

Late or missed childhood vaccination in the United Kingdom: Identifying the determinants

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Abstract

Background

Increasing vaccine uptake is a priority to protect children and the population against infectious diseases, alongside addressing socio-demographic uptake inequalities. Childhood vaccine uptake began declining before the COVID-19 pandemic in the United Kingdom (UK) and has worsened since—contributing to measles and pertussis outbreaks. This thesis investigated the determinants of missed childhood vaccines, including maternal factors, and how to increase vaccine uptake.

Methods

This mixed-methods thesis comprises two primary studies:

- A national birth-cohort study, using routine primary-care data to examine measles, mumps and rubella (MMR) uptake among children between 2000-2020 and associated socio-demographic determinants. A life-course approach investigated the relationship between pregnant women's pertussis vaccination and their children's subsequent MMR vaccination.
- A co-production study with public partners—Mosaic Community Trust to explore parents' attitudes towards childhood vaccines, including the pandemic's impact.

Results

The birth-cohort study found children living in more deprived areas, Black ethnicity children or those with teenage mothers were less likely to be vaccinated with MMR compared with children from less deprived areas, White ethnicity children or those with mothers aged 31-40 years. Children of mothers vaccinated against pertussis in pregnancy were more likely to receive MMR vaccines compared to children with unvaccinated mothers, independent of deprivation, ethnicity, or maternal age.

The co-produced questionnaire survey and focus groups found that some parents felt they lacked information and/or opportunities to talk to health professionals about vaccinations before appointments. Inconsistent reminders and difficulties booking or attending appointments also affected uptake. Some parents, particularly from ethnic minorities, have more questions about childhood vaccines since COVID-19.

Conclusions

A birth-cohort study suggests vaccine services should promote and facilitate access to both maternal and childhood vaccines during pregnancy. Co-production research suggests increasing childhood vaccine uptake requires simplified booking systems, easier access to appointments and more opportunities for discussion with health professionals, following COVID-19.

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Declaration of originality

I declare that the thesis presented here for examination for the degree of Doctor of Philosophy of Imperial College London is solely my own work other than where I have clearly indicated that it is the work of others (in which case the extent of any work carried out jointly by me and any other person is clearly identified in it) and that the thesis has not been edited by a third party.

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COVID-19 Statement

I put in the original application for the NIHR doctoral research fellowship to fund this PhD in December 2019. COVID-19 then delayed the NIHR application process, and I was not awarded the funding until September 2020. Due to redeployment, I was also then unable to start the PhD until March 2021. I have been lucky that the pandemic increased the acceptability of home working as it has enabled me to work flexibly and part time for the duration of this PhD, particularly after taking maternity leave for a year from February 2024. Though being in the office some days will always be invaluable!

When I applied for my DRF not many people were talking about childhood or maternal vaccination. Unfortunately, the pandemic caused already declining childhood vaccine uptake rates to decline even further meaning my work became more topical and relevant. Vaccination has also never been talked about more by the public and the media due to the pandemic. This also meant my PhD research questions changed—the impact of the pandemic on attitudes towards routine vaccines was not in the original application or research plan.

Outputs from this PhD

Please note the below is a list of all publications since the start date of my NIHR Doctoral Research Fellowship (1st March 2021). Some publications report on work done prior to the start of my part-time PhD, however, are included as encompass preliminary work that I used to refine my research and relate to the same broad topic area of vaccine uptake inequalities.

Original peer-reviewed publications directly relating to this work

1. **Skirrow H**, Foley K, Bedford H, Lewis C, Whittaker E, Costelloe C, Saxena S. *Impact of pregnancy vaccine uptake and socio-demographic determinants on subsequent childhood Measles, Mumps and Rubella vaccine uptake: a UK birth cohort study*. Vaccine. 2024 Jan 12;42(2):322-31.
2. **Skirrow H**, Lewis C, Haque H, Choundary-Salter L, Foley K, Whittaker E, Costelloe C, Bedford H, Saxena S. 'Why did nobody ask us?': A mixed-methods co-produced study in the United Kingdom exploring why some children are unvaccinated or vaccinated late. Vaccine 2024;42(22):126172. doi: 10.1016/j.vaccine.2024.126172 [published Online First: 20240821]
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4. **Skirrow H**, Foley K, Costelloe C, Bedford H, Lewis C, Whittaker E, Saxena S. Maternal predictors of timeliness & uptake of Measles, Mumps & Rubella vaccine: A birth cohort study. Eur J Public Health. 2023 Oct 24;33(Suppl 2):ckad160.139. doi: 10.1093/eurpub/ckad160.139.
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Impact and knowledge exchange from this thesis

Wider Patient and Public Involvement work beyond Mosaic

- Westminster Maternity Champions- setting research priorities and sharing research findings events (multiple).
- Connecting Care for Children Research Meetings (multiple).
- Imperial Spark live Covid-19 Q&A vaccine event 2021.

Regionally

- Throughout this PhD, I shared research methods and findings with the Westminster, Kensington and Chelsea Bi-borough Immunisation Board- they fed into the research methods and learnt from my results.
- NIHR North-West Thames Applied Research Collaborative Learning events.
- North-West London Integrated Care Board (ICB) meetings.

Nationally

- Briefings to the National Immunisation team at UKHSA.
- Policy briefing for the UKHSA Strategy, Policy and Programmes team's Measles Action Workshop on improving MMR coverage in August 2023.
- All party parliamentary roundtable exploring opportunities to recover MMR uptake in London and the South-East, November 2022.
- National Institute for Health and Care Research (NIHR) national Applied Research Collaboratives (ARCS) report on supporting the fight against Covid-19.

During this fellowship three of my first author research papers were cited in NICE guidance: Vaccine uptake in the general population.

