Health Intelligence and Insight

NHS Cambridgeshire and Peterborough Clinical Commissioning Group

Inequalities in child immunisation in Cambridgeshire & Peterborough (February 2020)

Background

Immunisation is one of the safest and most effective way of providing protection against disease as after vaccinating, people are far less likely to catch the disease if there are cases in the community. Beyond the individual level, vaccination has numerous benefits for society. If a proper immunisation regime is implemented in a population, even those who are not vaccinated such as new-born babies, elderly people and those who are too sick to receive vaccination, can benefit from this *herd protection*. In fact, when a high percentage of the population is immunised, it is difficult for infectious diseases to spread and reach those individuals who are vulnerable (Table 3 below represents the herd protection thresholds for some diseases from which we provide vaccination). **Antibiotic resistance** is likely to be one of the greatest challenges to health of the 21st century, and so vaccinating people is an effective solution because it prevents infection and the need for antibiotics (1). Even vaccinations against viruses – which are not treatable by antibiotics – have a role to play, because people often take antibiotics unnecessarily when they have a viral infection. In addition, it is widely acknowledged that vaccination programmes have an enormous **positive economic impact** (2). Though vaccines require funding, they lead to long-term savings through reduction in health costs and avoidance of loss of productivity from the workforce. Estimates of the savings from vaccination are in the order of tens of billions of pounds (3).

The ability to reliably measure vaccine coverage plays an essential role in evaluating the success of a vaccination programme, identifying susceptible populations for further interventions and informing future vaccine policy decisions (4). There is an expectation that the NHS Health inequality strategy will consider inequality in child immunisation as a topic to address.

Objective

This report aims to establish whether there are inequalities in child immunisation in Cambridgeshire and Peterborough. More precisely we are reviewing whether there is any correlation between immunisation coverage and the deprivation of an area in the last year recorded and the trend over recent years.

Methods

The Child Immunisation annual data from 2014/15 to 2018/19 for three cohort age groups 12 months, 24 months and 5 years have been made available by NHS Digital (4). These show immunisation coverage at GP practice and CCG level.

The immunisation recorded at 12 months are DTaP/IPV/Hib/Hep B (for diphtheria, tetanus, pertussis, polio, Haemophilus influenzae type b [Hib], Hepatitis B); Meningitis B; Pneumococcal Conjugate Vaccine (PCV); Rotavirus. At 24 months DTaP/IPV/Hib; MMR (for measles, mumps, and rubella), Hib/Meningitis C Booster and PCV Booster; while at 5 years are DTaP/IPV Booster; DTaP/IPV/Hib; Hib/Meningitis C Booster; MMR Dose 1 and Dose 2 (summary shown in Table 1).

Table 1. Summary timetable for child vaccinations

12 months	24 months	5 years
DTaP/IPV/Hib/Hep B	DTaP/IPV/Hib	DTaP/IPV Booster
Meningitis B	MMR	DTaP/IPV/Hib
Rotavirus	Hib/Meningitis C Booster	Hib/Meningitis C Booster
Pneumococcal Conjugate Vaccine (PCV)	PCV Booster	MMR Dose 1
		MMR Dose 2

In order to assess whether in the last year recorded we have inequalities in immunisation in our area (referred as **intra-year inequality determination**), GP practices were first ranked by their deprivation score using the Index of Multiple Deprivation (IMD) Score (low value, least deprived; high value, most deprived). Given that this data concerns the period 2014/15 until 2018/19 we used the more relevant IMD Score from 2015 which was available in that period rather than the more recent IMD 2019 (5). Data was then then split into deciles and the deprivation scores of GP practices were then plotted against the immunisation percentage coverage or uptake. For each vaccine subgroup, a linear trendline (best fit) was added (with equation and coefficient of determination, or R-squared) to observe whether there was a directly proportional correlation between changes in immunisation coverage and increased deprivation (see Figure 1). R-squared values smaller than 0.4 were considered not statistically significant for intra-year inequality analysis.

In order to better represent the trend over the years (referred as **inter-years inequality determination**) for each immunisation type, we used the inequality Analysis tool developed by Public Health England and plotted the slope index of inequality values against time (Figure 2 and table 2) (6). The Confidence Intervals (CI) resulting from the tool were considered to define whether the change in inequality from 2014/15 to 2018/19 were statistically significant.

