

ORIGINAL ARTICLE

Information on Measles, Mumps and Rubella Vaccine in the Copenhagen School Health Records Register

ONUR ALTINDAG¹, MATVEI ANDERSEN², JENNIFER L. BAKER³ ,
JANE GREVE²  & ERDAL TEKIN⁴

¹Department of Economics, Bentley University, USA, ²VIVE – The Danish Center for Social Science Research, Denmark, ³Center for Clinical Research and Prevention, Copenhagen University Hospital – Bispebjerg and Frederiksberg, Denmark, ⁴American University, School of Public Affairs, USA

Abstract

Background: The Copenhagen School Health Record Register (CSHRR) includes health information from school examinations and is now updated with information on measles, mumps and rubella vaccines for the cohorts born from 1977 to 1994. **Aim:** The aim of this study is to provide a comprehensive description and validation the newly digitised vaccine information in the CSHRR. **Methods:** We describe the data collection and the newly digitalised information in the CSHRR. We investigate the extent to which the full CSHRR population is representative of Copenhagen and the entire Danish population. Furthermore, we explore how the registry information on vaccination uptake based on reimbursement data matches the vaccine information obtained from CSHRR for the period during which both data are available. **Results:** The CSHRR population matches closely the complete population of all schoolchildren in Copenhagen, and information on vaccine uptake in CSHRR matches with vaccine registry data for later cohorts. However, a sizable proportion of the immigrant children in the CSHRR have missing information on vaccination. Removing children who have had no additional immunisations enhances data quality. **Conclusions:** The CSHRR covers a large share of the Danish population and includes detailed vaccine information. By linking the data to other registry data, the updated CSHRR is valuable resource for future research.

Keywords: School health records, children, adolescents, vaccine information, measles, mumps and rubella vaccine

Introduction

The combined measles, mumps and rubella (MMR) vaccine was developed in 1971, and by 1983, most nations had the MMR in their national children vaccination programme [1]. Yet, the MMR vaccine was not included in the Danish Child Vaccination Programme (DCVP) until 1 January 1987 [2]. The Danish National Health Service Registry (DNHSR) reimbursement records include MMR vaccine information from 1990 onwards, but services cannot be linked directly to children younger than 16 years of age prior to 1996 due to procedural reasons. As a result, although there is a growing interest in the direct and indirect effects of newly introduced vaccines on population health, there

is no detailed information available on the immunisation status of individuals born before, during and after the introduction of the MMR vaccine in Denmark. To improve the data availability, we digitised the individual vaccination records from the Copenhagen School Health Record Register (CSHRR) physical files for cohorts born from 1977 to 1994. The health information from school examinations in the CSHRR has already been digitised [3,4] and can now be merged with the information on MMR vaccines for cohorts born from 1977 to 1994. The aim of our study is to provide a comprehensive description and validation of the newly digitised MMR vaccine information in the CSHRR. By doing so, we seek to promote

Correspondence: Jane Greve, VIVE – The Danish Center for Social Science Research, Herluf Trolles Gade 11, Copenhagen, 1052, Denmark.
E-mail: jagr@vive.dk

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additional research and collaborative efforts utilising these new data.

MMR vaccination in Denmark

In 1987, when the MMR vaccine was included in the DCVP, the programme already included vaccines against diphtheria, tetanus, pertussis and polio. These immunisations were all administered before school starting age. Although not included in the DCVP, the MMR vaccine had been available for several years prior, and there was an increasing demand for the MMR vaccine among parents in the years before its introduction in the DCVP [5]. In 1983, for example, Statens Serums Institut distributed 9416 doses of measles vaccination, 3734 doses of mumps vaccine and 653 doses of rubella vaccine. The vast majority of these immunisations were administered to healthy children after the parents requested and paid for the vaccine.

