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# Measuring the timeliness of childhood vaccinations: Using cohort data and routine health records to evaluate quality of immunisation services

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ABSTRACT

*Background:* To achieve full benefits of vaccination programmes, high uptake and timely receipt of vaccinations are required.
*Objectives:* To examine uptake and timeliness of infant and pre-school booster vaccines using cohort study data linked to health records.
*Methods:* We included 1782 children, born between 2000 and 2001, participating in the Millennium Cohort Study and resident in Wales, whose parents gave consent for linkage to National Community Child Health Database records at the age seven year contact. We examined age at receipt, timeliness of vaccination (early, on-time, delayed, or never), and intervals between vaccine doses, based on the recommended schedule for children at that time, of the following vaccines: primary (diphtheria, tetanus, pertussis (DTP), polio, Meningococcal C (Men C), *Haemophilus influenzae* type b (Hib)); first dose of measles, mumps and rubella (MMR); and pre-school childhood vaccinations (DTP, polio, MMR). We compared parental report with child health recorded MMR vaccination status at age three years.
*Results:* While 94% of children received the first dose of primary vaccines early or on time, this was lower for subsequent doses (82%, 65% and 88% for second and third doses and pre-school booster respectively). Median intervals between doses exceeded the recommended schedule for all but the first dose with marked variation between children. There was high concordance (97%) between parental reported and child health recorded MMR status.
*Conclusions:* Routine immunisation records provide useful information on timely receipt of vaccines and can be used to assess the quality of childhood vaccination programmes. Parental report of MMR vaccine status is reliable.


## 1. Introduction

To achieve their full benefit, timely delivery of vaccines as well as high uptake are required [1]. The timeliness of vaccinations, that is vaccination at the earliest appropriate age, should be an important public health goal, and yet this information is often lacking as coverage is the usual metric used. Children receiving vaccinations late remain susceptible to vaccine preventable diseases: this may jeopardise their own health, as well as that of younger siblings and compromise herd immunity with consequent potential risk of disease outbreaks. Conversely, vaccines given too early or with a shortened interval between doses may result in a suboptimal immune response, leading to a false sense of protection. Timely immunisation is important to protect against infections with peaks in incidence or particular severity in the very young, for example pertussis, meningococcal B and *Haemophilus influenzae* type b.

Vaccination timeliness has been investigated in the USA, New Zealand, Australia, Belgium, Sweden and low income country settings, but there is a paucity of published research in the UK. In Australia, vaccination delays were more common for later doses and for vaccines given at an older age [2]. In the USA, only a quarter of children received all vaccines according to recommended immunisation schedules [3]. Luman found that timeliness varied significantly by vaccine type: 5–14% of children had received vaccines too early to be considered effective [4,5]. In Belgium up to 32% of infants experienced delay in receiving the first dose of measles, mumps and rubella (MMR) vaccine and 95% for the third dose of diphtheria, tetanus and pertussis (DTP) vaccine [6].

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In the UK, vaccination coverage is reported quarterly and annually for the routine vaccines for children reaching the ages of one, two and five years in the relevant evaluation period [7]. Although valuable for monitoring trends, these data give no insight into whether vaccines were given on time according to the schedule. For example, a fully vaccinated two year old child may actually have been under-vaccinated for a considerable period of that time. High overall coverage has been achieved in the UK, but persisting inequalities leave gaps in immunity. Exploring vaccine timeliness and ensuring timely vaccine delivery may help to address these inequalities.

Previous research based on parental report of immunisation status found high vaccine uptake among participants in the Millennium Cohort Study (MCS) [8–10]. In this study we linked routine child health vaccination records to children's MCS data to establish the timeliness of vaccine receipt in relation to recommendations in place at that time, with the objective of understanding the prevalence and distribution of delayed primary and pre-school vaccinations in a large nationally representative sample of children. Additionally, we compared parental report of their child's MMR vaccination status with that routinely recorded in child health systems.