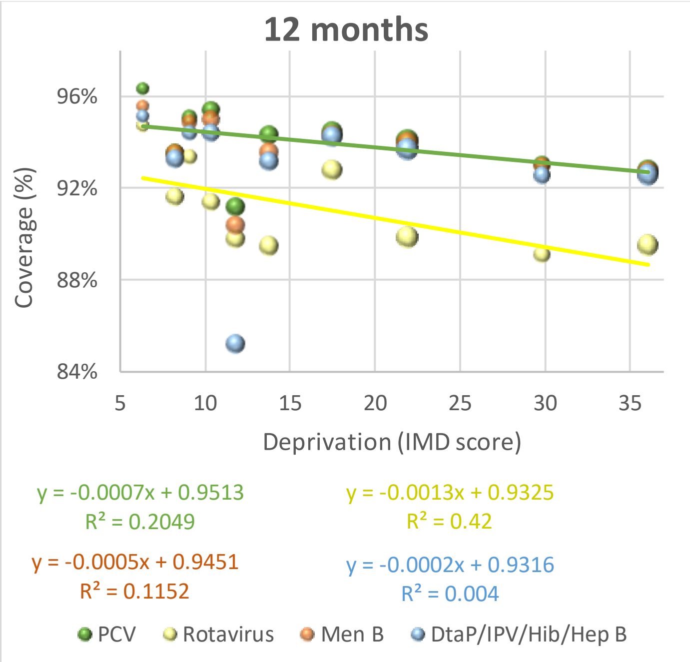
Results

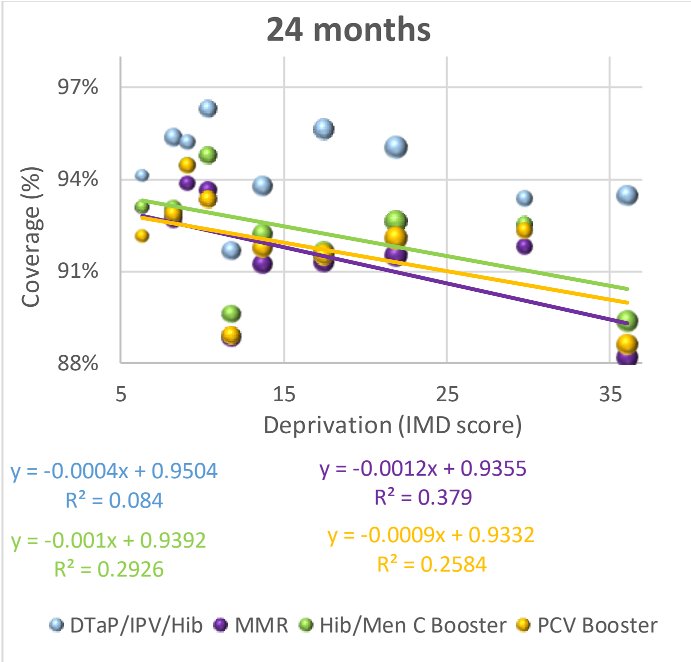
Child immunisation coverage in the last year recorded (Intra-year inequality determination)

Figure 1 shows that most of the best fit trendline equations have a negative '*y*' values, indicating that child immunisation coverage percentages decrease with deprivation of an area. However, the R-squared values fall far below 0.4 for most vaccinations, indicating that the model does not fit our data satisfactorily, hence this data shows that differences between points might not be significant. Only Rotavirus immunisation at 12 months presents a -4% difference in coverage between the least and most deprived deciles with a relatively good fit (R-squared of 0.42). Interestingly, MMR follows next with a R-squared of 0.379 but giving that for our analysis we 'set the bar' to 0.4 we consider this indicator a close to, but a non-statistically significant difference in coverage between areas. Hence, **according to this analysis in the last year recorded in Cambridgeshire & Peterborough, apart from Rotavirus immunisation, we do not observe a statistically significant decrease, or increase, in child immunisation coverage with an increase in the deprivation score** of a GP practice. Figure 1 shows the immunisation coverage for the three cohort age groups 12 months, 24 months and 5 years.

Overall there are 13 GP practices that score below 80% coverage for more than one vaccine (data not shown). It appears that immunisation coverage decreases as children get older since the number of GP practices that present coverage below 80% for a vaccination are 11, 14 and 35 for the cohort groups of 12 months, 24 months and 5 years, respectively - although the coverage for the 24 months group does fall below 75%.

One practice recorded multiple outliers with values that fall below 80%: DTaP/IPV/Hib/Hep B at 12 months are even recorded as 18.9%, while Men B, PCV and Rotavirus are logged as 73%. The number of eligible children is 37 for this cohort group. The 24 eligible children at 24 months instead score between 83.3% and 95.8% coverage, while the 33 eligible children from the 5-year cohort group scored 51.5% and 63.6% DTaP/IPV Booster and MMR Dose 2, respectively. It is not possible to determine whether this GP practice exercises a poor immunisation service or whether it is not keeping up to date with their data submission. Interestingly, in Cambridge there are practices with some of the lowest coverage for child immunization.





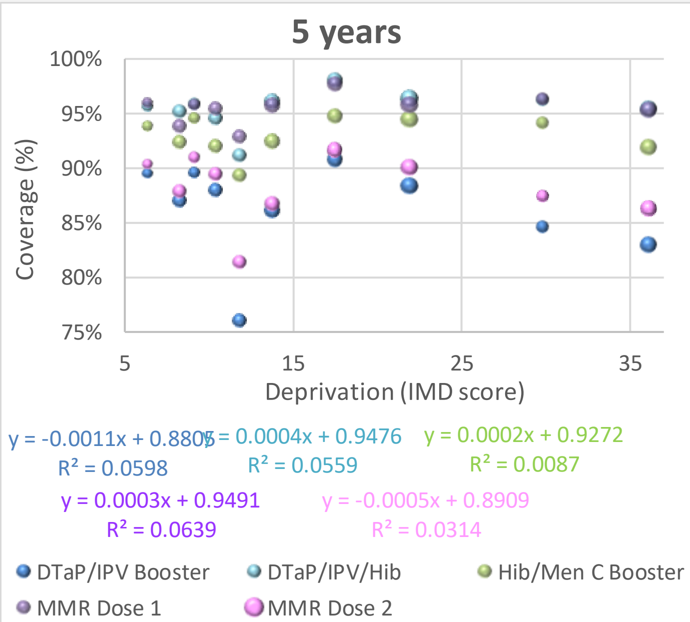


Figure 1: Immunisation coverage for the three cohort age groups 12 months, 24 months and 5 years. Only Rotavirus at 12 months displays a statistically significant inequality in child immunisation in Cambridgeshire and Peterborough in the last year recorded (2018/19). Each decile group is represented as a sphere and its size is proportional to the size of the decile group. The linear trendline for the best fit (solid lines) is shown for data with a R^2 above 0.15 (data below 0.15 is only shown as spheres). R_2 values smaller than 0.4 are considered not statistically significant for intra-year inequality analysis.