Vaccines in the DCVP are free of charge and administered by general practitioners (GPs). According to the Danish Health Care Act (Sundhedsloven), all children living in Denmark are offered seven preventive GP visits (Børneundersøgelser) before starting school. The GP visits are offered at the ages of five weeks, five months, one year, two years, three years, four years and five years. At the first visit following birth, the GP informs the parents about the immunisations included in the programme. Because the first MMR vaccination is administered at the age of 15 months, parents must schedule an extra appointment (aside from the seven preventive visits) with their primary care physician. Parents had to pay for the MMR vaccination until 1987, and the price for one dose of MMR vaccine in 1985 was DKK 110 (including tax), which corresponds to around DKK 225/USD 31 in 2020 [6], excluding a GP fee. There were variations in the fees charged by GPs for the vaccinations. In 2020, the cost was DKK 150–300. When adjusting this cost to 1985 prices, the amount makes up approximately half of the price of the vaccine.

When the MMR vaccination was introduced into the DCVP, there was a brief transition phase (about one year) during which all children aged 2–12 (who had not previously had measles or mumps) were administered the vaccine and immunised on a large scale [7]. From 1987 to 2016, the National Board of Health recommended MMR immunisations at the ages of 15 months (MMR1) and 12 years (MMR2) [8].

Data collection

Based on archived school health records, the CSHRR includes children who attended school in the

municipality of Copenhagen [4]. The information on vaccines in the CSHRR comes from the school health examinations conducted by school doctors or nurses. Parents or guardians were asked to be present at the first school health examination at school entry and to provide detailed information on their child's health and vaccination history, which was listed on a pre-printed record. Before the first school health examination, the parents received a home questionnaire to complete and return to the school doctor. The home questionnaire also included information on vaccines and was kept with the record afterwards.

In 1972, the number of health examinations administered from school entry at the age of six to school exit at the age of sixteen was five. In 1983, the number of health examinations required by law was reduced to one at school entry. However, many municipalities, including Copenhagen, retained at least three health examinations. Two examinations – one upon starting school and one on finishing school – were mandated by legislation in 1995. Consequently, for cohorts 1977–1983, data on the MMR2, which was administered after the commencement of schooling, may have been recorded less systematically.

In 2019, the front and back of the folder of the school health records and the home questionnaire for cohorts from 1977 to 1994 were scanned, and the vaccine information was typed in by trained personnel at the Centre for Clinical Research and Prevention, Copenhagen University Hospital-Bispebjerg and Frederiksberg. These data complement the already existing information in the CSHRR on basic characteristics, including the child's date of birth, sex, and height and weight measurements and dates of examinations for children born from 1930 to 1996 and birthweight for those born from 1936 to 1996 [4]. Additionally, a subset of children born from 1965 to 1976 have typed information on vaccinia and Bacillus Calmette–Guérin, and other subsets of data from across the years exist as well [9].

Newly available information in the CSHRR

Table I provides a summary of the newly digitised data extracted from the school health records, containing both the general and individual immunisation information. The general information includes the child's sex, birth date, ethnicity of the parents and personal identification code (CPR number). Information on parental ethnicity exist only for a subset of children from the cohorts 1977–1985. From 1982, information on parents' ethnicity exists in the Danish Civil Registration System. The data from the CSHRR can be linked to information from

Table I. Variable list.

| Category | Description |
|---------------------|---|
| General | Personal identification code from the Danish Civil Registration System (CPR) Sex Date of birth Ethnicity of the father Ethnicity of the mother |
| Vaccine information | Measles vaccination Month of measles vaccination Year of vaccination MMR1 vaccination Year of MMR1 vaccination Month of MMR1 vaccination Information about MMR2 vaccination Year of MMR2 vaccination Month of MMR2 vaccination Information on other vaccines than MMR in the home questionnaire or school record |
| School attendance | Last registered year of school attendance |

MMR: measles, mumps and rubella.

other Danish registries using the unique CPR number. The digitised data also contain detailed information on the type of measles vaccination, specifically whether the child received the MMR1 or MMR2 vaccine, in addition to the year and month of vaccination(s). As the physical files do not include a box to click if no MMR vaccine was administered, it is unknown if no administered MMR vaccination represents ‘no MMR vaccine’ or missing information. The data also include information on whether the child has received any additional vaccinations, apart from the MMR or measles vaccine. The newly digitised data also includes the child's last reported year of school attendance.

