, assuming that children migrating out of the area are as likely to be vaccinated as the other children currently resident in the area

- not all children resident in England are registered with CHIS. There was no information available regarding these children. Our estimates are based on the assumption that unregistered children are as likely to be vaccinated as the registered ones, while it is possible that this is not the case. The effect of this is that coverage may have been overestimated, however, the number of unregistered children is likely to be small and therefore the effect also small

- GP records themselves are not always accurate: this is especially true for children who change practice after having received the vaccine, as their records might not be kept up-to-date. This limitation is likely to have underestimated vaccination coverage

We believe that GP inaccuracies have the highest impact on the final figures. Thus, the figures presented might underestimate the real MMR coverage in children aged ten to 16 years, especially in London, where mobility is higher than in the rest of the country.

This study estimated that vaccine coverage (one dose of measles-containing vaccine) in England at baseline was higher than routinely reported, close to 95%; mid-point coverage reached an estimated 95.3%. Due to limitations highlighted above, it is possible that actual coverage among children aged ten to16 years is higher than we have estimated.

Eleven per cent of the target population (previously unvaccinated children aged ten to 16 years) were reached by the catch-up campaign at mid-point. Work is under way to identify factors associated with non-vaccination, and to compare the success rate of the different strategies used during the campaign.

Estimated coverage in London was 88% at mid-point, significantly lower than in the rest of England. It is believed that this is an underestimate due to less accurate data recording and higher mobility of the population in London compared to the rest of the

country. Further studies are necessary to assess the sensitivity of GP vaccination records, especially in London.

The main objective of the national catch up campaign was to ensure that at least 95% of children aged ten to 16 years in England received at least one dose of MMR vaccine by 30 September 2013. Our study found estimated that at mid-point of the campaign approximately 95% of 10-16 year olds in England have received at least one dose of measles containing vaccine. As our study demonstrates there is variation in vaccine coverage across local areas. Further work is required to increase coverage in geographical areas or populations groups with low uptake. Additional local vaccination activities are underway to reach these groups.

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Background

Increased incidence of measles in England in 2011-2013

In England, in 2011 and 2012, there was an increase in the number of confirmed cases and outbreaks of measles. In 2012, surveillance data reported 1,920 confirmed cases, the highest annual figure since 1994. In the first three months of 2013, there was an increase in number of cases to 587 confirmed cases, despite the highest ever national measles-mumps-rubella (MMR) vaccination level being achieved in England, with 94% of five-year-olds receiving one dose and 90% receiving two doses [1]. Cases were distributed across England with the highest numbers in the North West and North East. Almost 20% of cases (108) were hospitalised and 15 people experienced complications such as pneumonia, chest infection, meningitis and gastroenteritis [1].

This rise in measles cases in the first trimester of 2013 was mostly among 10-16 year-olds, the age group who missed out on vaccination in the late 1990s and early 2000s, when concern around the discredited link between autism and the vaccine was widespread. At that time measles had been virtually eliminated in the UK, but MMR vaccine coverage fell nationally to less than 80% in 2005. After a few years of low vaccination uptake, measles became re-established in 2007 [1].

Child Health Information System for routine surveillance of vaccination coverage

Local Child Health Information Systems (CHISes) record clinical and demographic information for all children resident in a specific health economy. This includes information on immunisations provided in any setting. These systems are the main source of population-based vaccine coverage and are used to identify children who are unimmunised at the coverage age two and five years (for MMR). Data for children above the age of five years, however, are less accurate than those in younger children, particularly for vaccines scheduled earlier in life and for families who have moved GPs or areas after the age of routine vaccination. In addition, a national programme to vaccinate children aged two to 18 years in 2008 was conducted in general practice, but data from this campaign was not collated nationally [2]. A record of a vaccination given is unlikely to be wrong, while it is possible that children who appear to be unvaccinated on CHIS have in fact been vaccinated without their records being updated, especially if a child has changed residence. [1]. Previous local experiences suggest that this proportion could be as high as 30-50% [3].

Estimates derived from vaccine coverage data when the children were aged five years suggest that there are approximately one third of a million 10-16 year-olds who are unvaccinated. This estimate has been derived assuming that 30% of children, whose immunisation status held on the CHIS are 'unvaccinated', have in fact received at least one dose of MMR [1, 3].

The catch-up campaign

NHS England Area Teams, alongside with the Directors of Public Health in Local Government, and with the support of PHE centres, launched a catch-up campaign in April 2013 with the objective of ensuring that 95% of children aged ten to 16 years in England received at least one dose of MMR vaccine by 30 September 2013 [1].

Further details on the campaign can be found on the Public Health England webpage: MMR catch-up programme 2013 [4].

Evaluation of the campaign

A national evaluation group of the campaign has been set up with the agreed objectives of: (1) assessing whether the campaign's primary objective of 95% coverage amongst 10-16 year olds was achieved; (2) determining the reasons for teenagers remaining unvaccinated at the end of the campaign (including factors associated with being inaccurately recorded as unvaccinated); (3) assessing whether the campaign had an impact in reducing inequalities; (4) evaluating the effectiveness of the different approaches used to deliver the campaign.

The current study focuses on the first objective, that is, to assess vaccine coverage in the population of interest at the end of the campaign.

In order to do this, given the concerns regarding the accuracy of the routine data systems, it is also necessary to generate a more robust estimate of vaccinated children aged ten to 16 years at baseline (31 March).

Although the campaign ended on the 30 September, the evaluation of the campaign was performed up to 20 August ("mid-point"). This is because the outcome data from an interim evaluation of the estimated size of the unvaccinated population could be used to inform decision makers on the need for further national or local campaigns such as a further school-based national catch-up programme at the beginning of the new school year.

London

There are considerable socio-demographic differences between London and the rest of the country such that they could be seen as heterogeneous populations. London is highly urbanised, has a high deprivation index and an estimated 37% of its population were born outside of the United Kingdom [5]. Given vaccination trends, it was estimated that the proportion of unvaccinated children was greater in London. Furthermore, in addition to the national primary care campaign in 2008, a school-based London-wide MMR catch up campaign had been conducted in 2004-2005 [6]. It was therefore believed that the underestimation of the vaccinated population in London was thought to be greater than outside London. Thus in order to give policy makers with useful information, we aimed at providing a separate assessment for the campaign in London and outside of London as well as a pooled country-wide assessment.

Aims and objectives

The aim of this evaluation was to assess whether the campaign objective of 95% coverage (1 dose of measles-containing vaccine) of the target group was achieved.

To achieve this, the objectives of the evaluation are:

1. To estimate, for children aged ten to 16 years at 1 April 2013 in England (and separately for London and the rest of England), the proportion that were vaccinated at baseline

2. To estimate, for all children aged ten to 16 years at 1 April 2013 in England (and separately for London and the rest of England), the proportion receiving at least one dose of MMR and the number of children who remained unvaccinated by the mid-point of the campaign

Methods

Study design

We used a multistage sampled survey to provide an estimate of the prevalence of vaccinated children aged 10-16 years in England. Children were sampled through CHISes.

We followed a multi-step approach to estimate proportion of vaccinated children at baseline and mid-point, as illustrated in Figure 1. All personal identifying information have been collected and handled according to current regulations and established best practice (*cf* Appendix 1: Information governance for details).

Figure 1. Methodology used to estimate the national proportion of vaccinated children aged 10-16 in England at baseline and mid-point; evaluation of the 2013 MMR catch-up campaign in England.
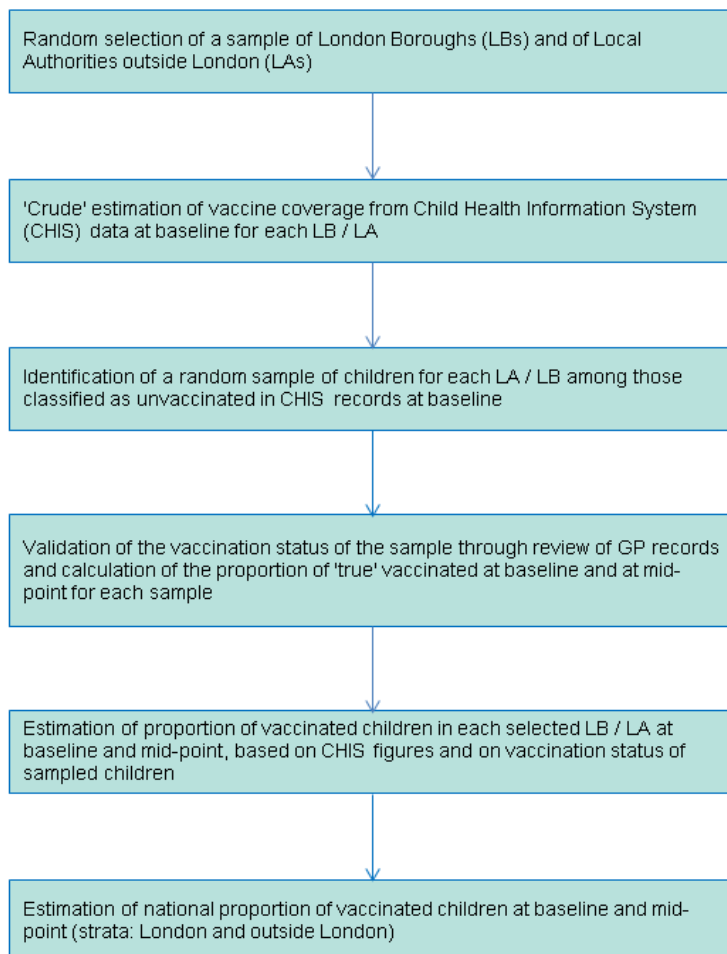
Random selection of a sample of LBs / LAs

We determined the sample size to obtain an appropriately precise estimate the MMR coverage in children aged ten to 16, before and after the campaign in England based on available evidence on vaccine coverage for MMR We estimated we would need a sample of children from:

- 12 London Boroughs (LBs) (around 1,800 children overall)
- 20 Local Authorities outside London (LAs) (around 3,000 children overall)

In order to allow for non-compliance of 15-20% of LBs / LAs, we adjusted the sample size to:

- 14 LBs (2,600 children overall)
- 24 LAs (around 5,000 children overall)

We assigned a random number to each LB / LA and selected the 14 LBs and 24 LAs with the largest random number.