More in detail, these vaccination percentages compare to national data from 2018/19 as follows:

Rotavirus (12 months): national data shows that the coverage in England was 91% (4). In Cambridgeshire and Peterborough the coverage ranges from around 92.5% to 89.5%. However, decile group 6, 9 and 10 display values lower than national (89.5%, 89.1% and 89.5%, respectively).

DtaP/IPV/Hib (24 months): national data shows that the coverage in England was 94.3% (4). Although the trend line in Figure 1 shows that in Cambridgeshire and Peterborough coverages range from about 95% to 94%, half of the decile groups are found below national level (decile 1, 5, 6, 9 and 10), with decile 5 scoring lowest with 91.7%. Hence, although these low values are somewhat worrying, they confirm that there is no inequality in the coverage of this type of vaccination between the least and most deprived areas.

Hib/Men C Booster (24 months): national data shows that the coverage in England was 91.8% (7). In Cambridgeshire and Peterborough coverages range from about 93% to 91%, but the decile groups that are found to have the lowest coverage are decile 5, 7 and 10 (the latter scoring poorest with 89.4%). In figure 1, the R-squared determined for this vaccination is 0.3, hence, although not statistically significant, this immunisation type should be monitored for future trends.

PCV Booster: national data shows that the coverage in England was 90.2% (7). Although in our CCG the coverage for this immunisation ranges from about 92.5% to 90.5%, decile group 5 and 10 are performing poorer than national average (with 88.9% and 88.6%, respectively).

MMR (24 months): While coverage in England in 2018/19 was 90.3% (7), our CCG shows a coverage ranging from 92.5% to 90%. Only decile 5 and decile 10 are below national level (88.8% and 88.2%, respectively), but this year, as mentioned above there is no statistically significant inequality gap between the least and most deprived areas for MMR vaccination at 24 months.

MMR Dose 2 (5 years): national data shows that the coverage in England was 86.4% (7). In Cambridgeshire and Peterborough we display an overall better picture than the national one. However, similarly to the scenario above, decile group 5 together with the most deprived decile (decile group 10) are scoring poorer than the national average with 81.4% and 86.2%, respectively.

Hib/Men C Booster (5 years): Decile group 4, 5 and 10, display coverage values (92%, 89.4% and 91.9%, respectively) that are below the national average of 92.4% (7).

<u>Child immunisation rates</u> **(Inter-year inequality determination)**

Apart from an Intra-year inequality analysis, we are also interested to see if any inequality is detectable **over time.** The monitored period goes from 2014/15 to 2018/19. For Rotavirus, which presented statistically significant inequality in the last year recorded (see above), we were provided only with coverage data for the last two years recorded, hence we could not analyse its trend over time. For the other child immunisation types instead, despite **the trend appear to be marginally worsening**, R-squared values fall far below 0.4, indicating that the model does not fit our data satisfactorily (data not shown). Therefore, in order to appreciate the overall trend of child immunisation over the last five years, we analyzed this data using the Inequality Analysis Tool (developed by the Public Health England Knowledge and Intelligence Teams in the East Midlands and London (8)) and by plotting the resulting **slope index of inequality** values against time and by plotting the Slope Index of Inequality (SII) values against time (shown in Figure 2 and Table 2). The slope index of inequality (SII) represents the linear regression coefficient that shows the relation between the level of health in each socioeconomic category and the hierarchical ranking of each socioeconomic category on the social scale (9). According to this analysis, despite **a worsening inequality over the years** seems visible, if we take into consideration the resulting Confidence Intervals to determine whether data over the analyzed period, we can appreciate how **only MMR (at 24 months) displays a statistically significant worsening trend over the analyzed period**.

It is crucial that these inequality trends are improved on, particularly as children at this age usually start school and mix with lots of other children, increasing the ability of diseases to spread and magnifying the importance of herd immunity (10).