Data description

The raw data include 68,239 children from cohorts 1977–1994 (see Supplemental Table SI). Out of these, 1421 observations have a missing CPR number. However, the remaining 66,818 individuals have a valid CPR number, and their information is successfully linked to the Danish population registers spanning from 1980 to 2018. Only 62 children have a CPR number that does not match in the registries, most likely because of data recording errors. Our final CSHRR population consists of 66,756 children (hereafter called the full CSHRR population). The full CSHRR population can be linked to other Danish registers for further studies. The children's CPR numbers have been linked to their parents in the Population Registry, with 66,620 children having at least one parent identified, while 63,110 have both parents identified. Among all

children, only 661 have a missing mother, whereas 3121 have a missing father.

Representativeness of the CSHRR

In this section, we investigate the extent to which the full CSHRR population is representative of Copenhagen and the entire Danish population. We compare the full CSHRR population with two samples based on the same cohorts (i.e. 1977–1994): (a) all children in the Danish population (DK) and (b) all children living in the Copenhagen municipality during their primary school ages (from age 6 through 16; CPH). We define the population of children living in Copenhagen as children who have had a permanent address, and thus lived, in the Copenhagen municipality for at least one full year during their school-age period. We investigate whether the CSHRR population differs from the CPH population by comparing the children in CSHRR to all children of school age living in the Copenhagen municipality. Furthermore, we examine differences in the share of girls, immigrants and parental characteristics between the three populations by cohort.

Figure 1 displays the distribution of females, ethnic Danes, children with mothers accessing further education and mothers older than 33 years of age. In Figure 1(a), we observe that the proportion of girls remains consistently around 49%–50% across all cohorts. Figure 1(b) illustrates that ethnic Danes constitute 87%–94% of all children in Denmark across the cohorts, in contrast to 69%–78% in the Copenhagen population. Figure 1(c) highlights that the share of mothers accessing further education is