## 2. Methods

### 2.1. Study population

We used data from the MCS, a UK-wide nationally representative birth cohort comprising 18,818 children from 18,552 families born between September 2000 and January 2002. Parents were interviewed at home when their child was aged nine months and subsequently at three, five, seven, eleven and fourteen years of age. At the age seven home visit, written consent was sought from parents to link MCS information collected until each child's 14th birthday, to data routinely collected by government departments or agencies, and other public sector organisations. The Northern and Yorkshire Research Ethics Committee gave approval for the MCS age seven survey; no additional approval was needed for this linked data analysis which focusses on those resident in Wales. Parents of 1840 (94.3%) of 1951 singletons resident in Wales, consented to health record linkage. Linked MCS and National Community Child Health Database (NCCHD) records were available for 1831 children. We excluded 46 children interviewed in countries other than Wales on one or more occasions by age 11 years and three for whom the main respondent was not the natural mother at the first interview, leaving a final sample of 1782.

### 2.2. Record linkage

We accessed coded data from the NCCHD, which brings together data from local child health system databases held by NHS organisations and includes information from birth registrations, child health examinations and immunisations.

We used the privacy-protecting Secure Anonymised Information Linkage (SAIL) Databank to store and access our data. Datasets imported into SAIL are anonymised and linked using a split file process preventing access to both identifiable data and clinical information at the same time. Records are linked through assigning unique encrypted Anonymised Linkage Fields (ALF) to person-based records [11].

### 2.3. Parental report of MMR vaccination

We compared parental response to the question "Has ^[cohort member] had any vaccination against measles, mumps or rubella (including MMR)?" asked at the age three interview, to NCCHD records of MMR vaccination, taking into account the age of the child at the interview and at MMR vaccination.

### 2.4. Timeliness of vaccinations

Vaccination schedules for the UK have changed repeatedly over the years. Children born in Wales between August 2000 and November 2001 should have received routine vaccinations as shown in Table 1. This cohort of children received separate DTP, polio, and Hib vaccines rather than the combination DTaP/IPV/Hib (5-in-1 vaccine) introduced in 2004. Although we considered analysing these vaccines as if they were a combination, a few children didn't receive all the vaccines or received them on different dates, so we considered each vaccine separately.

Timeliness of vaccination was classified as early, on-time, delayed, or never, based on the recommended vaccination schedule. For the primary vaccines (diphtheria, tetanus, pertussis (DTP); oral polio vaccine; *Haemophilus influenzae* type b (Hib); Meningococcal C (Men C)) we defined a vaccine as being given 'on time' if given in the interval between the age when the vaccine was due and the age when the next dose was due; 'early' as being given prior to these ages; and 'delay' when given after the latest 'on time' ages (Table 1). For MMR and pre-school boosters, 'on time' was defined as 12–15 months and three years four months to five years respectively.

Child's date of birth was supplied as week of birth (set to the Monday) and a day of birth within that week was assigned by add-

**Table 1**
Vaccine schedule and definitions used for timeliness of vaccinations.

| Vaccines | Vaccine doses due on the same occasion | Due at age | Timeliness of vaccination based on age at which vaccine received | | | |
|---|---|---|---|---|---|---|
| | | | Early | On time | Delayed | Never |
| Primary vaccines: | DTP 1, Hib 1, Polio 1, Men C 1 | 8 weeks | <8 weeks | 8–12 weeks | >12 weeks | Not at all |
| Diphtheria, Tetanus and Pertussis | DTP 2, Hib 2, Polio 2, Men C 2 | 12 weeks | <12 weeks | 12–16 weeks | >16 weeks | Not at all |
| *Haemophilus influenzae* type b | DTP 3, Hib 3, Polio 3, Men C 3 | 16 weeks | <16 weeks | 16–20 weeks | >20 weeks | Not at all |
| Oral Polio | | | | | | |
| Meningococcal group C | | | | | | |
| Measles, Mumps and Rubella | MMR 1 | 1 year | <12 months | 12–15 months | >15 months | Not at all |
| Pre-school boosters: | DTP PSB, Polio PSB, MMR 2 | 3 years, 4 months | <3 years, 4 months | 3 years, 4 months to 5 years | >5 years | Not at all |
| Diphtheria, Tetanus and Pertussis | | | | | | |
| Polio - oral or inactivated | | | | | | |
| Measles, | | | | | | |
| Mumps and Rubella | | | | | | |

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