In the occurrence of more than two non-compliant LBs and more than four non-compliant LAs (for example, due to paper records, lack of manpower, non-response), we introduced new LBs / LAs by selecting the next LB / LA from the top of the list until a sufficient number of LBs / LAs were included.

We sampled 200 children in year cohorts ten, 12, 14 and 16 years from each LB / LA from those reported as being unvaccinated (if the overall number of unvaccinated children was <200, we included all the unvaccinated instead).

The sampling strategy used is detailed in Appendix 2.

Figure 2 shows the process of validation of the sampled records and the following steps in the analysis of the proportion of vaccinated / unvaccinated.

Figure 2. Process of validation of the vaccination status of the sampled children through revision of GP records; evaluation of the 2013 MMR catch-up campaign in England.
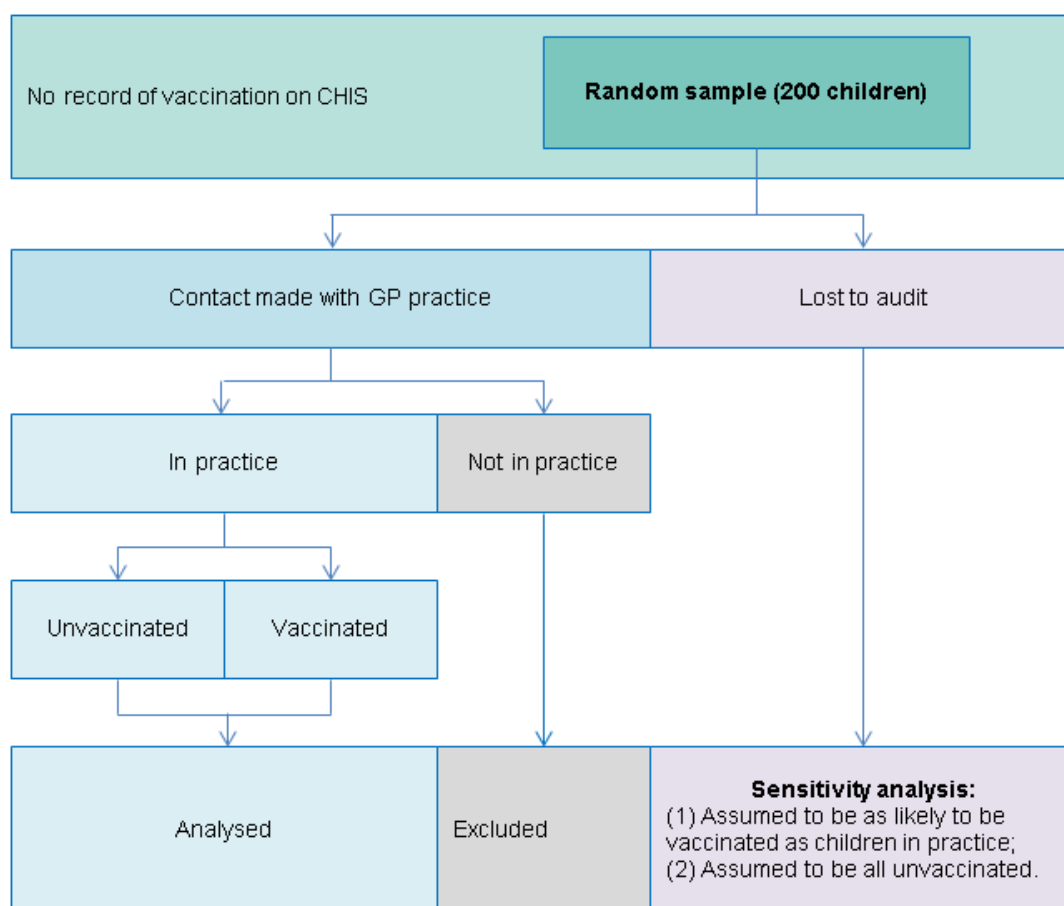
Proportion that are unvaccinated from CHIS data

The proportion of children that are vaccinated as reported on CHIS for each LA / LB is given by PU$_{CHIS}$ (number of children aged ten, 12, 14 and 16 years reported to be vaccinated / overall number of children registered in CHIS aged ten, 12, 14 and 16 years).

Population data sources

1. 2011 census data [9]
2. We requested the most recent denominator data available from each CHIS (obtained in 2013 before baseline). We contacted the reference person for CHIS data management

in each LB / LA to gather the figures (number of children aged ten to 16 years recorded on CHIS and reported as unvaccinated and overall number of children aged 10-16 years recorded on CHIS).

Identification of sample of children recorded as unvaccinated on CHIS

We contacted the reference person for CHIS data management in each LB / LA included in the study and requested the most recent list of children aged 10-16 years (obtained in 2013 before baseline) with no record of having received any dose of measles-containing vaccine (Appendix 2: Sampling strategy).

CHIS managers were requested to populate a standard data collection spread-sheet with the following information for each child with no vaccination record: NHS number, name, surname, date of birth, details of GP practice (National letter to CHISes from Public Health England; Appendix 4: Collection tool for CHISes). To validate the consistency of data, we also asked dates of MMR and/or single measles vaccine (SMV) vaccination. Children with records of having been vaccinated were excluded.

For each LB / LA we selected 200 children aged ten, 12, 14 and 16 years at the time the list was created in 2013 (that is, birth cohorts of 2003, 2001, 1999 and 1997).

Validation of CHIS data against GP records

Children no longer in the LA / LB

The details of the sampled children were passed to the Personal Demographic Service (PDS) [7] for the purpose of excluding any child no longer resident in the LA/LB of interest. Outside London, we excluded records of children who had moved to a different LB / LA. In London, we kept the records of children who had moved to a different LB (as discussion with CHIS providers and Immunisation managers suggested that these were common occurrences), but excluded records of children who had moved outside London.

Contact with GP practices

We contacted in advance the chairs of all Clinical Commissioning Groups (CCGs) to inform them about the project and to ask them to inform GP practices that they might be approached to take part in the study (Appendix 5: Letters to CCGs from NHS).

All data collection activities were coordinated by the Field Epidemiology Service, Public Health England. Administrative, clinical and scientific staff from the local Public Health England Centres, Screening and Immunisation Teams as well as from Field Epidemiology Services made contact via letter / fax and/ or phone with the GP practices of the children in the sample. Information was collected to populate a pre-set spread sheet with details relative to the children (Appendix 6: Fax / letter template for GP Practices; Appendix 7: Script to collect information from GP Practices). Several reminders were sent to non-compliant GP practices.

This allowed us to identify and exclude a further proportion of children who the GPs declared to be no longer registered with that practice. For the remaining children we collected the following information:

- Vaccination status: *no vaccination recorded, MMR, SMV*
- Date of administration of MMR (both dose 1 and dose 2, if applicable)
- Date of administration of SMV (if applicable)
- Notes (open answer, if applicable)

Proportion unvaccinated in the sample

Baseline

Our sample included 200 children recorded as unvaccinated in CHIS at baseline. We categorised them as follows:

1. No longer registered with the practice (either according to PDS or to information gathered from the GP practice) = Y
2. No information available ("lost to audit") = Z
3. Unvaccinated at baseline = U_{base}
4. Vaccinated at baseline = V_{base}
5. Children for whom it was possible to ascertain vaccination status (either vaccinated or unvaccinated) = N

$$200 = Y + Z + U_{base} + V_{base}$$
$$U_{base} + V_{base} = N$$

We excluded children classified as Y as of no interest to us and assumed that children classified as Z had the same probability of being vaccinated as those classified as N. Thus, we estimated the proportion unvaccinated in the sample as:

$$\frac{U_{base}}{200 - Y - Z} = \frac{U_{base}}{U_{base} + V_{base}} = \frac{U_{base}}{N}$$

Mid-point

We applied the same categorisation at mid-point:

1. No longer in practice (either according to the Patient Demographic System or to information gathered from the GP practice) = Y
2. No information available ("lost to audit") = Z
3. Unvaccinated at mid-point = U_{mid}
4. Vaccinated at mid-point = V_{mid}
5. Children for whom it was possible to ascertain vaccination status (either vaccinated or unvaccinated) = N

200 = Y + Z + U_{mid} + V_{mid}
U_{mid} + V_{mid} = N

Again, we excluded children classified as Y and assumed that children classified as Z had the same probability of having received the vaccine during the campaign as those classified as N. Thus, we estimated the proportion unvaccinated in the sample as:

$$\frac{U_{mid}}{200 - Y - Z} = \frac{U_{mid}}{U_{mid} + V_{mid}} = \frac{U_{mid}}{N}$$

Correction of CHIS estimates

Using data obtained from the sample, we corrected the CHIS estimate for each area.

If:

PU_{base} = Proportion of children unvaccinated at baseline among children registered with CHIS and resident in the LB / LA

PU_{CHIS} = Proportion of children reported unvaccinated in CHIS

PU_{mid} = Proportion of children unvaccinated at mid-point among children registered with CHIS and resident in the LB / LA

PV_{base} = Proportion of children vaccinated at baseline among children registered with CHIS and resident in the LB / LA

PV_{mid} = Proportion of children vaccinated at mid-point among children registered with CHIS and resident in the LB / LA

$P_{increase}$ = Proportion of children registered with CHIS and resident in the LB / LA who received MMR during the campaign (up to the mid-point)

$P_{received}$ = Proportion of previously unvaccinated children, registered with CHIS and resident in the area, who received MMR during the campaign (up to the mid-point)

We estimated as follows:

$$PU_{base} = \left(\frac{U_{base}}{N}\right) PU_{CHIS}$$

$$PU_{mid} = \left(\frac{U_{mid}}{N}\right) PU_{CHIS}$$

$$PV_{base} = 1 - PU_{base}$$

$$PV_{mid} = 1 - PU_{mid}$$

$$P_{increase} = PV_{mid} - PV_{base}$$

$$P_{received} = \left(\frac{U_{base} - U_{mid}}{U_{base}}\right) = \left(1 - \frac{U_{mid}}{U_{base}}\right) = \left(\frac{PU_{base} - PU_{mid}}{PU_{base}}\right) = \left(\frac{P_{increase}}{1 - PV_{base}}\right)$$

National estimation

Sample weights

Each LB had the same chance of being selected, regardless of different population weights. The same applied to selection of LAs. However, since we sampled 12/33 LBs and 21/116 LAs, any LBs had a higher probability of being selected than any LAs (0.36 versus 0.18).