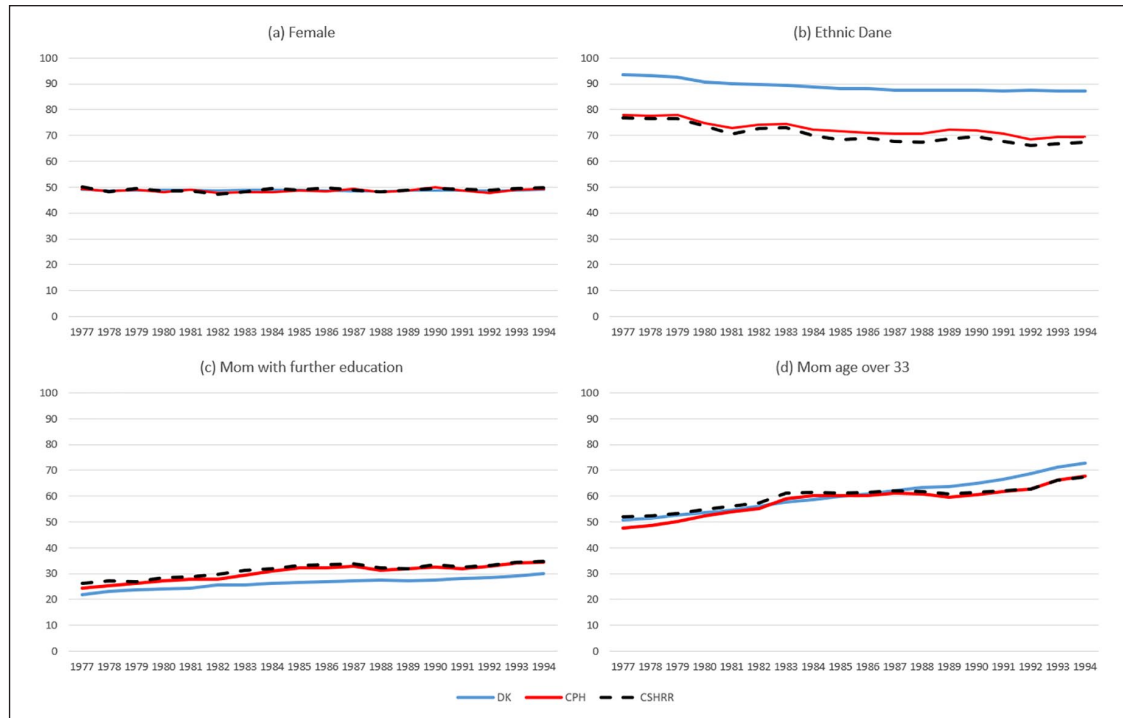


Figure 1. Sex, immigration status, mother accessing further education and mother's age for full sample of the Copenhagen School Health Records Register (CSHRR), children in Copenhagen municipality and all children in Denmark, cohorts 1977–1994.

Note: Information from Population Registry for populations: CSHRR ($N=66,756$), all children living in Copenhagen in school-age period (CPH; $N=75,923$) and all children living in Denmark (DK; $N=1,168,757$). Maternal characteristics are measured when the child was six years of age at school entry. t -Tests of difference in levels and trends between CSHRR and CPH shows no difference in the characteristics except for maternal age.

higher for the Copenhagen population (26%–36%) compared to all Danish children (22%–30%). Lastly, Figure 1(d) demonstrates that the mothers' ages are relatively similar across all three data sets. Across all cohorts, the CSHRR population closely mirrors the level and trend observed in the Copenhagen population. While the differences between the samples are small, we identify statistically significant disparities in maternal age for cohorts born after 1987. In summary, the patterns observed in Figure 1 indicate that the full CSHRR population is both comprehensive and representative of the Copenhagen population. It is worth noting that as a significant portion of immigrants and descendants in Denmark reside in Copenhagen, the CSHRR and Copenhagen populations differ from the population of all children in Denmark.

Supplemental Figure S1 shows the number of children (girls, boys, ethnic Danes and immigrants/descendants) in each cohort for the CSHRR population and a sample of children living in the Copenhagen municipality (CPH) when they are 6–16 years old. Descendants are individuals born in Denmark with immigrant parents. Information on child's immigrant status is based on the Danish Civil Registration System. The number of girls, boys, ethnic Danes and

immigrants/descendants is lower in the CSHRR sample than in the CPH sample population, but the trend across cohorts is similar. Upon linking the CSHRR with the Copenhagen population, 87% of the children in the CSHRR are matched. As not all children who live in the Copenhagen municipality attend schools in Copenhagen, a perfect match cannot be anticipated. Furthermore, school health reports may be missing if the children move in or out of the municipality between the ages of 6 and 16. The student registry data on Copenhagen's schools reveal that the unsuccessful matches are scattered around all of the schools in the city. As a result, the data do not appear to miss school health information from certain schools in Copenhagen systematically.

Comparing CSHRR data with population and reimbursement data

Representativeness of the subsample of children with any vaccine information

Given that the children with missing information on any additional vaccines other than MMR may consist of children whose parents did not provide the vaccination card or the home questionnaire during their initial visit to the school doctor or nurse, we have

Table II. Summary statistics for CSHRR and Copenhagen population (CPH).