- <https://www.nice.org.uk/guidance/ng218/evidence/k-covid19-call-for-evidence-pdf-398599982678> (Skirrow H, Barnett S, Bell S, Riaposova L, Mounier-Jack S, Kampmann B, Holder B 2022, *Women's views on accepting COVID-19 vaccination during and after pregnancy, and for their babies: A multi-methods study in the UK.*, BMC Pregnancy and Childbirth, Vol: 22, Pages: 1-15, <https://doi.org/10.1186/s12884-021-04321-3>)
- <https://www.nice.org.uk/guidance/ng218/evidence/b-barriers-to-and-facilitators-for-vaccine-uptake-pdf-11072221743> (Skirrow H, Beth Holder, Alison Meinel, Evelyn Narh, Beverly Donaldson, Anna Bosanquet, Sara Barnett & Beate Kampmann (2020) *Evaluation of a midwife-led, hospital based vaccination service for pregnant women*, Human Vaccines & Immunotherapeutics, DOI: 10.1080/21645515.2020.1770515)
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Glossary

- *Herd immunity*: A term describing a population with a high proportion of individuals with pre-existing immunity to an infectious disease because of previous infection or vaccination meaning the population is indirectly protected against the infectious disease spreading.
- *JCVI*: Joint Committee on Vaccination and Immunisation is an independent expert committee that advises the Department of Health and Social Care in the United Kingdom on vaccination and immunisation services for the prevention of illness.
- *MMR*: Measles, mumps and rubella combined vaccine.
- *Primary vaccine course*: Term commonly used in the UK vaccine programme to describe the vaccines given at 8, 12 and 16 weeks of age. Children who have completed their 'primary course' of vaccination are considered to have had three doses of a 6-in-1 vaccine.
- *Routine childhood vaccine schedule*: The schedule of vaccine doses and the ages when they should be administered as recommended for all children by the JCVI to the Department of Health and Social Care in the United Kingdom.
- *Selective vaccines*: Vaccines recommended for selective population groups with underlying medical conditions or circumstances that put them at increased risk of a particular disease or disease complications.
- *UKHSA*: UK Health Security Agency. Replaced Public Health England (PHE) from October 2021. An executive agency of the Department of Health and Social Care in the United Kingdom. Supports government, local government, the NHS, Parliament, industry and the public with scientific expertise including supporting local authorities and the NHS to plan, provide and monitor immunisation services.
- *Vaccine uptake*: The number of eligible individuals in an eligible population who have received a particular vaccine dose. In the UK vaccine programme vaccine uptake is commonly reported as vaccine coverage.
- *6-in-1 vaccine*: Combination vaccine containing diphtheria, tetanus, pertussis, polio, Haemophilus influenzae type B and hepatitis B recommended for UK infants at 8, 12 and 16 weeks of age.

CHAPTER 1: INTRODUCTION AND BACKGROUND

Understanding vaccine uptake in the UK

Background

Vaccine preventable diseases cause individual patient suffering, outbreaks of infectious disease in the population and increased pressure on health and care services.¹ Vaccines are safe, inexpensive, and effective at preventing infectious diseases,² so declining childhood and maternal vaccine uptake³⁻⁵ and their associated inequalities in the UK are concerning. Recent measles and pertussis outbreaks highlight the urgent need, both nationally in the UK,^{6,7} and globally,⁸ to ensure more children and pregnant women are vaccinated and protected against dangerous infectious diseases.

In the United Kingdom (UK) not enough children receive their recommended routine childhood vaccines,³ leading to rising cases of infectious diseases - in 2024 there were outbreaks of both measles and whooping cough in England.^{7,9} There has been a continuing downward trend in uptake of all routine childhood vaccines in the UK starting before the COVID-19 pandemic.^{3,5,10-12} Measles outbreaks have arisen as too few children have received the recommended two doses of measles, mumps and rubella (MMR) vaccine by age 5 years³ over recent years. Measles outbreaks have also been able to take hold as measles has been able to spread more easily through the population due to groups of susceptible unvaccinated young adults, who missed out on MMR vaccines over the last 20 years. In data from 2024 only 83.4% of children in England had received two MMR doses by aged five years - below the national 95% target, based on the World Health Organization's recommendation.³

Pertussis outbreaks have also arisen as not enough children are fully vaccinated against *Bordetella pertussis*,³ the causative agent of whooping cough. Children should receive three doses of the 6 in 1 vaccine containing pertussis at age 8, 12 and 16 weeks (appendix 1). Vaccination of pregnant women against pertussis also provides additional protection, through passive antibody transfer during pregnancy to newborn infants, therefore protecting them when they are most vulnerable to whooping cough at less than 8 weeks old. However, in the UK only 91.1% of infants had received the recommended three doses of the 6 in 1 vaccine, in 2024 by age 12 months in 2024, again below the 95% target.³ Maternal vaccination uptake is also suboptimal – only 64.4% of pregnant women were vaccinated against pertussis in 2024 data.⁴

Despite vaccine uptake declining in the UK before COVID-19 started in 2020, the pandemic worsened the situation,¹³ with routine vaccine uptake among children and pregnant women declining further subsequently. Huge variations in vaccine uptake also exist regionally in the UK – for example in some areas of central London only 56% of children are reported to have received two MMR vaccines by age 5 years.³ This variation is thought to be caused by inequalities in vaccine uptake associated with ethnicity,¹⁴ families living in poorer areas¹⁵ and other socio-demographic factors.¹⁶⁻²³

1.1 The Routine Childhood Vaccination Programme in the UK

The UK's routine vaccine programme, which has been added to over decades, has protected children from illness and death since the 1940s,²⁴ and now offers vaccines to all children by 5 years of age to protect them against fourteen diseases (Appendix 1). Vaccines are offered at 8, 12 and 16 weeks, one year and then again on or after 3 years, 4 months of age (Appendix 1). Though the schedule is due to be changing in mid 2025 to early 2026 to add in an 18 month vaccination visit.²⁵ Teenagers are offered Human Papilloma Virus (HPV) vaccine, an additional quadrivalent meningococcal vaccine and a booster dose of tetanus, diphtheria and polio (Appendix 1). Children who have not been vaccinated by the recommended ages can be vaccinated any time afterwards and catch-up doses are encouraged.²⁶ Additional selective vaccine programmes offer vaccines to children at increased risk of certain diseases such as tuberculosis due to demographic characteristics such as where they live or medical characteristics such as underlying health conditions (Appendix 1).