Differences in population size and in probability of being selected have been accounted for in the calculations for the national estimates.

If:

N_{LB} = overall number of London Boroughs (31) [8]

N_{LA} = overall number of Local Authorities outside London (121)

n_{LB} = number of London Boroughs sampled

n_{LA} = number of Local Authorities outside London sampled

$Pop_{England,10,12,14,16}$ = number of children in the cohorts selected in England (from 2011 census data) [9]

W_{LB} = weight of each London Borough sampled

W_{LA} = weight of each Local Authority outside London sampled

Then, the weight of each LB / LA will be given by:

$$W_{LB} = \frac{Pop_{LB}}{Pop_{England10,12,14,16}} * \frac{N_{LB}}{n_{LB}}$$

$$W_{LA} = \frac{Pop_{LA}}{Pop_{England10,12,14,16}} * \frac{N_{LA}}{n_{LA}}$$

National estimate

Using the above weights, we calculated weighted averages of the area-specific estimates. We estimated for the whole of London by including just the LBs; we estimated for the rest of England by including just the LAs; and we estimated for the whole of England by including all the areas.

If:

$Pop_{England10-16}$ = Population of children aged 10-16 years in England = 4,380,432 [9]

Then, the numbers of unvaccinated children at baseline ($N_{baseEngland}$) and at mid-point ($N_{midEngland}$) were estimated to be:

$$N_{baseEngland} = (Pop_{England10-16})(PU_{baseEngland})$$

$$N_{midEngland} = (Pop_{England10-16})(PU_{midEngland})$$

Estimate for London and outside London

Similarly, we estimated the numbers of unvaccinated children at baseline and at mid-point in London and outside London.

If:

$Pop_{London10-16}$ = Population of children aged 10-16 years in London = 642,790 [9]

$Pop_{OutLondon10-16}$ = Population of children aged 10-16 years outside London = 3,737,642 [9]

The numbers of unvaccinated children at baseline and at mid-point in London and outside London will be given by:

$$N_{baseLondon} = (Pop_{London10-16})(PU_{baseLondon})$$

$$N_{midLondon} = (Pop_{London10-16})(PU_{midLondon})$$

$$N_{baseOutLondon} = (Pop_{OutLondon10-16})(PU_{baseOutLondon})$$

$$N_{midOutLondon} = (Pop_{OutLondon10-16})(PU_{midOutLondon})$$

Sensitivity analysis

We repeated the analyses assuming that the children categorised as "lost to audit" (Z, that is, whose GP practices did not provide information on vaccination status) were all unvaccinated.

To calculate the estimate for PU_{base} in each LB / LA we used the following:

$$PU_{base} = \left(\frac{U_{base} + Z}{N + Z}\right) PU_{CHIS}$$

We used a similar equation to calculate PU_{mid}. We repeated the subsequent steps to calculate the estimates for England, London and outside London.

Results

LBs / LAs selected

Of the areas initially selected, 12/14 CHIS in London and 17/24 CHIS outside London provided information. We selected five additional substitute LAs outside London. Our final sample included data from CHISes from 12 LBs and 22 LAs.

Estimation of proportion of unvaccinated from CHIS data at baseline

The overall number and the number of unvaccinated children aged 10-16 years by LB / LA are shown in Table 2. The proportion of unvaccinated children, as recorded in CHIS, varied between 18 and 89% in London, and between 0 and 16% outside London. Some CHISes commented that the software systems were being moved from older databases thus may not hold the most up to date data hence the wide variation in London.

Table 2. Total number and number of unvaccinated children aged ten, 12, 14 and 16 years registered on CHIS, by LB / LA: data from CHIS query; evaluation of the 2013 MMR catch-up campaign in England.

LB / LA	2011 Census	CHIS data Overall	CHIS data Unvaccinated	%	LB / LA	2011 Census	CHIS data Overall	CHIS data Unvaccinated	%
London					LA5	22,568	22,429	3,090	13.78
LB1	10,231	11,555	3,099	26.82	LA6	11,990	13,425	725	5.40
LB2	17,026	20,317	3,648	17.96	LA7	32,871	44,719	5,271	11.79
LB3	15,159	18,878	16,794	88.96	LA8	15,215	14,545	633	4.35
LB4	16,546	16,667	8,207	49.24	LA9	28,349	29,518	1,839	6.23
LB5	13,506	14,118	3,377	23.92	LA10	11,548	11,454	597	5.21
LB6	11,230	11,531	2,616	22.69	LA11	33,386	29,948	578	1.93
LB7	4,948	5,068	1,648	32.52	LA12	21,325	23,427	2,806	11.98
LB8	12,155	12,368	8,155	65.94	LA13	11,782	10,485	686	6.54
LB9	14,907	15,482	3,678	23.76	LA14	37,824	37,824*	2,627	6.95
LB10	11,388	22,277	10,562	47.41	LA15	29,965	31,528	1,372	4.35
LB11	9,372	9,355	1,740	18.60	LA16	12,943	10,152	1,317	12.97
LB12	11,998	14,230	3,538	24.86	LA17	24,256	23,306	2,489	10.68
Outside London					LA18	12,962	12,962*	714	5.51
LA1	6,582	5,088	812	15.96	LA19	20,577	22,155	1,570	7.09
LA2	28,733	29,042	1,647	5.67	LA20	8,547	8,216	250	3.04
LA3	10,772	20,428	1,263	6.18	LA21	13,961	11,582	1,515	13.08
LA4	24,232	23,192	1,597	6.89	LA22	9,922	10,980	44	0.40

LB: London Borough; LA: Local Authority outside London; CHIS: Child Health Information System

* Data not available: 2011 census figures used instead

Vaccination status of sample selected

We selected a sample of 200 children aged ten, 12, 14 or 16 from CHIS data for all LBs / LAs, with the exception of one LA, where the overall number of children reported to be unvaccinated in those age groups was 44. For this LA, therefore, our sample was of 44.

The proportions of vaccinated and unvaccinated children at baseline and mid-point are illustrated in Table 3. The proportion of "lost to audit" records was 9.3% on average (3.1% London; 12.7% outside London).

Table 3. Vaccination status of a sample of 200 children from the LBs / LAs selected; evaluation of the 2013 MMR catch-up campaign in England.

LB / LA	Sample N	Lost to follow-up		Not in practice		Unvaccinated, baseline		Vaccinated, baseline		Unvaccinated, mid-point		Vaccinated, mid-point	
		N	%	N	%	N	%	N	%	N	%	N	%
London													
LB 1	200	4	2.0	34	17.0	55	27.5	107	53.5	49	24.5	113	56.5
LB 2	200	32	16.0	56	28.0	68	34.0	44	22.0	61	30.5	51	25.5
LB 3	200	0	0.0	13	6.5	57	28.5	130	65.0	54	27.0	133	66.5
LB 4	200	7	3.5	86	43.0	13	6.5	94	47.0	12	6.0	95	47.5
LB 5	200	4	2.0	17	8.5	94	47.0	85	42.5	86	43.0	93	46.5
LB 6	200	0	0.0	84	42.0	91	45.5	25	12.5	77	38.5	39	19.5
LB 7	200	0	0.0	39	19.5	48	24.0	113	56.5	47	23.5	114	57.0
LB 8	200	0	0.0	30	15.0	41	20.5	129	64.5	40	20.0	130	65.0
LB 9	200	27	13.5	44	22.0	37	18.5	92	46.0	36	18.0	93	46.5
LB 10	200	0	0.0	56	28.0	51	25.5	93	46.5	47	23.5	97	48.5
LB 11	200	0	0.0	13	6.5	95	47.5	92	46.0	88	44.0	99	49.5
LB 12	200	0	0.0	46	23.0	79	39.5	75	37.5	77	38.5	77	38.5
Outside London													
LA 1	200	54	27.0	18	9.0	64	32.0	64	32.0	62	31.0	66	33.0
LA 2	200	14	7.0	37	18.5	126	63.0	23	11.5	85	42.5	64	32.0
LA 3	200	18	9.0	13	6.5	147	73.5	22	11.0	147	73.5	22	11.0
LA 4	200	14	7.0	5	2.5	128	64.0	53	26.5	118	59.0	63	31.5
LA 5	200	0	0.0	2	1.0	49	24.5	149	74.5	37	18.5	161	80.5
LA 6	200	11	5.5	21	10.5	144	72.0	24	12.0	141	70.5	27	13.5
LA 7	200	52	26.0	20	10.0	57	28.5	71	35.5	49	24.5	79	39.5
LA 8	200	29	14.5	9	4.5	99	49.5	63	31.5	93	46.5	69	34.5
LA 9	200	31	15.5	27	13.5	63	31.5	79	39.5	56	28.0	86	43.0
LA 10	200	0	0.0	10	5.0	166	83.0	24	12.0	161	80.5	29	14.5
LA 11	200	64	32.0	5	2.5	98	49.0	33	16.5	97	48.5	34	17.0
LA 12	200	19	9.5	30	15.0	22	11.0	129	64.5	17	8.5	134	67.0
LA 13	200	0	0.0	3	1.5	161	80.5	36	18.0	136	68.0	61	30.5
LA 14	200	44	22.0	12	6.0	83	41.5	61	30.5	77	38.5	67	33.5
LA 15	200	27	13.5	2	1.0	134	67.0	37	18.5	130	65.0	41	20.5
LA 16	200	6	3.0	24	12.0	73	36.5	97	48.5	57	28.5	113	56.5
LA 17	200	12	6.0	19	9.5	63	31.5	106	53.0	58	29.0	111	55.5
LA 18	200	7	3.5	21	10.5	106	53.0	66	33.0	99	49.5	73	36.5
LA 19	200	89	44.5	8	4.0	72	36.0	31	15.5	70	35.0	33	16.5
LA 20	200	49	24.5	8	4.0	94	47.0	49	24.5	63	31.5	80	40.0
LA 21	200	16	8.0	4	2.0	79	39.5	101	50.5	76	38.0	104	52.0
LA 22	44	1	2.3	18	40.9	15	34.1	10	22.7	15	34.1	10	22.7

LB: London Borough; LA: Local Authority outside London

Correction of CHIS estimates

The corrected proportion of vaccinated children at mid-point and the proportion of previously unvaccinated children who received the vaccine during the campaign are illustrated in Table 4.

