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Vaccine uptake: New tools for investigating changes in age distribution and predicting final values

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Abstract

Knowing the age at which children are immunised, and detecting any changes gives important insight into aspects of parental decision-making and health service delivery. Estimating likely final vaccine uptake is also important; to ensure adequate population protection and indicate if any additional immunisation activity is required. We present two new applications of existing methodologies to facilitate these aims. Firstly, to enable easier visualisation of age at vaccine uptake, we have applied the technique of Kernel density estimates to detecting potential delays in childhood vaccination. Secondly, we present a method for predicting likely final vaccine uptake, from early data. Both give vital policy information on, for example, new vaccines and existent programmes, such as MMR vaccination.

Keywords: Immunization programs; Vaccine uptake; Kernel density estimator; Measles–mumps–rubella vaccine

1. Introduction

Monitoring of routine childhood vaccine uptake is essential public health surveillance. Data are generally presented as line graphs of uptake at a set age for consecutive birth cohorts (Fig. 1) or cumulative uptake curves for single birth cohorts (Fig. 2) [1–3]. The latter allow better representation of age at vaccination and can be used to compare rates at specified ages between cohorts. Nevertheless, it can be difficult to detect changes in the age distribution over time, particularly as the most important information is often compressed into the steepest part of a cumulative uptake curve, making it difficult to interpret (Fig. 2). Although, this can be alleviated, to some extent, by widening the graph and expanding the *x*-axis scale.

We propose applying the technique of using Kernel density estimates (KDEs) of the exact age, in days, that children in each cohort are vaccinated, as a method for easier visual discrimination of differences in age distribution. Possible changes in age distribution are that the density distribution maintains the same shape, but with a smaller median peak or a median peak at a different age, or that the density distribution adopts a different shape, perhaps with a longer tail. Such patterns are important as they may indicate parents delaying vaccination until children are older or point to infrastructure issues, such as appointment systems, which may also delay vaccination for some, or all children.

We have applied the KDE technique to two recent key vaccination issues in the UK. Firstly, to investigate MMR uptake, which declined for children born in 1999 onwards and for which there is evidence that parents are delaying vaccination [4]. Secondly to investigate uptake of routine primary infant vaccines, which, in September 2004, changed from DTwP-Hib, MenC and oral polio vaccines to DTaP-Hib-IPV and MenC [5]. The new combination vaccines are thiomersal-free and there was concern that parents may delay bringing their children for vaccination until the new products were available, despite no evidence of risk from thiomersal.

Uptake rates at younger ages can also be a useful early warning for decreased final uptake figures and hence

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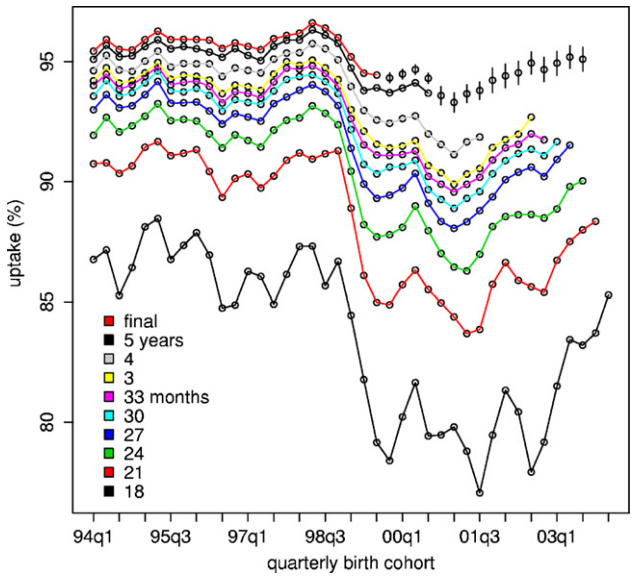

Fig. 1. MMR1 uptake rates for quarterly birth cohorts 1994 Q1 to 2004 Q1, as at 15th November 2005, with predictions for future 'final' uptake rates (95% confidence intervals) for cohorts 1999 Q4 to 2003 Q3 based on regression of latest available data.

increased population susceptibility to disease in the future. This would be particularly useful for MMR vaccine, for which uptake in Scotland decreased for children born in 1999 onwards [4,6]. Uptake at ages 18, 21, 24 months and so on could therefore be a useful early warning of changing patterns. We consequently also investigated a method to predict final MMR vaccine uptake rates from early data.