The recommended vaccine schedule is set by the Department of Health on the recommendations of the Joint Committee on Vaccination and Immunisation (JCVI).²⁷ Specialist input and expertise is provided the UK Health Security Agency (UKHSA) which took over from its predecessor, Public Health England. Oversight and implementation of vaccine programmes in primary care are provided through local area National Health Service (NHS) teams with input from specialist UKHSA staff.²⁸ The UKHSA and NHS measures childhood vaccine uptake by age 5 years at three age points: 12 months, 24 months and 5 years. The UK target is 95% uptake of all routine childhood vaccines at five years, in line with the World Health Organisation's recommendation for the measles, mumps and rubella (MMR) vaccine.³

While additional vaccines have been added to the schedule, and the number of some vaccine doses changed, the ages at which the vaccines are recommended for all infants has not changed since 1990.²⁹ For example, in 2017 primary vaccines changed from including a 5-in-1 vaccine offering protection against diphtheria, tetanus, polio, pertussis and *Haemophilus influenzae* type B to a 6-in-1 vaccine which also included hepatitis B protection.³⁰ However, the ages these vaccines were offered remained the same. Pneumococcal vaccine dosing in the UK was also changed in 2020 from the previous 2 doses given at 8 and 16 weeks of age and a booster dose at one year (2 + 1 schedule) to 1 dose at 12 weeks of age followed by a booster dose at one year (1+1 schedule).³¹ So while the vaccines offered at different ages changed, the number of vaccine appointments and age when routine universal vaccines were offered has been consistent over the last thirty years.

The universal vaccine programme for children under the age of 5 years is delivered through general practices (GP) in the UK.³² The exceptions to this are some selective vaccines given at birth may be delivered to at-risk babies in hospitals or other sites and the childhood influenza vaccine program includes school-based delivery for children under 5 years, who may already be at school. GP practices are contracted to provide vaccines according to the schedule to their eligible registered patients in England.³² In 2021 the GP contract in the UK, which outlines how GPs are paid for delivering different services to their practice population, changed to offer incentive payments to practices for achieving specific levels of population coverage for childhood universal vaccines classed as essential GP services (apart from childhood influenza vaccination which is an enhanced service).³²

1.2 The Routine Maternal Vaccination Programme in the UK

In the UK pregnant women are routinely offered pertussis vaccine,⁴ the seasonal influenza and COVID-19 vaccines,^{4 33} and since 2024 vaccination against Respiratory Syncytial Virus³⁴ (Appendix 1). Pertussis vaccine for pregnant women was introduced in 2012 following an outbreak which included infections and deaths among infants under 3 months of age and thus not yet themselves vaccinated.^{35 36} Pertussis vaccination in pregnancy has been shown to be safe³⁷ and effective at preventing infant infections and deaths,³⁵ by providing passive protection through mother to baby placental antibody transfer.³⁸

Seasonal influenza vaccine was introduced for pregnant women in the United Kingdom following the 2009/2010 H1N1 influenza pandemic when pregnant women were found to be at increased risk of severe illness and death.³⁹ Seasonal influenza vaccine for pregnant women has also been shown to reduce the risk of prematurity, babies being born small for their gestational age⁴⁰ and infant influenza infections.⁴¹

COVID-19 vaccine has been recommended in pregnancy since April 2021,³³ due to a greater risk of pregnant women becoming severely unwell with the infection and needing admission to intensive care with COVID-19 infection compared with non-pregnant adults of the same age.⁴² However, since the height of the pandemic the risk to pregnant women becoming severely ill with COVID-19 has been decreasing and in the December 2024 release from the UK's JCVI, they were not included in the at risk cohorts to be recommended for vaccination in 2025.⁴³

Respiratory Syncytial Virus vaccine was more recently added to the schedule in the UK for pregnant women and aims to protect babies against becoming severely ill with bronchiolitis in the first 6 months of their life.^{34 44-46} Pregnancy vaccines, like other routine vaccine programmes are delivered by GPs in the UK, however since 2016 some antenatal clinics in hospitals have also offered vaccines to pregnant women.^{47 48} With the RSV vaccine the primary delivery was planned to be through hospital maternity clinics with GPs commissioned to offer them opportunistically or on request.⁴⁹

1.3 How is vaccine uptake monitored in the UK?

There are a range of different stakeholders, processes and data flows involved in the monitoring of the childhood and maternal vaccine programs in England.^{50 51} Oversight and implementation of vaccine programmes in primary care is provided through local area NHS teams with input from specialist, historically PHE, and now UKHSA staff.³²

Two parallel systems exist for data collection: the Child Health Information Systems (CHIS)⁵¹ and Immform.⁵² Regionally collected CHIS data is used to generate COVER – ‘Cover Of Vaccination Evaluated Rapidly’ -estimates of vaccine uptake among children in the UK who reach their first, second or fifth birthday during each evaluation quarter. ImmForm is a website that functions as a platform for data collection, analysis and ordering vaccines and historically tended to monitor newer vaccine programmes.²¹

Vaccine uptake data estimates can be incorrect due to issues with denominator completeness and also coding accuracy in primary care records.⁵¹ The uncertainty about the

denominator for both childhood and maternal vaccine programmes arises from, for example families moving house but GP records not being updated in a timely manner, which can lead to under estimation of vaccine uptake.²¹ Coding inaccuracies can also arise for example if vaccines delivered in antenatal care settings are not recorded in GP records.⁴⁷