Table 4. Corrected estimates of the proportion vaccinated in the LBs / LAs selected; evaluation of the 2013 MMR catch-up campaign in England.

LB / LA	Population	Weight	%vaccinated at baseline	%vaccinated at mid-point	%vaccinated from baseline to mid-point	%of previously unvaccinated who were vaccinated from baseline to mid-point
			%/base	%/mid	%/mid-%/base	(%/mid-%/base)/ (100-%/base)
London						
LB 1	10,231	0.01	90.89	91.89	0.99	10.91
LB 2	17,026	0.02	89.10	90.22	1.12	10.29
LB 3	15,159	0.02	72.88	74.31	1.43	5.26
LB 4	16,546	0.02	94.02	94.48	0.46	7.69
LB 5	13,506	0.01	87.44	88.51	1.07	8.51
LB 6	11,230	0.01	82.20	84.94	2.74	15.38
LB 7	4,948	0.01	90.31	90.51	0.20	2.08
LB 8	12,155	0.01	84.10	84.49	0.39	2.44
LB 9	14,907	0.02	93.19	93.37	0.18	2.70
LB 10	11,388	0.01	83.21	84.53	1.32	7.84
LB 11	9,372	0.01	90.55	91.25	0.70	7.37
LB 12	11,998	0.01	87.25	87.57	0.32	2.53
Outside London						
LA1	6,582	0.01	92.02	92.27	0.25	3.13
LA2	28,733	0.06	95.20	96.76	1.56	32.54
LA3	10,772	0.02	94.62	94.62	0.00	0.00
LA4	24,232	0.05	95.13	95.51	0.38	7.81
LA5	22,568	0.05	96.59	97.43	0.83	24.49
LA6	11,990	0.03	95.37	95.47	0.10	2.08
LA7	32,871	0.07	94.75	95.49	0.74	14.04
LA8	15,215	0.03	97.34	97.50	0.16	6.06
LA9	28,349	0.06	97.24	97.54	0.31	11.11
LA10	11,548	0.02	95.45	95.58	0.14	3.01
LA11	33,386	0.07	98.56	98.57	0.01	1.02
LA12	21,325	0.05	98.25	98.65	0.40	22.73
LA13	11,782	0.02	94.65	95.48	0.83	15.53
LA14	37,824	0.08	96.00	96.29	0.29	7.23
LA15	29,965	0.06	96.24	96.69	0.45	11.96
LA16	12,943	0.03	94.43	95.65	1.22	21.92
LA17	24,256	0.05	96.02	96.33	0.32	7.94
LA18	12,962	0.03	96.61	96.83	0.22	6.60
LA19	20,577	0.04	95.05	95.18	0.14	2.78
LA20	8,547	0.02	98.00	98.66	0.66	32.98
LA21	13,961	0.03	94.26	94.48	0.22	3.80
LA22	9,922	0.02	99.76	99.76	0.00	0.00

LB: London Borough; LA: Local Authority outside London

Measles vaccination coverage estimates for England, London and outside London

We estimated the baseline proportion of vaccinated children aged ten to 16 years in England to 94.7% (95% confidence intervals, CI: 93.5-96.0%). The proportion vaccinated at baseline was lower in London (96.9%, 95% CI: 83.0-90.9%) than in the rest of the country (96.1, 95% CI: 95.5-96.8%). At mid-point, the vaccinated increased by 0.5% country-wise (0.9% in London, 0.5% outside London). Overall, the campaign reached 10.8% of its target (previously unvaccinated children; 7.1% in London and 11.4% outside London) (Table 5).

Table 5. Estimate for proportion vaccinated at baseline and at mid-point; evaluation of the 2013 MMR catch-up campaign in England.

	% vaccinated at baseline (95% confidence interval)	% vaccinated at mid-point (95%CI)	% vaccinated from baseline to mid-point (95% CI)	% of previously unvaccinated children who were vaccinated from baseline to mid-point (95% CI)
	%Vbase	%Vmid	%Vmid-%Vbase	(%Vmid-%Vbase)/ (100-%Vbase)
England	**94.73 (93.48-95.98)**	**95.25 (94.07-96.43)**	**0.52 (0.34-0.71)**	**10.77 (6.97-14.57)**
London	86.91 (82.97-90.85)	87.84 (84.11-91.57)	0.93 (0.54-1.32)	7.10 (4.9-9.3)
Outside London	96.12 (95.47-96.77)	96.57 (95.99-97.16)	0.45 (0.25-0.65)	11.42 (7.00-15.85)

Applying these proportions to the 2011 census data [9], we can estimate that approximately 230,000 children aged 10-16 years were unvaccinated in England at the beginning of the catch-up campaign (~85,000 in London and 145,000 outside London). At mid-point in the campaign, this number can be estimated to have decreased to approximately 210,000 (~80,000 in London and 130,000 outside London).

Sensitivity analysis

We generated a second set of estimates for unvaccinated children in each LB / LA, assuming all "lost to audit" records are unvaccinated (scenario 2) illustrated in

Table 6. Corrected estimates of the proportion of vaccinated in the LBs / LAs selected, assuming that all "lost to audit" records are unvaccinated; evaluation of the 2013 MMR catch-up campaign in England.

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Table 6. Corrected estimates of the proportion of vaccinated in the LBs / LAs selected, assuming that all "lost to audit" records are unvaccinated; evaluation of the 2013 MMR catch-up campaign in England.

LB / LA	% vaccinated at baseline	% vaccinated at mid-point	% vaccinated from baseline to mid-point	% of previously unvaccinated who were vaccinated from baseline to mid-point
	%Vbase	%Vmid	%Vmid-%Vbase	(%Vmid-%Vbase)/ (100-%Vbase)
London				
LB 1	90.47	91.44	0.97	10.17
LB 2	87.53	88.40	0.87	7.00
LB 3	72.88	74.31	1.43	5.26
LB 4	91.36	91.79	0.43	5.00
LB 5	87.19	88.24	1.05	8.16
LB 6	82.20	84.94	2.74	15.38
LB 7	90.31	90.51	0.20	2.08
LB 8	84.10	84.49	0.39	2.44
LB 9	90.25	90.41	0.15	1.56
LB 10	83.21	84.53	1.32	7.84
LB 11	90.55	91.25	0.70	7.37
LB 12	87.25	87.57	0.32	2.53
Outside London				
LA1	89.65	89.83	0.18	1.69
LA2	95.13	96.56	1.43	29.29
LA3	94.54	94.54	0.00	0.00
LA4	94.99	95.34	0.35	7.04
LA5	96.59	97.43	0.83	24.49
LA6	95.32	95.41	0.09	1.94
LA7	92.86	93.39	0.52	7.34
LA8	97.08	97.22	0.14	4.69
LA9	96.61	96.87	0.25	7.45
LA10	95.45	95.58	0.14	3.01
LA11	98.40	98.41	0.01	0.62
LA12	97.11	97.46	0.35	12.20
LA13	94.65	95.48	0.83	15.53
LA14	95.31	95.53	0.22	4.72
LA15	96.19	96.55	0.36	9.47
LA16	94.18	95.36	1.18	20.25
LA17	95.57	95.87	0.30	6.67
LA18	96.52	96.74	0.22	6.19
LA19	94.06	94.13	0.07	1.24
LA20	97.73	98.23	0.49	21.68
LA21	93.66	93.86	0.20	3.16
LA22	99.75	99.75	0.00	0.00

LB: London Borough; LA: Local Authority outside London.

In this second scenario, the estimates for both baseline and mid-term proportion vaccinated are 0.5-0.6% lower as would be expected. These estimates could be considered to represent the minimum possible estimate of the coverage (Table 7).

Table 7. Estimate for proportion vaccinated at baseline and at mid-point, assuming that all "lost to audit" records are unvaccinated; evaluation of the 2013 MMR catch-up campaign in England.

	% vaccinated at baseline (95% confidence interval)	% vaccinated at mid-point (95%CI)	% vaccinated from baseline to mid-point (95% CI)	% of previously unvaccinated children who were vaccinated from baseline to mid-point (95% CI)
	%Vbase	%Vmid	%Vmid-%Vbase	(%Vmid-%Vbase)/ (100-%Vbase)
England	**94.19 (92.89-95.49)**	**94.66 (93.42-95.89)**	**0.47 (0.29-0.64)**	**8.52 (5.10-11.95)**
London	86.09 (82.62-89.56)	86.98 (83.72-90.24)	0.89 (0.50-1.28)	6.22 (4.12-8.31)
Outside London	95.63 (94.85-96.42)	96.03 (95.28-96.78)	0.39 (0.21-0.58)	8.94 (4.93-12.94)

Again, applying these proportions to the 2011 census data [9], we can estimate that there were approximately 255,000 unvaccinated children aged 10-16 years in England at the beginning of the catch-up campaign (~90,000 in London and 165,000 outside London). At mid-point in the campaign, this number can be estimated to have gone down to approximately 235,000 (~85,000 in London and 150,000 outside London).

Discussion

This is the first study to estimate measles vaccine coverage nationally (beyond routine coverage data) in a systematic way. Previous estimates were based on limited, local evidence. The main strength of this work is the sampled survey design with an appropriate sample size, which allowed the calculation of robust estimates for England (and for London / outside London). Secondly, a random selection of LBs and LAs across the country removed the possibility of a selection bias as all ten, 12, 14 and 16 year old children reported as unvaccinated on the CHISes had a known probability of being selected.