| | (1) | (2) | (3) | (4) | (5) |
|--|----------------|-----------------------|--|-----------------------------|-----------------------------|
| | CPH population | Full CSHRR population | Subsample with any other vaccine information | Difference in means (1)–(3) | Difference in means (2)–(3) |
| <i>Panel (a): Registry information</i> | | | | | |
| Female | 0.49 | 0.49 | 0.49 | 0.01 | 0.00 |
| Ethnic Dane | 0.72 | 0.70 | 0.74 | 0.02*** | 0.04*** |
| Immigrant | 0.12 | 0.12 | 0.08 | -0.03*** | -0.04*** |
| Descendant | 0.16 | 0.18 | 0.17 | 0.01*** | -0.01* |
| Mother's age at child's entry to school (~6 years) | 33.57 | 33.79 | 33.85 | 0.28*** | 0.06* |
| Share with mother's age >33 years | 0.55 | 0.57 | 0.58 | 0.03*** | 0.01* |
| Mother accesses further education | 0.31 | 0.32 | 0.32 | 0.02*** | 0.01* |
| Father's age at child's entry to school (~6 years) | 36.95 | 37.19 | 37.21 | 0.25*** | 0.02 |
| Share with father's age >36 years | 0.54 | 0.56 | 0.56 | 0.02*** | 0.00 |
| Father accesses further education | 0.28 | 0.29 | 0.29 | 0.02*** | 0.00 |
| DNHSR MMR vaccine information | 0.53 | 0.55 | 0.55 | 0.03*** | 0.01 |
| <i>Panel (b): Vaccine information</i> | | | | | |
| Has any vaccine information | | 0.88 | 1.00 | | 0.12*** |
| Low quality of vaccine information | | 0.30 | 0.20 | | -0.09*** |
| Has measles vaccine (either measles, MMR1 or MMR2) | | | 0.78 | | |
| Has year information on vaccine | | | 0.57 | | |
| Has year/month information on vaccine | | | 0.34 | | |
| Observations | 75,923 | 66,756 | 58,735 | | |

Note: Differences between (1) and (3), and (2) and (3), have been tested with a simple *t*-test. Significant differences are indicated by * $p < 0.05$, ** $p < 0.01$ and *** $p < 0.001$.

CSHRR: Copenhagen School Health Record Register; DNHSR: Danish National Health Service Registry; MMR: measles, mumps and rubella.

compiled summary statistics for a subgroup of 58,735 children who possess information on additional vaccines. We subsequently perform a comparative analysis involving this subgroup, the full population and the population of Copenhagen (CPH). Table II presents summary statistics on three groups: all children in Copenhagen between the school ages of 6 and 16 years (CPH), the full CSHRR population and the subsample of CSHRR with any vaccine information. We show differences between the samples in columns 4 and 5 of Table II. In the full sample, 88% of children have additional immunisation information. The remaining 12% have missing information on other vaccines. This absence of data can stem from either the children not receiving additional vaccinations or the unavailability of information at the time of the school health examination.

In Table II, we observe that within the subsample of the CSHRR population with any vaccine information (column 3), the breakdown is as follows: 49% are girls, 74% are ethnic Danes, 8% are immigrants and 17% are descendants. Upon entering school at the age of six, the children's mothers are 34 years old on average, with 32% accessing further education, while fathers are 37 years old on average, with 29% accessing further education. Using reimbursement information from the DNHSR, which is only available from 1996 onwards, we find that 55% in both the full and subsample (columns 2 and 3) have

MMR vaccine information. It is worth noting that the differences between the subsample and the full CSHRR sample are relatively small (column 5), and these distinctions disappear when we restrict the sample to ethnic Danes, as can be seen in Supplemental Table SI.

The typist indicated the quality of reports when entering data from the school health records. In the full CSHRR population, 30% are labelled as having low-quality information. This share is significantly lower in the subsample, where 20% have low-quality information. The quality measure is positively correlated with the amount of information recorded in the school records. Consequently, most children without any other vaccine information have been coded as having a low-quality school record.

As for the full CSHRR sample, we find only small (quantitative) differences between the subsample with any other vaccine information and the CPH population, although many of these differences are statistically significant (see column 5).