1.4 Why is it important for children to be vaccinated on time?

Children need to be vaccinated at the recommended ages to provide maximum protection and prevent outbreaks.^{53 54} Meeting WHO coverage targets only by 5 years can leave some children unprotected at younger ages when they are vulnerable to infectious diseases. For example one study in the United States of America (USA) estimated that if children were vaccinated on time for their three doses of pertussis vaccines recommended at two, four and six months (in the USA) rather than the average observed delays of 16, 27 and 44 days then 278 cases of pertussis, 103 admissions to hospital and one death in a baby before 1 year could be prevented.⁵⁴ In the United Kingdom more children receive their primary vaccines, offered before the age of 1 year, on time compared to the preschool vaccines due at 3 years, 4 months which are the vaccines most likely to be delayed or missed completely.³

Studies of vaccine timeliness define delayed or late vaccination in different ways and obviously depending on each country's exact vaccine schedule, as there is some variation in when countries recommend childhood vaccines.⁵⁵ In the UK, as discussed, uptake is measured at 12 months, 2 years and 5 years, however ideally children should be vaccinated earlier at the recommended age to ensure maximal protection. A previous UK study of

vaccine timeliness by Walton et al using Millennium cohort data of 1782 children in Wales defined vaccine timeliness as being either early, on time, late or never at the three different ages when vaccines are recommended before age 5 years.⁵⁶ As with routine vaccine uptake statistics in the UK, Walton et al reported that 94% children received their first primary vaccine on time but fewer (88%) received their pre-school boosters on time.⁵⁶

1.5 Why is the uptake of the MMR vaccine a concern?

In the United Kingdom the uptake of the MMR vaccine has been a particular concern for the last quarter century since 2000,⁵⁷⁻⁵⁹ which is the same period this thesis examines. Children missing out on both MMR vaccine doses or having only one MMR dose before 5 years of age leaves them vulnerable to catching measles, as two doses are required to ensure that an individual child is fully protected.⁶⁰ A decline in MMR uptake initially began at the turn of last century, due to the now discredited claims by Andrew Wakefield, that led to parental concerns regarding the safety of the MMR vaccine.^{61 62} Subsequent outbreaks have arisen as this under-vaccinated cohort has reached different milestones, such as starting secondary school in 2011, and leaving home in 2018.^{63 64} Due to rising measles outbreaks the UK lost its WHO measles elimination status in 2019.⁶⁴ This was mainly because imported cases resulted in community transmission among adolescents and young adults who were unvaccinated or incompletely vaccinated. Persistent inaccurate beliefs and mistrust of the MMR vaccine among parents over the last quarter of a century has contributed⁶⁵ to variable MMR vaccine uptake and resulting measles outbreaks.⁶⁶

1.6 What are the socio-demographic determinants associated with childhood vaccine uptake?

Socio-economic deprivation

Many studies using smaller or regional population cohorts over the last twenty years that have reported the association between socio-economic deprivation and vaccine uptake. This association is seen globally^{67 68} mirroring the UK's context where children living in more deprived areas are at higher risk of being unvaccinated,¹⁷⁻¹⁹ or vaccinated late,⁶⁹⁻⁷³ compared to children living in less deprived areas. A recent study of childhood vaccinations in England between 2019 and 2023 found that inequalities had increased over the study period and the inequalities between richer and poorer areas was greatest for the second dose of the MMR vaccine.¹⁵ Hence addressing inequalities relating to MMR vaccine uptake, particularly given the recent measles outbreaks have been and continue to be a major policy priority in the UK.⁵⁸ Inequalities do not only exist in England, for example in a Welsh study of infant pertussis vaccine uptake among children in the most deprived area, 81.5% had received all three doses of the primary course by 24 weeks of age compared to 91.9% in the least deprived area.⁷²

In Scotland, Haider et al found that children from more deprived areas were at higher risk of delayed late vaccination – a gap of 14% was observed between the most and least deprived deciles.⁷³ However, conversely primary vaccines and second MMR vaccine dose coverage was greater for more deprived children compared to less deprived children.⁷³ Analysis of 1 million Scottish children between 1997-2004 focusing on the impact of the “Wakefield” controversy on MMR vaccine uptake also found that while delayed vaccination was more likely among children born in more deprived areas, more affluent children were more likely to either be vaccinated on time or remain unvaccinated.⁶² In another study

examining MMR uptake following the scandal – which caused some parents to be concerned about the combination of three antigens in one MMR vaccine – mothers with higher incomes were more likely to have chosen to vaccinate their children with single antigen measles, mumps and rubella vaccines and refused the MMR vaccine.⁷⁴

So, while overall living in deprived areas increases the risk of delayed or no vaccination the relationship between higher deprivation and lower childhood vaccine uptake is not always linear- conscious vaccine refusal of the combined MMR vaccine has been associated with more affluent parents. However, subsequent studies have consistently shown that living in more deprived areas is associated with lower vaccine uptake.^{15 17 18 56 69-71 75}

Ethnicity

Differences in vaccine uptake by ethnicity are reported worldwide. For example, in the United States children of Black or Hispanic ethnicity have historically been less likely to be vaccinated.⁷⁶⁻⁷⁸ In Australia children of Aboriginal mothers were also less likely to be vaccinated against MMR.⁷⁹ In the UK children belonging to ethnic minorities, including White minority ethnicities, are more likely to be unvaccinated and vaccinated late compared with White-British ethnicity children.^{14 17-19 73 75 80 81} A study examining ethnicity inequities in children's vaccine uptake in England, by Zhang et al, found that children born to mothers of White British ethnicity had higher vaccine coverage for all vaccines due before age 5 years, compared to children born to mothers belonging to Caribbean, Any other ethnic group, White and Black Caribbean, and Any other Black, African or Caribbean ethnicity backgrounds. Zhang also found that even prior to the pandemic, the difference in vaccine uptake between

different ethnicity groups had widened – for example they reported that the absolute difference in coverage between the Caribbean and White British groups for two doses of MMR vaccines increased from 12% in 2011–12 to 22% in 2019–20, to 29% by 2020–21.