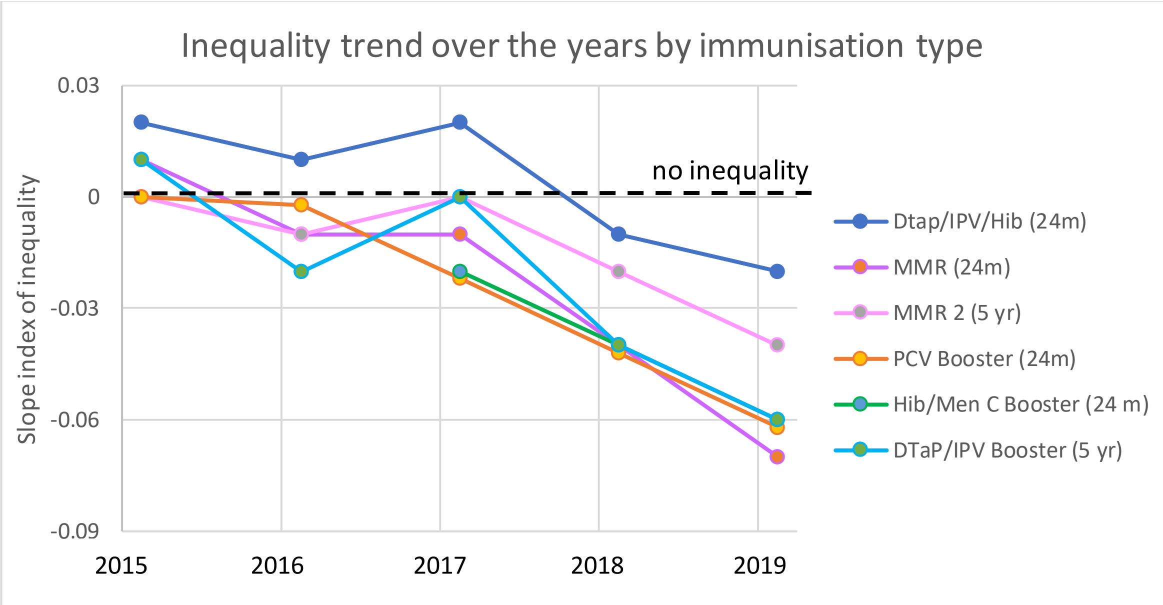


Figure 2. Slope Index of Inequality plotted against time for various child immunisation types. Despite the inequality appears to be getting worse with time for every child immunisation type, we can conclude that only for MMR (24 months) the difference in inequality is statistically significant for the time period analyzed (see Table 2 below for Confidence Interval errors). The black dotted line marks the '*no inequality*' benchmark line between the most and least deprived areas. Points below zero indicate the presence of inequality towards more deprived area.

	2014/15		2015/16		2016/17		2017/18		2018/19	
	SII	CI	SII	CI	SII	CI	SII	CI	SII	CI
Dtap/IPV/Hib (24m)	+0.02	0.0, +0.04	+0.01	-0.02, +0.04	+0.02	0.0, +0.04	-0.01	-0.03, +0.01	-0.02	-0.05, +0.01
MMR (24m)	+0.01	-0.02, +0.03	-0.01	-0.05, +0.02	-0.01	-0.04, +0.02	-0.04	-0.07, -0.01	-0.07	-0.1, -0.04
MMR 2 (5 yr)	0.0	-0.05, +0.04	-0.01	-0.06, +0.05	0.0	-0.04, +0.04	-0.02	-0.06, +0.02	-0.04	-0.09, 0.0
PCV Booster (24m)	0.0	-0.03, +0.03	-0.02	-0.06, +0.02	-0.02	-0.05, +0.01	-0.04	-0.07, -0.02	-0.06	-0.1, -0.03
Hib/Men C Booster (24 m)	-	-	-	-	-0.02	-0.05, +0.01	-0.04	-0.07, -0.01	-0.06	-0.09, -0.03
DTaP/IPV Booster (5 yr)	+0.01	-0.04, +0.06	-0.02	-0.07, +0.03	0.0	-0.05, +0.04	-0.04	-0.1, +0.01	-0.06	-0.11, 0.0

Table 2. Inequality in children immunisation over time. Slope index of inequality (SII) values and their confidence intervals (CI). Over the 2014/15 to 2018/19 period only values for MMR (at 24 months) show a statistically significant worsening trend of inequality gap between the least and most deprived areas (values highlighted in red).

While the Slope Index of Inequality quantifies in absolute terms the linear association between the socioeconomic rank and a chosen health outcomes (in this case child immunisation), the Relative Index of Inequality (RII) aims to quantify these in Relative terms (11). Interestingly, if we take into consideration the Relative Index of Inequality, together with MMR also PCV Booster immunisation shows a statistically significant worsening inequality gap between the least and most deprived areas over the 2014/15 and 2018/19 period (data shown in Figure S1 and Table S1 in the Supplementary material).

Fortunately, even if child immunisations are in decline for some types of vaccinations, we do appear to be on the safe side of the herd protection threshold for all diseases (Table 3). To get herd immunity against Diphtheria or Polio, for example, >86% of the population have to be vaccinated against these two diseases, while we present 95% coverage.

Disease	Herd protection thresholds	Coverage in our CCG	Transmission
Diphtheria	85%	95%	Saliva
Measles	83-94%	87-95% *	Airborne
Mumps	75-86%	87-95% *	Airborne droplet
Rubella	83-85%	87-95% *	Airborne droplet
Polio	80-86%	95%	Fecal-oral route
Pertussis	92-94%	85-94% #	Airborne droplet
Meningitis C	17-26%	92%	Saliva
Influenza	-	53% & 73% ǂ	Airborne droplet

* For Measles, Mumps and Rubella we are considering coverage for MMR dose 2 and 1 at year 5, respectively.

For Pertussis we are considering coverage at year 5 and 2, respectively.

ǂ For influenza, Flu data represents uptake for (not 'at risk') children aged 3 and 65+, respectively (12) (13).

Table 3. Estimated herd immunity threshold indicative of the minimum proportion of a population needed to be immunized for elimination of infection (12) (13) (14) (15). The '*coverage in our CCG*' column represents Q4 data for Cambridgeshire and Peterborough for 2018/19. For Diphtheria this percentage is calculated based on receiving four doses.

Summary of results

Intra-year inequality determination (Children immunisation)

According to our analysis, although all the child immunisation types display a minor negative trend for the last year recorded (2018/19), in Cambridgeshire & Peterborough we only observe a statistically significant decrease of child immunisation coverage with increased deprivation for Rotavirus immunisation (at 12 months). However, decile groups 5 together with the most deprived decile 10 consistently perform poorer than national average (and the rest of the CCG).

Inter-years inequality determination (Children immunisation)

In contrast, if we consider the trend over the years only MMR (at 24months) displays a worsening scenario in terms of increasing the inequality gap between the least and most deprived areas. For other types of child immunisations, even if we present coverage levels well above the herd protection threshold values, we should be wary of the trend over the last five years recorded, despite not statistically significant stats, show a worsening scenario for all immunisation types and we should promptly address this issue to reverse the trend.

Searching the Evidence:

Barriers to child immunisation

This year, a report by the Royal Society of Public Health (RSPH) undertook a survey to identify barriers to vaccination across the life course (1). The report stated that **accessibility and convenience of vaccination services can be important determinants of vaccine uptake** and this may be particularly true for parents who are not explicitly anti-vaccination, but perhaps are more questioning, as reassurance from a healthcare professional (usually a nurse) is the most effective way of encouraging them to vaccinate (1) (16).