Vaccine information

Below, we explore how the vaccine information obtained from the CSHRR match the vaccine information obtained from the DNHSR for the cohorts where information from both sources exist. First, we examine how the vaccine uptake differs

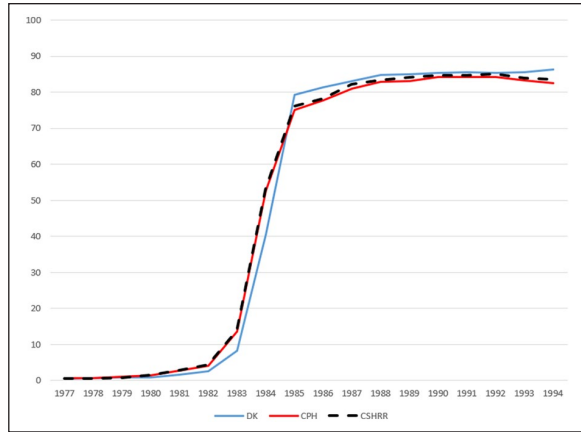


Figure 2. Information on measles, mumps and rubella (MMR) vaccination by year of birth.

Note: Received vaccine at any age. Information on MMR vaccine from the Danish National Health Service Register (DNHSR) 1995–2010 for populations: CSHRR ($N=66,756$), all children living in Denmark (DK; $N=1,168,757$) and all children living in Copenhagen in school-age period (CPH; $N=75,923$).

among three populations, including the full CSHRR, children living in Copenhagen and all children living in Denmark, using reimbursement data from 1996 to 2010 (see Figure 2). As the first year that the child's identifying number is recorded with the vaccination reimbursement is 1996, the DNHSR only provides information on immunisations for children administered the vaccination after 1995. Since the MMR vaccination was administered at 15 months and 12 years of age for all cohorts from 1987 through 2004, the children who received the MMR vaccine in 1996 were born in 1994–1995 and 1984–1985, respectively. As a result, the 1984–1985 birth cohorts should be the first in the DNHSR registry to have received the MMR vaccination, even though we observe a small number of older children with immunisation records. Consequently, Figure 2 shows a dramatic rise in immunisation rates for the 1984 cohort.

Importantly, Figure 2 confirms that the uptake of vaccines is consistent across all three populations. The uptake is somewhat greater for 1985–1986 cohorts for the entire Danish population compared to the Copenhagen sample. For 1983–1984 cohorts, the uptake is a marginally higher for children in Copenhagen relative to the full Danish population of children. For the 1987–1994 cohorts, the samples follow a similar uptake rate of approximately 82%–85%. Across all cohorts, the CSHRR population's vaccination rate mirrors that of the Copenhagen population. Based on the information presented in Figure 2, we conclude that the CSHRR data are representative of the vaccination uptake of the Copenhagen school-age children.

Second, we compare the vaccination rates recorded in the reimbursement data (DNHSR) and the school health records (CSHRR) for the children who are part of the CSHRR population. We examine the disparities in vaccination uptake between the full CSHRR population and the subsample with any other additional vaccine.

Figure 3 presents the results by sex and immigration status for the full CSHRR (the blue dotted line and blue dot-dashed line) and the subsample of the CSHRR (the black solid line and the black dashed line). In samples including only ethnic Danes, the full population and the subsample with any other vaccine information have similar vaccine uptake based on the reimbursement information. For the sample of immigrants and descendants, the vaccine uptake based on reimbursement information is markedly higher in the subsample than in the full CSHRR population for children born after 1984.