Previous studies over the period this thesis examines have also found associations between ethnicity and vaccine uptake among children. For example, a study by Wagner et al examined vaccine uptake by ethnic group in London among a cohort of 315,381 children.⁷⁵ They found that minority ethnicity children from Somali or White-Polish backgrounds had lower vaccine uptake (<60% and <50% uptake respectively of pre-school booster by 5 years) compared to White-British children (>70% uptake of pre-school booster by 5 years).⁷⁵ Using the same cohort of 315,381 children in London, Tiley et al found that after adjusting for deprivation and local health administrative area, 11% fewer Black or Black-British Somali children and 5% fewer Asian-Bangladeshi children had been fully vaccinated with three primary vaccines doses by age one year, compared to White-British Children.¹⁷ In another study examining rotavirus vaccine uptake among 459,074 babies born across England between 2013 and 2015 Bryne et al found that even after adjusting for deprivation and area, Black-Caribbean children had 10.7% lower rotavirus vaccine uptake compared to White-British children.¹⁸

A review of qualitative studies into vaccine attitudes among Black and Asian minority groups in England found that parents religion, country of birth and migration, language and also perceived differences in their susceptibility to both vaccine side effects and infectious disease, all affected vaccine decisions.⁸⁰ Children who belong to families where English is not the main language spoken at home have also been reported to be as less likely to be

vaccinated.⁸² Some communities have been found to have certain attitudes to different vaccinations – for example Somali mothers have reported particular suspicion about the MMR vaccine and autism⁸³ A qualitative study by Bell et al into Polish and Romanian communities’ experiences of accessing vaccine services was undertaken in three different areas of England. They found that barriers to vaccination included language and a lack of understanding about UK vaccine services and schedules.⁸⁴ For example, Eastern European parents in the study reported anxiety about vaccines being delivered by nurses whereas in their country of birth vaccines were delivered by doctors. There was also confusion about why not all babies were vaccinated with the BCG (Bacillus Calmette-Guerin) vaccine in the UK,⁸⁴ as well as safety concerns about MMR vaccines.⁸⁴

In contrast to other studies in the ‘Born in Bradford’ cohort of 6977 children, vaccine uptake at ages 1, 2 and 5 years was higher among Pakistani children compared to-White British Children, though White ethnicity children whose mothers were born abroad were more likely to be partially vaccinated.¹⁶ Similarly in a cohort study in Manchester of over twenty thousand babies born between 2000-2007 those of Indian, Pakistani and Bangladeshi ethnicity were most likely to have had the MMR vaccine (96%, 95%, 95% respectively) whereas White babies were least likely to have had it (88%).⁷¹ However, higher deprivation among all ethnicity communities was associated with lower vaccine uptake, as discussed previously.^{16 71}

Regional variation

There is also longstanding regional variation in childhood vaccine uptake, with London historically having lower uptake compared to national figures. In 2023-24 only 73.3% of 5 year

olds in London had received two doses of MMR vaccines, 10.6% lower than the average national uptake.⁵

Intersecting socio-economic factors

There are several intersecting socio-economic factors that mean families living in cities such as London or Manchester with large, ethnically diverse and mobile populations have lower vaccine uptake.^{17 71} Children whose families moved during pregnancy for example are at higher risk of being unvaccinated,⁸⁵ while children belonging to a family with a single or teenage parent are also less likely to receive their pre-school booster.^{56 86} Vulnerable 'Looked after children' in the care of the state are likewise less likely to be vaccinated or vaccinated late, particularly older, looked after adolescents.⁸⁷ The Millennium Cohort study of timeliness of childhood vaccines also found that late vaccination was associated with children belonging to larger families particularly with four or more children.^{56 74} Sociodemographic factors such as large family size are also associated with lower vaccine uptake in the USA.⁸⁸ Children in the UK who belong to traveller communities have also been identified as a group at higher risk of missed vaccination.⁸⁹

Children with intellectual disabilities had lower vaccine uptake compared with children without intellectual disabilities in a study by Emerson et al.⁹⁰ However, the difference reduced after adjusting for other socio-demographic characteristics such as deprivation suggesting that some of the increased risk of lower uptake among children with intellectual disability is related to the association between intellectual disability and lower family socio-economic circumstances.⁹⁰ Children born prematurely have also been identified as risk group

for late vaccination, though recent studies in the UK population are lacking.⁹¹ There is also a lack of studies about the relationship between chronic health conditions in childhood such as diabetes, asthma and epilepsy and timely or complete childhood vaccination.

Vaccine uptake among different ethnic and sociodemographic groups is therefore context specific and influenced heavily by previous experiences, health status and cultural influences.^{56 80 92} Improved understanding of different communities vaccines barriers and enablers are needed to inform targeted interventions to reduce vaccine uptake inequalities among different groups in the UK.

1.7 Vaccine confidence

Vaccine uptake can be affected by vaccine confidence⁹³ which is described by The Vaccine Confidence project at The London School of Hygiene and Tropical Medicine as ‘the belief that vaccination – and by extension the providers and range of private sector and political entities behind it – serves the best health interests of the public and its constituents.’⁹⁴ Vaccine confidence can be related to a range of social and demographic factors that vary geographically.⁹³ So for example confidence in the wider health care system, social norms, religious practices and also cultural health beliefs can all impact on different individuals’ and communities’ confidence in vaccination.⁹⁵ Most parents have confidence in the childhood vaccination programme in England, for example a survey prior to the pandemic reported that only 2% of parents had refused vaccines for their children and 90% automatically vaccinated their children when due.⁹⁶ However, as previously discussed, some parents from particular demographic groups lack confidence in routine vaccines and choose

not to vaccinate their children.⁹⁷ Though these beliefs vary culturally and between different ethnicity⁸³ and income groups.⁷⁴ In the 2022 UKHSA survey, 90% of parents were reported to have ‘trust’ in vaccines.⁹⁸ However, the 2022 United Kingdom’s Health Security Agency (UKHSA) survey recruited parents registered with the commercial marketing parent app ‘Bounty’ and under-represented parents from London and from ethnic minorities⁹⁸- groups who are less likely to have their children vaccinated.^{17 80} In the 2023 survey by UKHSA, parents and teenagers were asked about their attitudes to the teenage vaccine programme and 78% of parents reported that they ‘trusted’ vaccines.⁹⁹