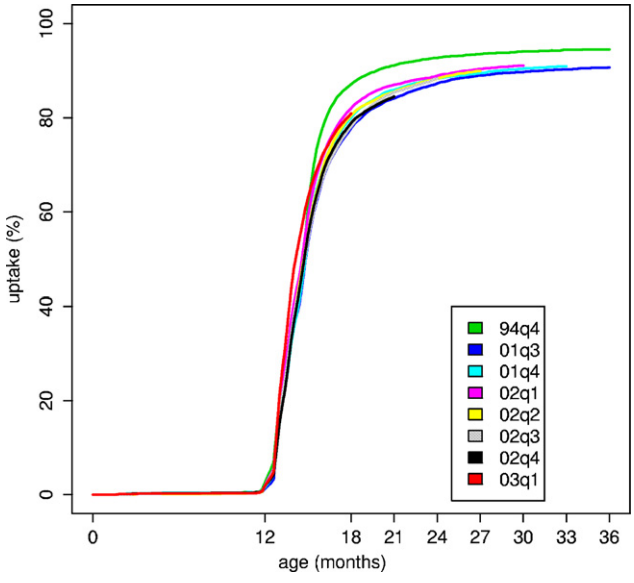

Fig. 2. Cumulative MMR vaccine uptake rates as at 15th November 2004 for birth cohorts 1999 Q4 and 2001 Q3 to 2003 Q1.

2. Methods

2.1. Vaccine uptake data

Data on vaccines received by individual children throughout Scotland are held on the Scottish Immunisation and Recall System (SIRS). As on 15th November 2004, we obtained data for all children born between 1st January 1997 and 11th November 2004 ($n = 428{,}739$). These data include date of birth and date of vaccination for each individual, allowing the age, in days, for each vaccination to be calculated. Deprivation category (1–7) is also provided, determined according to the proportion of the population in the postcode sector with access to a car, in overcrowded households, with the head of household in social class IV or V, and in households with unemployed men, using the Carstairs and Morris index [7].

2.2. Kernel density estimates (KDEs)

KDEs are similar to histograms, and are used to display the frequency distribution of a dataset [8]. While histograms use class intervals of equal width to generate vertical bars in discrete steps, KDEs represent the distribution in smooth curves, generated using a distribution function. Full details of the definitions and properties of KDEs are given in Appendix A. In our analyses, the number of children vaccinated at the same age, in days, was counted, and the final graphical display smoothed according to a visually chosen smoothing parameter. The technique was applied to the two recent issues of decreased MMR vaccine uptake and a change in the routine infant vaccinations.

2.2.1. Age distribution of MMR vaccine uptake

MMR vaccine is currently offered to all children aged around 13 months (MMR1), followed by a second dose preschool (MMR2). We analysed the age distribution of MMR1 vaccine uptake for children born between 1997 and 2002, using KDEs. These yearly birth cohorts were chosen, as there was prominent adverse publicity from early 1998 onwards, to which birth cohorts 1997 onwards were exposed. We also used KDEs to investigate differences in age distribution of MMR vaccine uptake in 15 different NHS Board areas across Scotland, and to investigate any differences by deprivation category.

2.2.2. Age distribution of primary vaccine uptake (change from DTwP-Hib to DTaP-Hib-IPV)

Vaccination against diphtheria, tetanus, pertussis, *Haemophilus influenzae* type b (Hib) and polio is offered to all children in the UK at ages 2, 3 and 4 months. Prior to September 2004 this was by combined diphtheria-tetanus-whole cell pertussis-Hib (DTwP-Hib) and oral polio vaccines. From week commencing 27 September 2004, it was by one combined diphtheria-tetanus-acellular pertussis-Hib-inactivated polio (DTaP-Hib-IPV) vaccine. We analysed the age distribution of diphtheria-containing