In brief, based on that survey, the most common barriers to getting children vaccinated in the UK are:

- timing of appointments (49%)
- availability of appointments (46%)
- childcare duties (29%)

Healthcare workers who work in GP surgeries also acknowledged that parents, especially those in work, struggle with busy schedules.

More precisely, the most common barriers identified were (see also Figure 3):

Access

- The timing, availability and location of appointments were identified as barriers to vaccination by the public and by healthcare professionals. [According to Sherwood 2018, *a lack of affordable transport can be a barrier to vaccination for some families and so increasing the availability and accessibility of healthcare services could improve vaccine coverage* (10). *There has been an indication of successes with this in the past: an increase in health visitors who could vaccinate children in a domestic setting coincided with improvements in vaccination rates seen between 2010 and 2015* (17) (18)].
- Improving access to vaccinations remains crucial especially when tackling inequalities in uptake, for example relating to ethnicity or socioeconomic status [*A key issue with vaccines, is differences in uptake of vaccines relating to ethnicity, geographic location, socioeconomic status, and religious beliefs – factors their survey was unable to sufficiently explore*] (1)

Forgetting appointments

- *Due to the wide range of vaccinations available, the immunisation schedule can become confusing – especially when there is more than one child requiring vaccination* (10). *Parents may simply not know or lose track of which vaccines are required when* [Due to this, a child's birth order is inversely related to vaccination status (19)]. *The NHS does provide an online vaccination 'planner', however increasing visibility of this service could improve uptake* (10).

Attitudes

- Attitudes to vaccines are largely positive, especially for parents of whom 91% agreed vaccines are important for their children's health.
- Fear of side effects of vaccines was consistently found to be the primary reason for choosing not to vaccinate (except for the childhood flu vaccine, for which it was the second most common reason).
- Lack of confidence in the effectiveness of the vaccine was the number one reason for parents choosing not to vaccinate their children against flu.
- There was a fairly low understanding of herd protection, especially for working-age adults, and the myth of vaccine overload remains persistent, with just over a quarter (28%) of people believing incorrectly that 'you can have too many vaccinations' (explored below).

Influences

- Trust in healthcare professionals remains very high, with doctors and nurses consistently identified as a valued source of information about vaccines.

- Social media was identified as propagating negative messages around vaccinations, especially for parents, with two in five (41%) saying they are often or sometimes exposed to negative messages about vaccines on social media. This increased to as many as one in two (50%) among parents with children under five years old.
- Traditional media continues to be influential, particularly seen in the ongoing ramifications of the Wakefield scandal (1) (explored below).

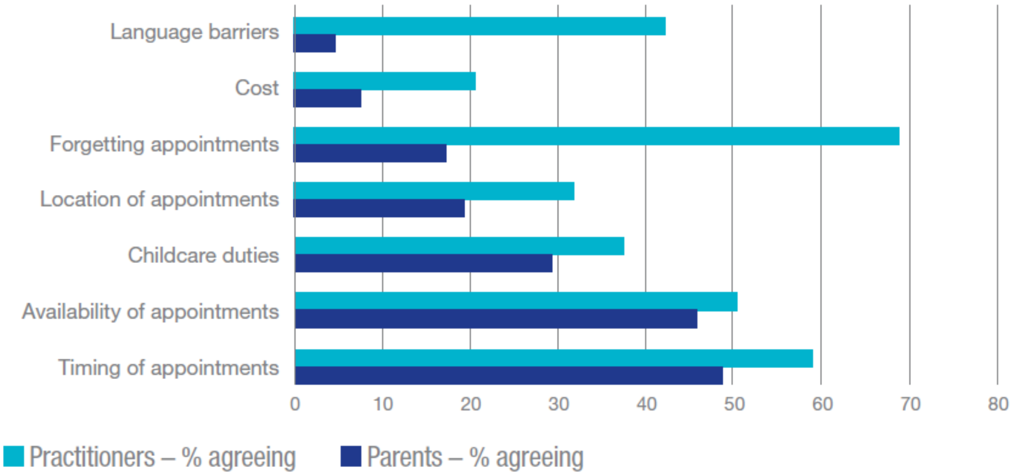


Figure 3: Barriers to accessing appointments for child immunisation according to practitioners and parents. Taken from Royal Society Public Health Report (Jan 2019) Moving the needle - Promoting vaccination uptake across the life course (1).

<u>False myths</u>

- Vaccinations cause autism

Confidence in the safety and effectiveness of vaccines is one of the drivers of the reduction of vaccine uptake (20). For example, in 1998 the now-discredited gastroenterologist Andrew Wakefield published a fraudulent paper claiming that there was a link between the MMR vaccine and autism. Following this, a minority of people lost confidence in the safety of the MMR and uptake fell, leading to outbreaks of mumps and measles throughout the 2000s (10).

- Vaccine overload

The myth that you can overload an immune system with too many vaccines is prevalent in the United States where some doctors have even published 'alternative' vaccination schedules for children despite there being no evidence that children's immune systems need vaccinations to be spread out (21). On the contrary, **spreading vaccinations out means children** are exposed to dangerous diseases for longer periods of time and parents **are less likely to complete the full vaccination course**.

- Measles cures cancer

Interestingly, the United States saw the rise of a new argument against MMR vaccination as it was perceived that measles immunity is undesirable because measles virus is protective against cancer. This idea originated, in part, following the findings from cancer research results studying the development of engineered measles viruses as anticancer therapies. The authors of this pioneering work had to step in and rectify the confusion in an article where they address this new misinformed antivaccination argument by concluding that measles is not protective against cancer and that **its potential utility as a cancer therapy will be enhanced, not diminished, by prior vaccination** (22).