1.8 Vaccine access

A report by the Royal Society of Public Health on childhood vaccination in the UK, which included a survey of 2,622 parents, in 2018, reported that access to childhood vaccine appointments is a larger driver of missed vaccinations in the UK than anti-vaccination sentiment.¹⁰⁰ The most common barriers to vaccination reported by parents were the timing of appointments (49% parents), availability of appointments (46% parents) and childcare duties (29% parents). Inconsistent recall and reminder services by different GP practices have also been identified as a barrier to children being vaccinated, particularly with their preschool vaccines.^{28 101} For example a study by Lonergan et al found that while over 8 in 10 GP practices used a form of recall and reminder system for vaccines the type of system and number of reminders varied between practices.¹⁰² Robust recall and reminder systems are key drivers of improving childhood vaccine uptake,^{103 104} as well as conversations with trusted healthcare providers.¹⁰⁵

Work by Edelstein et al examined whether anti-vaccination sentiment was the likely cause of declining vaccine uptake in England since 2012-13 by examining vaccine-related data against the Bradford-Hill causation criteria.¹⁰⁶ Edelstein et al concluded that anti-vaccine sentiment was not a major driver of vaccine uptake in the UK and that other issues may represent larger barriers to vaccination, though further work is needed to identify underlying causes of variable vaccine uptake in the UK.¹⁰⁶ This is supported by work with specific communities such as Bell et al's qualitative study into Romanian and Polish parents experience of the UK vaccine program which found that lack of knowledge about UK vaccine services affected parents awareness and ability to access vaccine appointments.⁸⁴ There is therefore a need for research to focus on not only attitudinal reasons behind low vaccine uptake among different demographic groups, but to investigate concepts related to access to understand and address declining vaccine uptake.¹⁰⁷

Research has shown that locally developed and multi-component interventions maybe needed in ethnically diverse, socially deprived communities to improve vaccine uptake.¹⁰⁴ To date, surveys of parental attitudes and experiences of childhood vaccination have not been representative of Black and minority ethnic populations^{98 100} whom have lower childhood vaccine uptake.^{17 18} There is thus a need for more primary research to understand why lower vaccine uptake is associated with belonging to a minority ethnicity group and living in a deprived area in the UK.⁸⁰ To inform such interventions the relationship between vaccine confidence, vaccine access and uptake inequalities among children in the UK needs further exploration.

1.9 Maternal characteristics and childhood vaccine uptake

The relationship between vaccine uptake, living in a more deprived area and other sociodemographic characteristics shows that early life circumstances are associated with childhood vaccination uptake. This supports consistent findings among previous studies that maternal characteristics impact on childhood vaccine uptake. For example, children who are breastfed are more likely to be vaccinated.⁷¹ Globally higher maternal education has been found to be associated with increased likelihood of complete childhood vaccination.¹⁰⁸ This was also found in the Millennium cohort study which reported that 8.9% of children whose mothers had no academic qualifications had late vaccinations compared to only 1.2% of children whose mothers had a degree.⁵⁶ Maternal unemployment and smoking during pregnancy has also been found to be associated with lower childhood vaccine uptake.^{19 56} In a retrospective cohort study using CPRD, maternal mental illness was associated with a lower likelihood (odds ratio 0.86) of children completing their vaccines by age 2 and 5 years, compared to children of mothers with no record of mental illness.¹⁰⁹ In an American study the children of mothers who attended fewer antenatal care visits had lower vaccine uptake.⁸⁸ There is also evidence from other settings, predominantly low and middle income countries such as India, on the importance of antenatal care attendance for improving childhood vaccine uptake.¹¹⁰

1.10 Relationship between maternal vaccine uptake and childhood vaccine uptake

As with childhood vaccines, uptake for maternal vaccines also varies by ethnicity and deprivation in the UK, with women of Black ethnicity or living in more deprived areas being less likely to be vaccinated against pertussis, influenza or COVID-19 vaccines in pregnancy

compared to White-British ethnicity women.^{4 18 22 23 111} For example, in a study by Walker et al uptake for pertussis vaccine was 10% lower in the most deprived areas of England compared to the least deprived areas and Black ethnicity women had 55% reduced odds of being vaccinated against pertussis in pregnancy, compared to White-British women.²³ Again similar to childhood vaccine uptake, maternal uptake varies regionally and in the 2024 data pertussis uptake was lowest in North Central London (25.6%) and highest in Shropshire, Telford and Wrekin (84.7%).⁴ National pertussis vaccine uptake figures for 2023 to 2024 also varied by ethnicity, with highest coverage among White British (66.8%) and Chinese women (66%) and lowest among Black or Black British women (36.6%) and Black or Black British Caribbean (29.9%).⁴

Seasonal influenza uptake among pregnant women is lower in the UK than pertussis uptake with only 32.1% of pregnant women in the 2023 to 2024 season being vaccinated - the lowest recorded uptake since 2011 to 2012.¹¹² Seasonal flu vaccine uptake among pregnant women also shows similar inequalities related to ethnicity and deprivation.¹¹² Walker et al also found that women aged less than 20 years had a 21% lower odds of being vaccinated in pregnancy compared to women over 20 years.⁷⁶ Vaccination in pregnancy was also increasingly less likely with increasing number of children in the mother's household – it was reported to be 53% less likely among women with two children and 65% less likely among women with three or more children.⁷⁶

Previous research in Australia has found that vaccine hesitancy in pregnancy is associated with infant vaccine uptake post-delivery.¹¹³ Danchin et al found mothers who reported 'a lot of concern' in pregnancy about vaccines were less likely to have children who were up to date with their vaccines compared to mothers without concerns (vaccine uptake

difference in proportions 58%).¹¹³ Therefore, understanding the relationship between maternal and childhood vaccine uptake in the UK is important for informing future interventions and maternal vaccine delivery programs. Particularly as more pregnancy vaccines, such as the recent RSV vaccine, are being added to the UK vaccine schedule in future years.³⁴ Pregnancy offers a unique opportunity to promote and inform new families about routine childhood vaccines and antenatal interventions to improve both maternal and childhood vaccination are already being piloted in Australia.^{114 115}

There is an increasing body of evidence that pregnancy vaccine intentions relate to subsequent childhood vaccine attitudes and uptake.¹¹⁵⁻¹¹⁷ In previous work for example, COVID-19 vaccine acceptance among UK pregnant women was associated with likelihood of also accepting a COVID-19 vaccine for their children.¹¹¹ However, in the UK the relationship between maternal pertussis vaccine uptake and subsequent childhood vaccine uptake was, as yet, unquantified despite predictive factors associated with both being similar, such as ethnicity and deprivation.