In Figure 3, the black dashed line shows the vaccine uptake based on school health record information for the subsample of the CSHRR. When the sample is restricted to children who have had any other vaccination record, the CSHRR-based vaccine uptake for cohorts after 1987 matches the DNHSR-measured vaccine uptake. This pattern holds for both boys and girls, as well as ethnic Danes. Between 40% and 80% of ethnic Danes who were born before 1984 received the MMR immunisation. These cohorts of children have probably been exposed to measles. When vaccine information is based on reimbursement data, immigrants and their descendants in the subsample of the CSHRR show comparable vaccination rates for the 1984 and 1985 cohorts. However, the uptake is higher for cohorts born in 1987 and after. The blue dot-dashed line in Figure 3 shows vaccination uptake using data from the school health records for the full CSHRR population. When MMR vaccinations are measured by the CSHRR as opposed to the DNHSR, vaccine uptake is noticeably lower for all populations, including girls, boys, Danes, immigrants and their descendants. However, when the CSHRR population is limited to the subsample of children who have had any other vaccine records, the DNHSR and CSHRR-based vaccine uptake estimates are comparable, particularly for the group of ethnic Danes. For the group of immigrants and descendants in the CSHRR population, 40% have missing information on any vaccine. Therefore, we conclude that the vaccine information for immigrant children is generally of lower quality.

Discussion

The CSHRR now includes updated data on vaccination uptake that was digitalised in 2019. For the

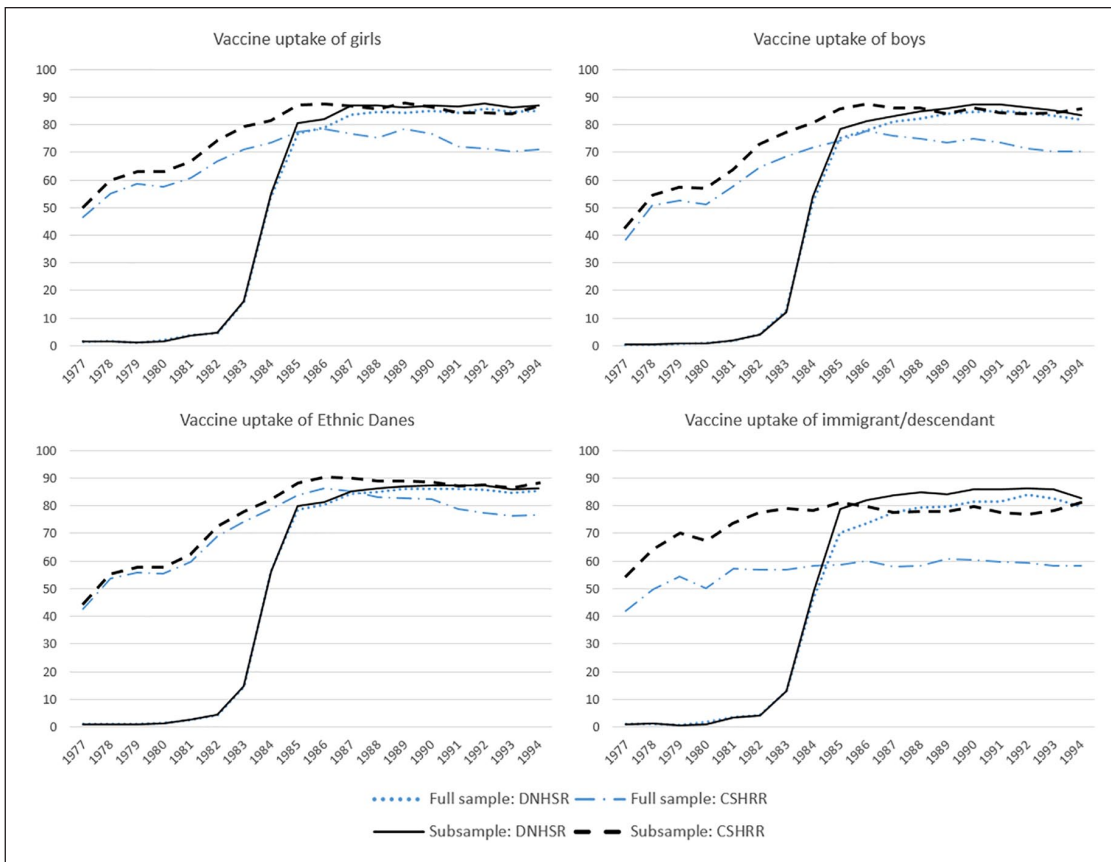


Figure 3. Comparison of vaccine information from CSHRR and DNHSR by year of births.