Recommendations for GPs to improve vaccine uptake - adapted from *Public Health Matters* (16).

(some descriptions have been omitted for document length reasons – follow reference link for full details)

1. Send invites and reminders

Ensure that everyone is invited for their vaccination in good time, and that those who do not attend when they are due get a reminder. This may mean ensuring that your IT system is configured correctly for call/recall or checking local arrangements with your Child Health Records Department.

Evidence shows that call/recall is the single most effective intervention to increase vaccine uptake (23). If you have a high rate of non-attendance for vaccine appointments, you could consider using text message reminders (e.g. iPlato), and including information about the cost of missed appointments, as this can significantly reduce the rate of non-attendance (24).

2. Create a call-back system

Create a system where a nurse or doctor can phone back and discuss vaccination with parents or patients who are unsure. A strong recommendation from a healthcare worker is effective at encouraging people to get vaccinated (25). Consider offering your reception staff training so they understand the importance of vaccination and can encourage people to attend too.

3. Check that GP's IT system flags when people have missed out

4. Record vaccinations with the appropriate codes

Vaccinations that are not recorded using the appropriate Read 2, CTV 3 or SNOMED codes are not counted in uptake figures and may make your practice coverage seem lower than it actually is. This is particularly important when patients move from abroad. PHE is shortly releasing an online tool to support the coding of vaccines given abroad.

5. Check children are up to date at GP reception

When children and young adults (particularly those up to the age of 25 years) visit the GP practice, receptionists can use this opportunity to check whether they're up to date and offer them an appointment for any missing vaccinations.

6. Plan sufficient appointments

Assess your practice register to make sure you have sufficient appointments slots to vaccinate everyone. If you are aware of insufficient capacity or you have waiting lists for vaccination at your practice, seek support from your local clinical commissioning group. Evidence suggests that practices with more clinic slots have higher coverage.

7. Speak confidently about vaccines

8. Provide leaflets and posters

9. Signpost people to online resources

10. Offer additional and more flexible appointments

Consider offering more convenient clinic times and locations for people - such as evenings and weekends -for vaccination appointments. The RSPH report found that *those* ***GPs who offered more flexible appointments seemed to feel this was effective*** *in overcoming the barrier for most people* (1). *(…) In recent years, pharmacies begun to offer some vaccinations. Although there is mixed evidence regarding how effective this has been in increasing uptake, this may in part be due to issues with loss of data between pharmacies and GPs which should now be improved. Although the GP surgery and pharmacy were by far the most convenient places (95% and 90%), more than half of people we surveyed agreed that a hospital, community centre or high-street pop-up facility would be convenient* (1).

Recommendations for wider system - adapted from *RSPH* (1).

11. Responsibility of the press

The Independent Press Standards Organisation (IPSO) should enforce the Accuracy clause in the Editor's Code with special attention paid to health information and misinformation that may jeopardise the public's safety. The potential health impact of misinformation should be considered when sanctions are applied. Social media 'influencers' also have a responsibility to make sure they are not sharing health misinformation.

12. Counteracting health misinformation online and via social media

Efforts to limit health misinformation online and via social media should be increased, especially by social media platforms themselves

13. Better education on popular myths around vaccinations

Education on vaccines in schools should be increased and improved, especially in the PSHE curriculum.

14. Implementing Making Every Contact Count (MECC) across the health system

The National Institute for Health Care and Excellence provides additional guidance on reducing differences in uptake in under 19s (https://www.nice.org.uk/guidance/PH21)

Summary of evidence searches:

The most common barriers to getting children vaccinated in the UK appear to be the timing of appointments, availability of appointments and childcare duties which can be faced by a number of solutions by either GPs (such as optimising invites and reminders, improving IT systems, advertising) or the wiser system (e.g. better education, counteracting health misinformation online).

Similarly, the barriers reported for adults range from forgetting appointments to availability, timing and the location of appointments. These could be overcome by sending reminders, having more convenient appointments possibly even in pharmacies.

Responsibilities for ensuring adequate immunisation uptake

Responsibility for ensuring adequate immunisation uptake sits with NHS England who work with the embedded screening and immunisation teams of Public Health England.

The Clinical Commissioning Group, under delegated commissioning, has a contractual relationship with primary care providers for general medical services and, although it does not hold the contract for immunisation, is in a position to encourage improved immunisation uptake in deprived areas.

Recommendations for NHS Cambridgeshire and Peterborough Inequality Strategy

Given that adult immunisations do show a statistically significant inequality in the last year recorded and considering that this trend of inequality gap is worsening with time, we recommend that the Health Inequality Strategy addresses this issue to reverse the negative trend.

References

1. **Royal Society Publc Health.** *Moving the needle - Promoting vaccination uptake across the life course.* 2019.

2. *Estimated economic impact of vaccinations in 73 low- and middleincome countries, 2001–2020.* **Ozawa, Sachiko, et al.** 9, s.l. : World Health Organization, 9 1, 2017, Bulletin of the World Health Organization, Vol. 95, pp. 629-638. 10.2471/BLT.16.178475.

3. *The value of vaccination: a global perspective.* **Ehreth, J.** 2003, Vaccine, pp. 21(27-30; p 4105-4117.

4. **NHS England.** Child Immunisation GP/Q4 Data from 2013/14 to 2018/19. *NHS England.* [Online] 2019. [Cited: 11 25, 2019.] https://www.england.nhs.uk/statistics/statistical-work-areas/child-immunisation/.