1.11 Impact of the COVID-19 pandemic on routine vaccine uptake

The pandemic caused a decline in routine childhood vaccination uptake globally,¹¹⁸ with disruption to routine vaccine services reported across 170 countries.¹¹⁸ In the UK the declines in childhood vaccine uptake have persisted past the initial stages of the pandemic.⁵
^{119 120} In the UK, parents experienced difficulties accessing routine childhood vaccines during the first wave of the pandemic and confusion about whether routine vaccines were continuing.^{121 122} Pre-existing inequalities in childhood vaccine uptake between different ethnicity groups and among more disadvantaged areas were also exacerbated.^{13 14} Ethnic

minority women were also more likely to report feeling unsafe or find it physically difficult to access vaccine appointments for their babies during the first wave of the COVID-19 pandemic.¹²² In the United States, parents' attitudes to routine childhood vaccines were found to have been impacted by the pandemic,^{123 124} however there is a lack of primary research in the UK on the impact of the pandemic on parents' attitudes to routine childhood vaccines. The UKHSA's post pandemic surveys on childhood vaccine confidence among parents in particular was not representative of ethnic minority parents or parents from London,⁹⁸ whose children are less likely to be vaccinated.

1.12 Engaging communities with low vaccine uptake

To date, surveys of parental attitudes and experiences of childhood vaccination have not been representative of minority ethnic populations,¹⁰⁰ which have lower childhood vaccine uptake.^{17 18} More primary research is needed to understand why lower vaccine uptake is associated with belonging to a minority ethnicity group and living in deprived areas in the UK.⁸⁰ To understand these health inequalities, further exposed by COVID-19, more participatory health research has been called for to give a voice to those with lived experiences of an issue^{125 126 127} By involving parents and public partners living in an area with historically low vaccine uptake and using a community based participatory research approach,¹²⁸ the perspectives of community voices who do not normally engage in research can be explored.^{126 129}

Participatory research centres on giving a voice to those with lived experiences of an issue,¹²⁷ which in the context of this thesis means involving parents belonging to communities

historically experiencing low vaccine uptake to fully understand the problem. By exploring parental perspectives in a less affluent, ethnically diverse area of London with low vaccine uptake, previously unidentified opportunities to improve vaccine uptake among these populations maybe revealed. For example, parents could suggest how vaccine appointments recall, and reminders can be improved.¹³¹

Research gaps this thesis aims to address

The below table outlines the research gaps this thesis aims to address and the associated research questions.

Table 1: Overview of Thesis

PhD Study	Research Questions	What is the research gap this is trying to address	What are the potential implications
1.a	What are the characteristics of children at risk of missing out on routine vaccines or being vaccinated late before age 5 years in the UK	Large maternal and child data linkage study over 20 years between 2000-2020 examining maternal and infant predictors of vaccine uptake.	Inform individual and population level interventions to identify families at risk of missing out on routine vaccines.
1.b	Do children whose mothers are not vaccinated in pregnancy have a higher risk of being vaccinated late or missing vaccines before 5 years old in the UK?	First study to examine the association between pregnancy vaccine uptake and childhood vaccine uptake in a UK birth cohort of mother-baby linked pairs	Inform antenatal interventions to improve maternal and child vaccine uptake.
2.a	Why do parents and families think some children are vaccinated late or miss out on routine vaccines?	Need for more primary research among different ethnicity and more deprived communities to understand low vaccine uptake, including access and confidence.	Inform targeted interventions to increase vaccine uptake using participatory research principles.
2.b	How has the COVID-19 pandemic influenced parents' attitudes towards and experiences of accessing routine childhood vaccines?	Lack of research examining how the pandemic impacted routine vaccine attitudes among UK parents.	Inform how vaccine communications and services may need to be adapted post pandemic.

Aims, rationale and objectives for thesis

This thesis examines the problem of suboptimal vaccine uptake and associated inequalities, both nationally and in an area of London with historically low vaccine uptake. It focuses specifically on examining the relationship between maternal pertussis vaccine uptake and subsequent childhood MMR vaccine uptake, as it was unknown whether those women who were vaccinated in pregnancy were more likely to get their children vaccinated in the UK – despite predictive factors for both being similar.¹⁸ It also explores parents' perspectives about the reasons why some children aren't vaccinated. It focuses particularly on parents whose children are less likely to be vaccinated, such as those from ethnic minority groups or living in poorer neighbourhoods whose voices have not been represented previously in vaccine uptake research.¹⁰⁰ It also explores the impact of the pandemic on parents' routine vaccine attitudes, as while the effect of COVID-19 on uptake figures has been well described,¹³ there is a lack of research in the UK about the impact of the pandemic on parental attitudes to routine childhood vaccinations.