Note: Received a MMR vaccine (or a measles vaccine) at any age by cohort. Vaccine information from the CSHRR and from reimbursement data in the DNHSR (only available from 1996 through 2010). Populations: full sample from the CSHRR ($N=66,756$) and subsample of CSHRR children with any vaccine information ($N=58,735$). Vaccine information from the CSHRR is illustrated by the dashed line and the dotted line. Full sample is coloured blue, and subsample is coloured black. t -Tests of difference in levels and trends between the full and subsample of CSHRR shows no difference for the subgroups of girls and boys (except for cohorts born in 1985 and 1986) and for the subgroup of ethnic Danes. For the subgroup of immigrants/descendants, the vaccine uptake in full and subsample differs in almost all cohorts.

cohorts from 1977 to 1994, details on MMR vaccinations were provided. While the MMR vaccine has been available since 1971, the vaccine was only included in the Danish child vaccination schedule from 1987. Vaccine information on Danish children also exists based on reimbursement data from the DNHSR. However, as the reimbursement data on children starts in 1996, the information on vaccine uptake in the CSHRR provides information on vaccine uptake for a wider range of cohorts.

While the cohorts in the CSHRR population differ from the full population of children living in Denmark, we document that the CSHRR population represents the full population of all school children in Copenhagen with regards to ethnicity and parental characteristics. Among all children in the CSHRR sample, 12% have no record of any previous vaccine included in the Danish childhood vaccination schedule. As discussed previously, the absence of information regarding these prior vaccines implies that either parents did not

provide the vaccine card or the home questionnaire during the initial meeting with the school doctor, or the child has not received any of the other vaccines recommended and included in the Danish childhood vaccination schedule. It is important to note that these vaccines are administered before a child reaches school age and therefore should have been recorded in the school health record.

Based on the cohort, sex- and ethnicity-specific vaccination rates obtained from the reimbursement data and the school health records for years when vaccine information overlaps, we find that for the full sample and the subsample of children with any vaccination information, the vaccine uptake matches with vaccine registry data for later cohorts, especially for ethnic Danes. Thus, removing children who have had no additional immunisations does not introduce selection to the sample. Focusing on the subsample of children enables us to distinguish between children who received the MMR vaccination and those who did not

as we remove observations for children without vaccine information in their school health records.

A sizable proportion of immigrant children in the CSHRR have missing information on vaccination, suggesting potential challenges in collecting complete immunisation records for this group. One possible explanation for missing information among immigrant children is that they may have started school at a later grade and missed the first school doctor examination, which is typically when past immunisation records are collected. Additionally, missing information for the group of immigrant children can also potentially be explained by poor registration when the vaccines are received in a country other than Denmark or by immigrants simply having a lower vaccine uptake. Overall, the validity of vaccine information in the CSHRR appears to be lower for immigrant children compared to ethnic Danes.

Despite the sizable amount of missing vaccine information observed for immigrant children in our analysis, it is important to highlight that the data set provides complete, comprehensive and innovative immunisation data for other demographic groups. Through linking these data with other registry sources, it becomes feasible to extract critical insights into vaccination uptake, both before and during the period when the MMR vaccine was introduced in the Danish child immunisation programme. Consequently, we believe that the updated CSHRR stands as a valuable resource for future research endeavours.

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ORCID iDs

Jennifer L. Baker  <https://orcid.org/0000-0002-9649-6615>

Jane Greve  <https://orcid.org/0000-0003-2138-4640>

Supplemental material

Supplemental material for this article is available online.

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