The use of GP records to cross-check a sample of CHIS records improved considerably our understanding of true vaccine coverage in England.

Since CHIS records are known to be specific (children with a vaccination record are, in all likelihood, vaccinated), but not as sensitive (children with no vaccination record have often, in fact, received the vaccine), we restricted our sample to children with no record of being vaccinated on CHIS: this allowed us to focus our resources where it was more necessary.

Finally, the timeliness of this study was crucial to inform public health action. The interim results of this study were provided to the National Measles Oversight Group to inform discussions as to the possible need of further national catch-up campaigns at beginning of the new school year.

This study has, however, some limitations which need to be considered carefully for the appropriate interpretation of results.

Limitations

Key limitations

The main limitations of this study arise from the quality of routine data systems, which could not be overcome by adjusting the study design. While CHIS databases are generally up-to-date with regards to recording new children who move into the LB / LA area, they appear not to have been as up to date for children who move out. CHIS lists, therefore, report larger numbers of the population of interest that the population estimates obtained from ONS (table 2). This discrepancy is particularly marked in London, presumably due to higher mobility compared to the rest of the country. For this reason we chose to apply a post-hoc adjustment of the sampling weights and to apply

the estimated proportion unvaccinated on the 2011 census figures for England (London and Outside London) to get an overall estimate of number of unvaccinated children in the country.

This provides our best estimate for the number unvaccinated in England; however, not all children resident in England will be registered with CHIS. It was not possible to quantify the number of resident children who are not registered with CHIS, but this figure is likely to be small. Our key assumption was that the proportion of unvaccinated and vaccinated children was similar in the census population as the corrected baseline CHIS population. This is a limitation of the study, as it is possible that children not registered with CHIS might be less likely to be vaccinated. It is possible; therefore, that this assumption may cause an overestimation of the proportion of vaccinated children in England.

Some CHISes commented that their systems were in the process of transferring or updating records- thus data supplied may not be up to date-hence the wide overestimates of unvaccinated children, especially in London. The process of checking the PDS and GP records of a sample of 200 children from each provided the residency status which has been corrected for in the final estimate. However in London, as there are many instances of individuals with GPs not resident in their borough of residence; residences in other London boroughs were included in the study.

It has to be noted that, while most CHISes sent data relative children born in the calendar years 1997, 1999, 2001 and 2003, some sent data referring to financial years (therefore, year cohorts referring to children born between 01/04 and 31/03 of the following year). While this makes the definition of cohorts not entirely accurate, we have no reason to believe this difference would in any way alter the final estimates.

Finally, GP records themselves are not always accurate: while we have used GP records as a 'gold standard' to assess vaccination status, there are situations where GP registers fail to record vaccinations: this is for example when the vaccination is administered abroad or privately. Mostly, however, GP registers might not be updated when children change practice after having received the vaccine. In addition, general practice records may not record vaccines given in other settings, such as schools, and may be less complete for campaigns such as the Capital Catch-up programme undertake in London in 2004. It is therefore reasonable to assume that the use of GP records as gold standard to assess vaccination status is likely to have underestimated the MMR coverage and number vaccinated.

We cannot quantify the extent of (1) overestimation due to children not registered with CHIS, and of (2) underestimation due to inaccuracies in GP records. We believe that

GP inaccuracies are likely to have the highest impact on the final figures, thus the figures presented might underestimate the real number of vaccinated children, especially in London, where mobility is higher than in the rest of the country.

Children vaccinated at the end of the campaign

We proceeded with contacting GP practices before 30 September in order to provide timely preliminary results in time for the beginning of the school year.

Data collection from GP practices was time-consuming and spanned over several weeks. Although we defined mid-term as 20 August 2013, it has to be noted that the first returns from GP practices date 01 August, and the last 31 August. The median date of return was 20 August. It is therefore likely that we did not capture a proportion of children who were immunised during the campaign, later in August and September. However, most of the vaccination activities in general practice, were performed in May and June: in our sample of 6,644 children, 254 were vaccinated during the campaign, and only 20 of them (8%) were immunised in the first 20 days of August. It is therefore likely that only a small proportion of children, vaccinated during the campaign, were not captured by our study (Figure 3) but we are aware that in some areas additional vaccination efforts were made through schools or with vulnerable groups which may have increased vaccination coverage further

Figure 3. Cumulative number of children from the sample (n=6,644) who received a dose of MMR during the campaign (August in blue shade); evaluation of the 2013 MMR catch-up campaign in England.
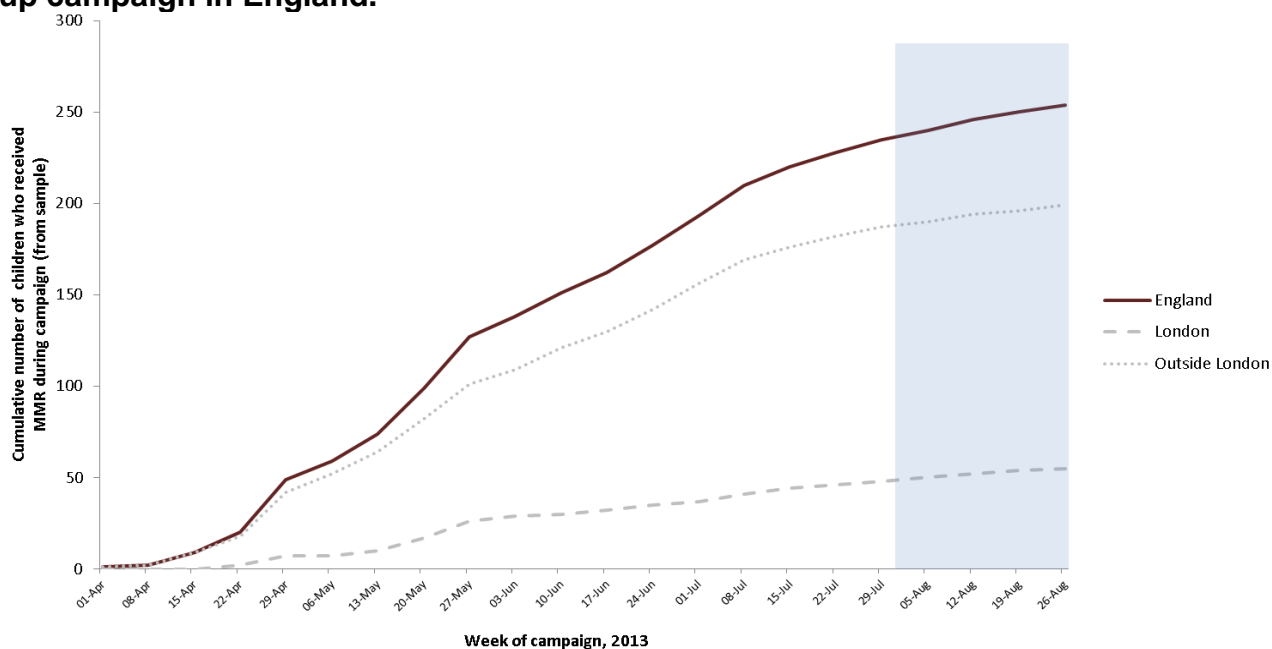
The possibility of contacting the GP practices again after 30 September for an end of campaign estimate was discussed. This will be considered further in future as efforts

continue in areas or groups of particular low coverage. It should be noted that re-calling the same GP practices a second time could have led to bias, as the GP practices selected may have been more likely to vaccinate their children

Non-compliance of LBs / LAs

Not all LBs / LAs provided CHIS data. The study population was increased beyond the estimated powered sample size to account for some non-compliance. In London, two initially selected boroughs did not provide data in time, in spite of several reminders. Outside London, four LAs were lost because of difficulties in retrieving data (i.e. paper based data systems or private providers holding the data). It is possible that non-compliant LAs might have higher proportions of unvaccinated children than compliant LAs if their CHIS systems are less efficient. We also lost two LAs who undertook previous, local validations and one LA that did not provide data in time. However, there is no reason to believe that these would be in any way different from compliant LAs.

Selection of age cohorts

We decided to include in our sample only children aged ten, 12, 14 and 16 years (cohorts of 2003, 2001, 1999 and 1997). This decision was taken for pragmatic reasons; on the assumption that we expected no significant differences with the other age cohorts (children aged 11, 13 and 15). Overall proportions of unvaccinated children, at baseline and mid-point, did not change significantly in the four age groups considered. Thus, there is no reason to believe that they would be different in the other age groups.

Sensitivity analysis

In the sensitivity analysis we assumed the extreme scenario where "lost to audit" children were all unvaccinated. It can be argued that practices that did not respond might be more likely not to have adhered to the catch-up campaign; however it is unlikely that none of these children had received a dose of MMR.

We did not consider the records reported as "not in practice" in the sensitivity analysis for the following reason: generally, CHISes are usually updated in terms of new children who move into their area of competence, whereas children who move out are less likely to be deleted from the records. Additionally, records of children who move within the CHIS are less likely to be updated. Therefore, the 'in practice' proportion of our sample (vaccinated, unvaccinated) already included children who had moved from another practice or LB / LA. Furthermore, by using census data for our denominator, we consider that this would only include children resident in the area.

We also performed an additional analysis using sampling weights calculated directly from the CHIS information which do not take and ONS population estimates into account as previously described. These results are presented in Appendix 8 and are extremely close to the coverage estimates presented in Table 7, providing reassurance that these results are robust to assumptions made regarding the weights used in the analysis.

Children "not in practice"

We found a considerable proportion of children reported as "not in practice" in our samples. This proportion was considerably higher in London, where mobility is higher; above 20% in six out of the 12 LBs selected (table 2). These figures are useful in understanding the quality of CHISes in terms of keeping their records up-to-date; (excluding issues with changes from an old database to a new) but also represent a picture of the higher mobility of children in London. The number of "not in practice", however, did not seem to have any relevant association with vaccination coverage or with the success of the catch-up campaign in the area.

There are heterogeneities in the characteristics of children reported as "not in practice": some of them had moved to another LB / LA. (Children were excluded if they had residences outside the area; except in London if they were resident in another London borough); some had been transferred to another GP practice at different points in time; finally, in a few cases the GP practices declared the children were never registered with them.