5. **Public Health England.** National General Practice Profiles. *Fingertips.* [Online] 2015. [Cited: 11 25, 2019.] https://fingertips.phe.org.uk/profile/general-practice/data#page/9/gid/2000005/pat/152/par/E38000001/ati/7/are/B83620/iid/91872/age/1/sex/4.

6. **World Health Organisation.** *Health Equity Assessment Toolkit.* World Health Organisation.

7. **Public Health England.** Public Health Profiles. *Fingertips.* [Online] 2018/19. [Cited: Feb 18, 2020.] https://fingertips.phe.org.uk/search/vaccination#page/0/gid/1/pat/6/par/E12000006/ati/202/are/E10000003.

8. **Gov.uk.** Inequalities calculation tool. *webarchive.nationalarchives.gov.uk/.* [Online] https://webarchive.nationalarchives.gov.uk/20170106081903/http://www.apho.org.uk/resource/item.aspx?RID=132634.

9. *Methods for measuring health inequalities: part 2.* **E., Regidor.** 2004, Vol. 58. 900-903.

10. **Sherwood, Eleanor.** Child immunisation statistics - the good, the bad and the three C's. *British Society for Immunology.* [Online] October 2018. [Cited: 11 25, 2019.]

11. *Relative index of inequality and slope index of inequality: a structured regression framework for estimation.* **Moreno-Betancur, et al.** 4, s.l. : Epidemiology, 2015, Vol. 26. 518-527.

12. **ImmForm.** Flu Monthly GP Child Collection 2018-19 (NHS Cambridgeshire and Peterborough CCG). *Flu Data Collections.* [Online] Feb 2019. [Cited: Nov 28, 2019.] https://www.immform.dh.gov.uk/.

13. Flu Monthly GP Main Collection 2018-19 (NHS Cambridgeshire and Peterborough CCG). *Flu Data collections.* [Online] Jan 2019. [Cited: Nov 28, 2019.] https://portal.immform.dh.gov.uk/.

14. **Fine, Paul E M.** *Herd Immunity: History, Theory, Practice.* 1993.

15. *PROTECTING THE HERD: THE REMARKABLE EFFECTIVENESS OF THE BACTERIAL MENINGITIS POLYSACCHARIDE-PROTEIN CONJUGATE VACCINES IN ALTERING TRANSMISSION DYNAMICS.* **Stephens, David S and Atlanta, Georgia.** 2011, Transactions of the American Clinical and Climatological association, Vol. 122, pp. 115-123.

16. **Kassianos, George and Ramsay, Mary.** Increasing vaccine uptake: strategies for addressing barriers in primary care. *Public Health Matters.* [Online] Public Health England; Gov.uk, May 2019. [Cited: 11 25, 2019.] https://publichealthmatters.blog.gov.uk/2019/05/16/increasing-vaccine-uptake-strategies-for-addressing-barriers-in-primary-care/.

17. **Gov.uk.** Health Visitor Numbers . *Gov.uk.* [Online] May 21, 2013. [Cited: 11 25, 2019.] https://www.gov.uk/government/news/health-visitor-numbers.

18. **World Health Organisation .** *Report of the sage working group on vaccine hesitancy.* 2014.

19. **PHE.** Tailoring immunisation programmes: Charedi community, north London. *Gov.uk.* [Online] Nov 2018. https://www.gov.uk/government/publications/tailoring-immunisation-programmes-charedi-community-north-london.

20. *Sustaining Vaccine Confidence in the 21st Century.* **Hardt, Karin, et al.** 3, s.l. : MDPI AG, 6 24, 2013, Vaccines, Vol. 1, pp. 204-224. 10.3390/vaccines1030204.

21. **Wessel, Lindzi.** Four vaccine myths and where they came from. *Science Journal.* [Online] April 2017. [Cited: 11 25, 2019.] https://www.sciencemag.org/news/2017/04/four-vaccine-myths-and-where-they-came.

22. **Russell, Stephen J., et al.** Oncolytic Measles Virotherapy and Opposition to Measles Vaccination. *Mayo Clinic Proceedings.* s.l. : Elsevier Ltd, 9 1, 2019. 10.1016/j.mayocp.2019.05.006.

23. *Interventions to reduce inequalities in vaccine uptake in children and adolescents aged <19 years: a systematic review.* **Crocker-Buque, Tim, Edelstein, Michael and Mounier-Jack, Sandra.** 2017, J Epidemiol Community Health. 10.1136/jech.

24. **Gurol-Urganci, Ipek, et al.** Mobile phone messaging reminders for attendance at healthcare appointments. *Cochrane Database of Systematic Reviews.* s.l. : John Wiley and Sons Ltd, 12 5, 2013. Vol. 2017, 12. 10.1002/14651858.CD007458.pub3.

25. *Health care professional communication about STI vaccines with adolescents and parents; 32(14):.* **Hofstetter and Rosenthal.** 14, s.l. : Vaccine, 2014, Vol. 32. 1616-23.

26. **Smith, Louise E., et al.** A systematic review of factors affecting vaccine uptake in young children. *Vaccine.* s.l. : Elsevier Ltd, 10 27, 2017. Vol. 35, 45, pp. 6059-6069. 10.1016/j.vaccine.2017.09.046.

27. **Jacobson Vann, Julie C., et al.** Patient reminder and recall interventions to improve immunization rates. *Cochrane Database of Systematic Reviews.* s.l. : John Wiley and Sons Ltd, 1 18, 2018. Vol. 2018, 1. 10.1002/14651858.CD003941.pub3.

28. **ImmForm.** *ImmForm.* [Online] [Cited: Dec 03, 2019.] https://portal.immform.dh.gov.uk/.

29. **NHS.** Pneumococcal vaccine. *nhs.uk.* [Online] Feb 14, 2019. [Cited: Dec 03, 2019.] https://www.nhs.uk/conditions/vaccinations/pneumococcal-vaccination/.

30. Shingles. *nhs.uk.* [Online] Feb 27, 2018. [Cited: Dec 03, 2019.] https://www.nhs.uk/conditions/shingles/.

31. Who can have the shingles vaccine. *nhs.uk.* [Online] July 06, 2018. [Cited: Dec 03, 2019.] https://www.nhs.uk/conditions/vaccinations/who-can-have-the-shingles-vaccine/.

32. Whooping cough vaccination pregnant. *NHS.uk.* [Online] Oct 17, 2019. [Cited: Jan 28, 2020.] https://www.nhs.uk/conditions/pregnancy-and-baby/whooping-cough-vaccination-pregnant/.

Acknowledgments:

Many thanks to the *Screening & Immunisation* team, NHS England and NHS Improvement – East of England; Public Health England East).

Author: Research Officer of the *Clinical Outcomes and Population Health Strategy* team, Cambridgeshire and Peterborough Clinical Commissioning Group.

Health Intelligence and Insight

NHS
Cambridgeshire and Peterborough
Clinical Commissioning Group

Supplementary Material

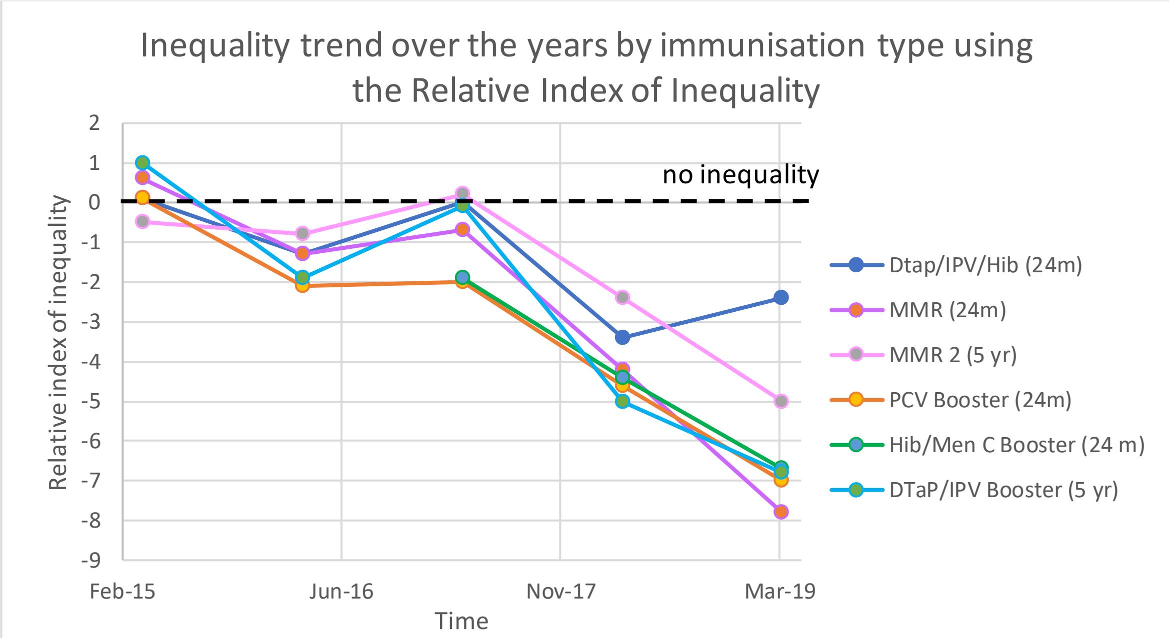


Figure S1. The Relative Index of Inequality plotted against time for various child immunisation type. Despite the Inequality appears to be getting worse with time for every child immunisation type, we can conclude that, if measuring with the Relative Index of Inequality, only for MMR (24 months) and PCV Booster (24 months) the difference in inequality is statistically significant for the time period analyzed (see Table S1 below for Confidence Interval errors). The black dotted line marks the '*no inequality*' benchmark line between the most and least deprived areas. Points below zero indicate the presence of inequality towards more deprived area.

	2014/15		2015/16		2016/17		2017/18		2018/19	
	RII	CI	RII	CI	RII	CI	RII	CI	RII	CI
Dtap/IPV/Hib (24m)	+0.1	(±2.3)	-1.3	(±2.5)	0	(±3.2)	-3.4	(±3.1)	-2.4	(±3.1)
MMR (24m)	+0.6	(±3.1)	-1.3	(±3.9)	-0.7	(±3.3)	-4.2	(±2.8)	-7.8	(±3.7)
MMR 2 (5 yr)	-0.5	(±5.5)	-0.8	(±6.3)	+0.2	(±4.8)	-2.4	(±4.4)	-5	(±5)
PCV Booster (24m)	+0.1	(±3.3)	-2.1	(±4)	-2	(±3.4)	-4.6	(±2.9)	-7	(±3.7)
Hib/Men C Booster (24 m)	-	-	-	-	-1.9	(±3.5)	-4.4	(±3)	-6.7	(±3.5)
DTaP/IPV Booster (5 yr)	+1	(±5.5)	-1.9	(±5.6)	-0.1	(±5.2)	-5	(±6.2)	-6.8	(±6.2)

Table S1. Inequality in children immunisation over time. Relative Index of Inequality (RII)values and their confidence intervals (CI) are expressed as percentages. Over the 2014/15 to 2018/19 period only values for MMR (at 24 months) and PCV Booster (at 24 months) show a statistically significant worsening trend of inequality gap between the least and most deprived areas (values highlighted in red).