While it would be useful to explore these heterogeneities further to audit the CHIS systems, this went beyond the purposes of the current study and has not been undertaken.

Comparison with other sources of information on the campaign

Data from internal sitreps indicate that an estimated additional 250,000 doses of vaccine have been ordered since 1 April 2013. These vaccines will have been used for a range of population groups, including those aged 10-16 years, young adults (aged 16 years and over), and younger children. In addition, many of the vaccines will have been 2nd doses and so not included in the number of doses measured in our study (which was focused only on the number of children aged 10-16 receiving a first dose of MMR). Local reporting in one area suggests that the number of second doses received by 10-16 year olds in the campaign exceeds the number of first doses by around 50%. Data on vaccination of those aged over 16 years will be collected through GP payment claims at a later date. Data on coverage in children aged two and five years has shown an

increase in recent quarters, suggesting that the publicity around the campaign may have led to an increase in demand in younger children and therefore that some of the additional vaccine supply may have been used in the routine programme.

A data extraction from GP IT systems was undertaken by Immform [10] covering the cohort of children who would be 10-16 in August 2013 and comparing the recorded MMR status for the same practices and the same group of children (those aged 9-15 years in August 2012). Data was returned from 4369 of around 8000 eligible practices). These data suggested a reduction in the proportion recorded as unvaccinated of 1.8%; corresponding to a national increase of 78 000 previously unvaccinated children receiving MMR. This estimate is almost fourfold greater than the number recorded as actually vaccinated in our study. The difference is likely to be that the change on the IT systems represents both vaccines delivered and records updated at general practice level. During the process of the campaign, GPs were checking the written notes for records of vaccines given at the start of the campaign and correcting the IT record for children who were recorded as unvaccinated on the system. This confirms that misclassification in GP systems may be similar to that observed in Child Health Information Systems.

Conclusions

On further national catch-up campaigns

Estimates from the present study suggest that vaccine coverage for measles in England at baseline was higher than reported through routine systems, close to 95%; mid-point coverage reached 95.3%. Given some of the limitations of this study, it is likely that coverage among children aged ten to 16 years might be even higher than we have estimated, particularly in London.

Given the high estimated baseline figures for coverage, it is likely that the occurrence of outbreaks in different parts of the country in 2013 is due to (1) pockets of population with lower vaccination coverage; and (2) heterogeneities in coverage in small geographical areas. Overall in England, estimated coverage was high, but given the high transmissibility of measles, particularly in the secondary school setting, those specific schools with coverage below 95% were at risk of small outbreaks. This is consistent with the relatively low attack rate (<1%) within the affected English schools.

Assessment of heterogeneities in coverage across the country, and identification of vulnerable groups was beyond the objectives of this study.

While further national campaigns do not seem necessary, further efforts are required locally where there are areas or population groups with low coverage. Work is underway in local communities to target areas or population groups with low coverage. Local authorities should consider whether a local assessment of the accuracy of vaccine coverage data is needed, particularly in older age groups, and therefore whether local vaccination activities are in order. There is also clearly a longer term need to obtain accurate coverage data in older children, and to ensure that records on vaccines given early in childhood are retained on children's records right up to adulthood (and ideally beyond).

Effect of the current campaign

Eleven per cent of the estimated target population in England was effectively reached by the catch-up campaign. This can be, to some extent, explained by the fact that coverage was already relatively high at baseline, and that the remaining unvaccinated includes: (1) traditional decliners; and (2) children who cannot be immunised for clinical reasons. In addition, some of those recorded as unvaccinated on both CHIS and GP systems may still have been vaccinated and yet records are incorrect. The remaining proportion of unvaccinated children, who could reasonably be expected to be reached, may be low, especially outside London.

For a better understanding of the low apparent degree of adherence of the public to the campaign, and to improve strategies for future vaccination campaigns, a further

assessment is necessary to: (1) identify factors associated with non-vaccination; and (2) compare the success rate of the different strategies used during the campaign.

Estimated coverage in London

Estimated coverage in London was 88% at mid-point. This estimate is believed to be lower than the true coverage because it is inconsistent with measures of coverage for the same cohorts when these children were aged five years. It is likely therefore that the estimate in London was compromised by less accurate data recording and higher mobility of the population in London compared to the rest of the country, and by high annual turnover on GP lists which complicates transfer of data and data recording.

While it is likely that coverage in London is lower than in the rest of England, relatively low incidence of measles and of outbreaks suggest that the actual coverage is considerably higher that estimated.

Further studies are necessary to assess the reliability of GP vaccination records, especially with regards to London, to increase resolution of our estimates.

Impact on measles epidemiology

Despite the relatively low figure for those in the key target group who were vaccinated in the campaign, the high level of awareness generated, and the high number of vaccines ordered in April, suggests that some uptake of vaccine occurred in other age groups. Alongside the overall high baseline coverage in 10-16 year olds, this vaccination activity in other age groups may be contributing to the current pattern of measles since summer 2013. The numbers of cases has fallen to very low levels with only 13 cases being confirmed in England in September.

http://www.hpa.org.uk/hpr/archives/2013/news4513.htm#msls1309

Further studies

As part of the evaluation of the MMR catch-up campaign, and consistently with the results of the current work, further studies are underway, in order to:

- determine the reasons for teenagers remaining unvaccinated at the end of the campaign (including factors associated with being inaccurately recorded as unvaccinated)
- assess whether the campaign had an impact in reducing inequalities (by reaching vulnerable groups and groups with historically low uptake) in keeping with PHE's mission;
- evaluate the effectiveness of the different approaches used to deliver the campaign, by:
    - o determining the effectiveness of the delivery of the campaign through general practice;
    - o determining the contribution to the increase in coverage of school-based approaches;

- o evaluating the social media campaign;
- determine the acceptability of the campaign amongst participating organisations and to identify lessons to be learned for the delivery of future public health interventions.

Appendix 1: Information governance

PHE is provided with a legal gateway for the processing of patient data without consent by Regulation 3 of Statutory Instrument 1438 The Health Service (Control of Patient Information) Regulations 2002.

The Regulation states that the processing of confidential patient information for the purposes specified above may be undertaken by the Public Health laboratory Service (PHLS) and has since been notated by HPA and subsequently PHE.

The Regulation 7 also provides PHE with a legal gateway that permits the processing of personal confidential (patient) data without the consent of the individuals. The transfer of personal data to PHE and the further processing of CHIS system data and information collected from General Practice will be conducted safely and securely and complies with the conditions set out in the SI 1438, in particular Regulation 7.

Regulation 3 of the 2002 Health Services Regulation:

Subject to paragraphs (2) and (3) and regulation 7, confidential patient information may be processed with a view to:

> *(a) diagnosing communicable diseases and other risks to public health;*
> *(b) recognising trends in such diseases and risks;*
> *(c) controlling and preventing the spread of such diseases and risks;*
> *(d) monitoring and managing*
> *(i) outbreaks of communicable disease;*
> *(ii) incidents of exposure to communicable disease;*
> *(iii) the delivery, efficacy and safety of immunisation programmes;*
> *(iv) adverse reactions to vaccines and medicines;*
> *(v) risks of infection acquired from food or the environment (including water supplies);*
> *(vi) the giving of information to persons about the diagnosis of communicable disease and risks of acquiring such disease.*

(2) For the purposes of this regulation, "processing" includes any operations, or set of operations set out in regulation 2(2) which are undertaken for the purposes set out in paragraph (1).

(3) The processing of confidential patient information for the purposes specified in paragraph (1) may be undertaken by:

> *(a) the Public Health Laboratory Service;*
> *(b) persons employed or engaged for the purposes of the health service;*
> *(c) other persons employed or engaged by a Government Department or other public authority in communicable disease surveillance.*

(4) Where the Secretary of State considers that it is necessary to process patient information for a purpose specified in paragraph (1), he may give notice to anybody or person specified in paragraph (2) to require that person or body to process that information for that purpose and any such notice may require that the information is processed forthwith or within such period as is specified in the notice.

(5) Where confidential information is processed under this regulation, the bodies and persons specified in paragraph (2) shall make available to the Secretary of State such information as he may require to assist him in the investigation and audit of that processing and in his annual consideration of the provisions of these Regulations which is required by section 60(4) of the Act." (SI 1438, Regulation 3)

Regulation 7 of the 2002 Health Services Regulation states:

(1) Where a person is in possession of confidential patient information under these Regulations, he shall not process that information more than is necessary to achieve the purposes for which he is permitted to process that information under these Regulations and, in particular, he shall—

> *(a) so far as it is practical to do so, remove from the information any particulars which identify the person to whom it relates which are not required for the purposes for which it is, or is to be, processed;*
> *(b) not allow any person access to that information other than a person who, by virtue of his contract of employment or otherwise, is involved in processing the information for one or more of those purposes and is aware of the purpose or purposes for which the information may be processed;*
> *(c) ensure that appropriate technical and organisational measures are taken to prevent unauthorised processing of that information…" (SI 1438, Regulation 7)*

To those ends the transfers to PHE were short-term, one-off transfers, rather than regular flows of data.

In addition, personal data on the population studied have been kept and handled in compliance with the Caldicott Principles [11].

PHE managed the secure, encrypted transfer of the personal confidential data, known as "PHE Secure dropbox". PHE established a clear and confidential sharing protocol with the local authority and provided guidance to the specific system administrator required to transfer the personal confidential data from the LBs / LAs.

All personal confidential data (names, surnames, dates of birth and postcodes) have been kept confidential and the line list of names encrypted. A list of the people with access to the files to the personal confidential has been maintained by nominated staff within PHE. All the personal confidential data will be deleted at the closure of the Measles evaluation group.

Appendix 2: Sampling strategy

To calculate the sample size needed for the study, we made the following assumptions based on available data:

1. There were approximately 330,000 unvaccinated 10-16 years old in England at baseline, about 100,000 of which were in London [1]
2. Average population of children aged 10-16 years registered in each LB / LA: 20,000-30,000 (range up to 100,000) [1, 3].
3. Average proportion of unvaccinated children: 10% (7-15%) [3]
4. Correction factor for children who have been vaccinated but are not recorded as such on CHIS: 0.3 [3]
5. Loss to follow-up (children recorded on CHIS who have moved and are no longer on the list of their GP, as stated on CHIS): 10%

It was assumed that the proportion of previously unvaccinated children vaccinated during the campaign could be 25% and we required the sample size that would allow this to be estimated with a precision of ±5%.

Hence, we obtained the number of children required to be sampled in each stratum, London and outside London separately, using the following equation:

$$n = \frac{1.96*1.96*p*(1-p)}{d} * d \; n = \frac{1.96^2 (p)(1-p)}{d^2}$$

$$n = 1.96^2 * p * (1 - p) * d$$

Where *p* is the anticipated vaccine coverage during the campaign and is set to 0.25 and *d* is the precision (half-width of the 95% confidence interval set as 0.05.

Thus, the sample size required for a simple random sample would be 288 children. To account for the cluster sampling we assumed that the intra-cluster correlation was 0.035 within London and 0.065 outside London (due to greater inter-cluster heterogeneity outside London). Also assuming the average cluster size to be 200 ten, 12, 14, and 16 year olds, in each CHIS the design effect for London and outside London is 7.965 and 13.935, respectively.

Thus, the overall number of LBs / LAs needed for this evaluation was:
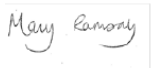
- 12 LBs, that is 2,400 children of which around 1,440 were unvaccinated at baseline

- 20 LAs, that is 4,000 children of which around 2,400 were unvaccinated at baseline

In order to allow for non-compliance of 15-20% of LBs / LAs, we aimed for:

- 14 LBs (around 2,800 children overall)
- 24 LAs (around 4,800 children overall)

Appendix 3: National letter to CHISes from Public Health England

Public Health England

Field Epidemiology Services
Public Health England
2 Rivergate
Temple Quay
Bristol
BS1 6EH

Tel: 0845 504 8668 option 4
17/07/2013

Dear Colleagues,

As part of the investigation of the recent measles outbreaks, Public Health England (PHE) has been commissioned by the MMR catch-up campaign Oversight Group to audit the vaccination records of children in the target group for the current national MMR catch-up campaign. PHE is working closely with the Screening and Immunisation Leads (SILS) in NHS England to undertake a rapid study of children recorded as unvaccinated on the local CHIS and to evaluate the campaign and to inform decisions about further efforts to control the outbreaks of measles across England.

The audit will involve sampling children in a random sample of **14 London boroughs** (LB) and **24 local authorities** (LA) outside of London who are recorded as completely unvaccinated and validating this against GP records.

In essence the study will involve four key steps

1. CHIS teams are asked to identify <u>ALL</u> children aged **10, 12, 14** and **16** years with <u>NO</u> record of MMR vaccination as of the 1st April 2013 (<u>NO MMR 1</u>).

2. PHE to choose a random sample of approximately 180 children for LB and 200 LA per area identified in step 1.

3. PHE to review the GP record for children identified in step 2 to ascertain vaccine history at baseline and current date.

4. For those identified as truly unvaccinated in 3, PHE to review the GP record to ascertain vaccine history at end of the campaign (October 2013).

Your local area has been selected for inclusion in this study and we have been in contact with your local SILS team to discuss the process. We are now writing to you to ask for your assistance in completing the first step of this study.

We would be grateful if you could generate a file in the format of the attached excel document containing information for each child aged **10,12, 14** and **16** years old who was recorded as having no MMR as of the 1st April 2013 and to provide this as soon as possible (by the Monday 29th July). If you are unable to fulfil this request please contact us (as below) to discuss alternative approaches to generating this sample.

PHE, under Regulations 3 and 7 of the 2002 Health Services Regulation is authorised to access Patient Identifiable Information in absence of patient consent and will handle personal information in accordance with the Data Protection Act and Caldicott Principles.

You will be contacted by email regarding access to PHE Secure *Dropbox* and in the meantime please contact Maya Gobin (maya.gobin@phe.gov.uk or 08455048668 option 4) if you have any questions regarding this study and the above request for information.

Yours sincerely

Isabel Oliver

Dr Isabel Oliver, Director of Field Epidemiology Services, Public Health England

Mary Ramsay

Dr Mary Ramsay, Head of Immunisation, Hepatitis & Blood safety, Pubic Health England

Appendix 4: Collection tool for CHISes

Sheet 1: Notes

The following spreadsheet should be populated by the CHIS team of behalf of the selected Local Authority/London Borough.

The CHIS team are asked to identify **ALL** children aged **10, 12, 14 and 16** years old as of the 1st April 2013 who have **NOT** had their first dose of MMR (**MMR1**)

Age group	Year of birth
10	2003
12	2001
14	1999
16	1997

The CHIS team should provide the information on sheet 2 for each individual/child that meets the above criteria.

Please contact benedetto.simone@phe.gov.uk if you have any queries regarding this data collection form

The Health Service Regulation 2002 stipulates that confidential patient information may be processed with a view to monitor and manage the *delivery, efficacy and safety of immunisation campaign*s. The Regulation stated that the processing of confidential patient information for the purposes specified above may be undertaken by the **Public Health laboratory Service** (PHLS) and has since been novated by **HPA** and subsequently **PHE**.
http://www.legislation.gov.uk/uksi/2002/1438/regulation/3/made

The data collected in the spreadsheet will be handled in compliance with the Data Protection and Caldicott Principles. All transfers of personal and sensitive information will be undertaken in a secure and confidential manner. The data will be used within a secure data processing environment and access by unauthorised personnel will be prevented.

Sheet 2: data sheet

Local Authority/London Borough:
Name of person completing the fo
Date of form completion (dd/mm/y

Please only report children 10, 12, 14, 16 of age, who have **NOT** received **ANY** dose of MMR as of 01/04/2013.
For queries, please email benedetto.simone@phe.gov.uk.

	First name	Surname	NHS number	Date of Birth (dd/mm/yyyy)	Country of birth	Sex	GP NACS code	GP name	GP Address	GP Telephone	Has a single measles vaccine ever been given? *[This does not qualify as MMR]*	Has at least one dose of MMR vaccine been given since 01/04/2013?	If yes, date of administration of MMR (dd/mm/yyyyy)
1													
2													
3													
4													
5													
6													
7													
8													
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22													
23													

Appendix 5: Letters to CCGs from NHS

NHS England

4th Floor,
Southside,
105 Victoria Street,
London,
SW1E 6QT.
Tel No: 02079329080
Email: Catherine.heffernan@nhs.net

1st August 2013

To: **CCG Chairs**

      General Practitioners

      Practice Managers of GP practices

Re: **GP Involvement in audit to inform the national MMR Catch-Up Campaign 2013**

Dear Colleague,

As part of a national evaluation into the current MMR catch-up campaign, the London offices of NHS England and Public Health England (PHE) have been asked to contribute to a rapid audit of MMR vaccination records. This audit will validate the vaccination history of children in the target population of 10 to 16 years old. This will assess the true coverage in London, help evaluate the current campaign, and inform if further campaigns are necessary.

Child Health Information System (CHIS) providers from fourteen randomly selected boroughs of London have been asked to identify children aged 10, 12, 14 and 16 with no record of MMR vaccination as of 1st April 2013. From these unvaccinated cohorts, a random sample of approximately 200 children per borough will be selected. The information on these unvaccinated children and young people will need to be validated against what is recorded for the children and young people on the GP systems.

Your practice may be contacted by a staff member of Public Health England by telephone or fax in August 2013, requesting information on the immunisation status of some children in your practice. If contacted, you will then be asked to review the selected children's vaccine history (to define if the child has had MMR vaccination and if so, at what date. If contacted, your practice will also be called again at the end of the campaign.

Under Regulations 3 and 7 of the 2002 Health Services Regulation, Public Health England (PHE) is authorised to access Patient Identifiable Information in absence of patient consent and will handle personal information in accordance with the Data Protection Act and Caldicott principles.

If you have any questions regarding this study, please contact immunisation-submissions.london@nhs.net.

I would like to thank you in advance for your support for this audit.

Yours faithfully,

Dr Catherine Heffernan, D.Phil, FFPH, FRSS,

Principal Advisor on Commissioning Early Years, Immunisation and Vaccination Services

Appendix 6: Fax / letter template for GP Practices

1. Front page

Public Health England

CONFIDENTIAL

Fax

To.	[Practice manager name]	Fax No.	[Practice fax number]
From.	[Your name]	Fax No.	[Your fax number]
Date.	[dd/mm/yyyy]	No of pages. 2	(including this page)

To: [Practice manager name, address]

Dear Colleague,

Public Health England and NHS are currently running a national MMR catch-up campaign. To evaluate this campaign we are checking the vaccination records of a randomly selected group of children. Some of these children, who are listed below, are registered at your Practice.

We would like you to complete all the fields in the table below and return it to us on the fax number above, if possible by tomorrow.

Please contact me on [your telephone number] if you have any queries.

With kind regards,

[Your name, title, affiliation]

2. Spread sheet

Name	Surname	NHS Number	DOB	Sex	Not found	No MMR vaccine	1 MMR + date	2 MMR + dates	Single vaccine date
██	████	█████	████	█					
██	██████	█████	████	█					
██	█████	█████	████	█					

Appendix 7: Script to collect information from GP Practices

Good morning/afternoon.

This is (*name, surname*) from (*Public Health England, xxx office / …*). May I please speak to the practice manager? (*If not, prompt immunisation nurse*)

Public Health England and NHS are currently running a national MMR catch-up campaign. To evaluate this campaign we need to check the vaccination records of a selected group of children. (*X, number*) of children are registered at your Practice and we would like to check if they have had their MMR vaccination.

If the practice you are contacting has a long list of children (8 or more), prompt whether you can send a fax with the list for their convenience to send back quickly (template 47). If so, make sure to go through and explain how to fill the blank fields (ask for a fax number!). If the practice has few children, you can go through them one by one over the phone.
If you send a fax, use the template, populating it with the PII of children of the practice you are contacting (name, surname, NHS number, date of birth, gender).

First child: (*you can start using the date of birth, then name/surname, or by NHS number. Confirm that the other information you have – name, surname, sex, date of birth, NHS number – are correct. If not, take a note). If the child is not registered in the practice click on "child not in practice" in the vaccination field and continue to the next record.*
Can you confirm if the child received any dose of MMR? (*If yes, ask for date and if second dose of MMR – MMR2 – was administered and when. Note that single measles antigen vaccine does NOT count as MMR – there is a separate option of single measles antigen. If the child has not received any dose of MMR, ask whether single measles antigen was given instead, and when*).

Move on to:

Second child: …

When you are finished, thank them for the contribution.

*If requested, you can send a copy of the letter to CCGs from NHS (for London, **Error! Bookmark not defined.**; for outside London, **Error! Bookmark not defined.**)*

Appendix 8: Weights based on sampling design

It is generally considered preferable to use weights based on the sampling design. This is, however, predicated on the sampling frames being at least a good approximation to the population of interest, which CHIS not always is. It seemed therefore reasonable to use 2011 Census data, as described in the Methods section, to obtain the weights for each LBs / LAs.

We estimated vaccine coverage in England (London and outside London) using an alternative weighting system based on sampling design using just the CHIS data, i.e. the sampling fraction for each LB/LA being $200 / N_{RU}$, where N_{RU} is the number of children reported as not vaccinated on the CHIS. These estimates of the percentage unvaccinated as shown in the table below did not differ significantly from the estimates of the percentage vaccinated as shown in Table 7 in the Results section.

	% unvaccinated at baseline (95% confidence interval)	% unvaccinated at mid-point (95%CI)	% of previously unvaccinated children who were vaccinated from baseline to mid-point (95% CI)
	%base	%mid	(%base-%mid)/%base
England	**5.57 (3.54-8.49)**	**5.08 (3.10-7.96)**	**8.91 (6.23-12.6)**
London	13.46 (6.60-23.94)	12.55 (5.98-22.78)	6.76 (4.83-9.38)
Outside London	3.96 (2.38-6.16)	3.55 (1.99-5.77)	10.33 (6.27-16.53)

Appendix 9: Workforce

<u>Field Epidemiological Services</u>
London and South East England

Sooria	Balasegaram	Protocol, coordination
Benedetto	Simone	Protocol, coordination
Charlotte	Anderson	Protocol, scientific advice
Helen	Maguire	Protocol, scientific advice
Chas	Rawlings	Coordination, data collection
Sarah	Anderson	Data collection
Helena	Calixte	Data collection
Jacqui	Carless	Data collection
Anna	Goncalves	Data collection
Esther	Hamblion	Data collection
Karen	Johnson	Data collection
Lamya	Kanfoudi	Data collection
Sanch	Kanagarajah	Data collection
Piers	Mook	Data collection
Chantil	Sinclair	Data collection
Angeline	Walker	Data collection
Amanda	Wright	Data collection

South West England

Maya	Gobin	Protocol, coordination
Isabel	Oliver	Protocol, coordination
Bogusia	Torbus	Coordination, data collection
Iro	Evlampidou	Coordination, data collection
Rahim	Shabbir	IT support

Yorkshire and Humber

Louise	Coole	Coordination
Simon	Padfield	Coordination

East of England

Amy	Trindall	Coordination

East Midlands

Joan	Birkin	Coordination

North East England

Russell	Gorton	Coordination

North West England

Roberto	Vivancos	Coordination
Michelle	Mann	Coordination
Dan	Hungerford	Coordination

West Midlands

Keith	Neal	Coordination
Helen	Bagnall	Coordination

<u>Immunisation, Hepatitis & Blood Safety Department, London Colindale, PHE</u>

Mary	Ramsay	Protocol, scientific advice

<u>Public Health England, London Colindale, PHE</u>

Andre	Charlett	Protocol, statistical support
Tom	Nichols	Protocol, statistical support

<u>National Health System</u>

Imran	Choudhary	Scientific advice
Catherine	Heffernan	Scientific advice
Richard	Pearce	Scientific advice
Thara	Raj	Scientific advice

<u>Health Improvement, London, PHE</u>

Michael	Brannan	Data collection

<u>Public Health England Centres; Screening and Immunisation Leads</u>
North East

Malathi	Natarajan	Data provision
Shirley	Wran	Data provision
Kate	Birkenhead	Data provision
Sheron	Robson	Data provision

Cumbria and Lancashire

Martin	Samangaya	Data provision

Yorkshire and the Humber

Rona	Cruickshank	Data provision
Wendy	Bradley	Data provision
Fiona	Jorden	Data provision

Greater Manchester

Graham	Munslow	Data provision

Cheshire and Merseyside

Dan	Seddon	Protocol, coordination, data provision
Tracie	Duffy	Data provision
Helen	Lewis-Parmar	Data provision

Lynn	Simpson	Data provision

East Midlands

Linda	Syson-Nibbs	Data provision
Tim	Davies	Data provision

West Midlands

Nicola	Benge	Data provision
Nicola	Greaves	Data provision
Neil	Adams	Data provision

Norfolk, Suffolk, Cambridgeshire and Essex

Shylaja	Thomas	Data provision
Debbie	Saban	Data provision

London Integrated Region and Centre

Deborah	Turbitt	Coordination, scientific advice
Johanne	Drake	Data collection
Merrilyn	Williams	Data collection
Diana	Gudeliene	Data collection
Joanne	Thompson	Data collection

North East and North Central London

Erika	Huszar	Coordination, data collection
Dawn	Moult	Data collection

North West London

Louise	Bishop	Coordination, data collection
Margie	Meltzer	Coordination, data collection
Claude	Seng	Data collection
Hazel	Nyamajiyah	Data collection
Kamil	Kanji	Data collection
Laila	Ali	Data collection
Natasha	Hamilton	Data collection
Neel	Bhaduri	Data collection
Nila	Bhatt	Data collection

South West London

Rachel	Heathcock	Coordination, data collection
Rebecca	Cordery	Data collection
Emma	Crawley-Boevey	Data collection
Anne	Maduma-Butshe	Data collection
Elizabeth	Merchant	Data collection
Sam	Perkins	Data collection
Simon	Thorn	Data collection

South East London

Peter	English	Coordination, data collection
Barry	Walsh	Data collection
Steve	Bow	Data collection
Marlene	Callender	Data collection
Edel	Keenan	Data collection
Kasia	Wisniewska	Data collection

Thames Valley Public Health England Centre

Paula	Jackson	Data provision
Christine	Cook	Data provision

Additional colleagues from Thames Valley

Devon, Cornwall and Somerset Public Health England Centre

Alison	McKenzie	Data provision
Suzanne	Tiffany	Coordination, data collection

Avon, Gloucestershire and Wiltshire Public Health England Centre

Julie	Yates	Protocol, coordination, data provision
Christine	Woodward	Data provision
Matthew	Dominey	Data provision
Pamela	Akerman	Data provision
Rob	Tolfree	Data provision

NHS Sussex

Max	Kammerling	Data provision
Fiona	Bower	Data provision
Ishani	KarPurkayastha	Coordination, data collection

<u>Child Health Information Systems</u>

Chris Amos, Daniel Barnes, Sue Clark, Michael Corr, Carol, Dawson, Michael Denson, Mark Elverstone, Helen Finnie, Elaine Flavell, Adeola Gbadegesin, Lynette Gillibrand, David Griffiths, Teresa Heffernan, Nicola Hunt, Kassim Hussein, Sharon Irving, Gary James, Richenda Kemp, Simon Kendrik, Mark Love, Chris Lovelace, Rebecca Munden, Donna Newman, Olivier Paulides, Elizabeth Powell, Dave Price, Paul Purwell, Mathew Read, Iona Rees, Lynn Robinson, Amanda Sadler, Jamie Scott, Sood Soowamber, Angelica Tatam

Others
Any others whose names were inadvertently not provided to us

References

[1] Press release. National MMR vaccination catch-up programme announced in response to increase in measles cases. Public Health England. Published 25th April 2013. Available on https://www.gov.uk/government/news/national-mmr-vaccination-catch-up-programme-announced-in-response-to-increase-in-measles-cases (accessed: 25 September 2013)

[2] Chief Medical Officer. *MMR catch-up programme CEM/CMO/2008/12*. London: Department of Health, 2008. Available on http://www.hpa.org.uk/hpr/archives/2008/news3208.htm#mmr (accessed: 13 November 2013)

[3] MMR ready reckoner background document. Published 23rd April 2013; Updated 25th April 2013. Available on https://www.gov.uk/government/publications/calculating-mmr-coverage-ready-reckoner-tool-2013 (accessed: 25 September 2013)

[4] Series: MMR catch-up programme 2013. Public Health England. Published 11 June 2013 Available on https://www.gov.uk/government/organisations/public-health-england/series/mmr-catch-up-programme-2013 (accessed: 26 September 2013)

[5] Focus on London - Population and Migration. Greater London Authority. Published November 2010. Available on http://data.london.gov.uk/datastore/applications/focus-london-population-and-migration (accessed: 26 September 2013).

[6] Hitchen L. London's catch-up vaccination campaign against measles, mumps, and rubella reaches less than a quarter of children who were unvaccinated. BMJ 2008;337:a1797

[7] The Personal Demographics Service, NHS. Updated in 2013. Available on http://www.connectingforhealth.nhs.uk/systemsandservices/demographics/pds/ (accessed: 03 October 2013)

[8] Health Protection Profiles. Public Health England. Available on http://www.hpa.org.uk/Topics/InfectiousDiseases/InfectionsAZ/HealthProfiles/HPPSummaryInformation/ (accessed: 03 October 2013)

[9] 2011 Census, Population Estimates by single year of age and sex for Local Authorities in the United Kingdom. Available on http://www.ons.gov.uk/ons/publications/re-reference-tables.html?edition=tcm%3A77-294277 (accessed: 03 August 2013)

[10] Immform outline http://www.gov.uk/government/collections/immform 294277(accessed: 03 November.2013)

[11] Surveillance and confidentiality – information for health care professionals. Public Health England. http://www.hpa.org.uk/web/HPAweb&HPAwebStandard/HPAweb_C/1195733746440 (accessed: 30 September 2013)