Aim

By: i) examining the maternal drivers of missed or late childhood vaccine uptake in a large representative UK birth cohort study and ii) exploring parental perspectives on childhood vaccines, I aim to identify opportunities to improve vaccine services to increase vaccine uptake and reduce inequalities, which have only been further exacerbated by the COVID-19 pandemic.¹³

Rationale

Using a mixed methods approach this thesis aims to inform how local and national vaccination policies and services can increase childhood vaccine uptake, reduce inequalities and protect the wider population. Declining vaccine uptake rates as well as increased outbreaks of vaccine preventable diseases in the UK means increasing vaccine uptake is an urgent national priority - a National Vaccine Strategy was published in December 2023.¹³⁰

In the first study utilising routine general practice data from the UK, the demographic characteristics associated with MMR vaccine uptake between 2000-2020 will be examined. This will enable a description of which children in a large twenty-year birth cohort are at increased risk of missing out on their MMR vaccines. Additionally given the already known association between maternal characteristics and children's vaccination, for the first time in a UK birth cohort study, the relationship between how maternal and childhood vaccination are related will be examined using mother-baby linked pairs. This life course approach to vaccination¹³¹ - which considers maternal and childhood vaccination together - is an important step in vaccine studies using routine data. Maternal and childhood vaccination have tended to

be seen as separate programmes, but with more pregnancy vaccines being added to the schedule, to protect newborn infants, it is important for interventions to aim to increase both maternal and childhood vaccination.

The second study in the thesis will use participatory research methods, which have been missing from previous vaccine uptake studies, to investigate why some children miss out on their routine vaccines. The perspectives of previously unheard parental voices – namely of those from ethnic minority communities living in an area with historically low vaccine uptake – will be considered. Using these participatory methods will also enable the impact of the pandemic on parents' attitudes to childhood vaccines to be explored for the first time in a research study in the UK.

Objectives

(note objectives 1 and 2 relate to the first study (birth-cohort study) and objective 3 and 4 the second study (co-production research)

1. Estimate the proportion of children born between 2000-2020 with missed or late MMR vaccination before 5 years old and describe associated child and maternal socio-demographic characteristics.
2. Estimate the risk of missed or late vaccination in children under 5 years old between 2013-2020 whose mothers did not receive pertussis vaccine in pregnancy.
3. Explore parents' attitudes and experiences of accessing routine childhood vaccines due before age 5 years.
4. Explore how the COVID-19 pandemic has impacted parents' attitudes towards and experiences of routine childhood vaccines due before age 5 years.

CHAPTER 2: STUDY 1:

What are the characteristics of children at risk of missing out on routine vaccines or being vaccinated late before age 5 years in the UK?

Do children whose mothers are not vaccinated in pregnancy have a higher risk of being vaccinated late or missing vaccines before 5 years old in the UK?

METHODS

2.1 Publication

The published version of this study is available from Vaccine¹³² and is also appended in Appendix 39.

Skirrow H, Foley K, Bedford H, Lewis C, Whittaker E, Costelloe C, Saxena S. *Impact of pregnancy vaccine uptake and socio-demographic determinants on subsequent childhood Measles, Mumps and Rubella vaccine uptake: a UK birth cohort study.* Vaccine. 2024 Jan 12;42(2):322-31. <https://doi.org/10.1016/j.vaccine.2023.11.063>

2.2 Ethical approval

This study uses routine general practice data from the Clinical Practice Research Datalink (CPRD). CPRD has ethics approval from the Health Research Authority (HRA) for anonymised CPRD data to be used for public health research.¹³³ Access to CPRD data requires approval via a Research Data Governance process (formally known as the Independent Scientific Advisory Committee, prior to 1 June 2021).¹³⁴ I obtained ethical and scientific approval for the use of CPRD for this study from the Independent Scientific Advisory Committee (ISAC), Protocol number: 20_010 in 2020.¹³⁵

2.3 Data source – the Clinical Practice Research Datalink (CPRD)

CPRD is a primary care research database with, at the time data was extracted for this thesis, 952 contributing UK general practices.¹³⁶ The CPRD GOLD database has been validated as nationally representative of the UK population for age, sex and ethnicity,¹³⁷ though there are some limitations such as geographical spread. For example the North-East of England has been traditionally underrepresented in CPRD GOLD.¹³⁷ The database contains anonymised data from GP practices using the patient record system called 'VISION.'¹³⁸ This study used the CPRD GOLD database, as opposed to the newer CPRD AURUM database, that collects patient records from GP practices using the EMIS patient record system.¹³⁹ The ISAC protocol for this study was submitted in 2019, prior to the pandemic, and while AURUM has had better coverage of England in more recent years, when the protocol was developed, AURUM was still a relatively new database so GOLD was used. This is also justified due to the retrospective nature of this study dating back to 2000 and GOLD coverage has only been decreasing more recently.

CPRD as a database includes all primary care contacts for patients registered at CPRD participating practices, which are recorded in the patient's electronic medical records, though individual patients at CPRD practices can choose to opt out of contributing their data to CPRD. Clinical staff use Read codes to record diagnoses, prescriptions and procedures, including vaccinations into patients' electronic health records. Read codes are a clinical classification system with over 90,000 codes covering clinical symptoms and signs, diagnoses, referrals, investigations and treatments.¹⁴⁰ CPRD has been used previously to study vaccine uptake in the UK, and for evaluating effectiveness of new vaccine programmes.^{23 35 141} Any information that is added to the clinical record by staff as a 'freetext' observation is not available to

researchers – only data that are assigned a code or in the case of some observations such as weight, height or blood pressure, a numerical value. The format of the database means that as a researcher you receive ten different ‘files’ each containing different data on different elements of the patient’s record: i) Patient, ii) Practice, iii) Staff, iv) Consultation, v) Clinical, vi) Additional Clinical, vii) Referral, viii) Immunisation, ix) Test, x) Therapy. These files can then be merged using either the unique patient identifier variable or in the case of the Consultation file the unique consultation id.^{136 137}

2.4 Data linkage – the Mother-Baby Link

This retrospective birth cohort study also used the CPRD Mother-Baby link available from CPRD to create the cohort. The Mother-Baby (MBL) link in CPRD enables researchers to study mother-baby linked dyads and study the relationship between maternal and child health. CPRD uses a validated process to identify mother and baby linked pairs which are then made available to researchers. Only live births born since 1987 are included.¹⁴² The steps in this process are outlined in figure 1. A researcher receives three main datasets when using the MBL data linkage process:

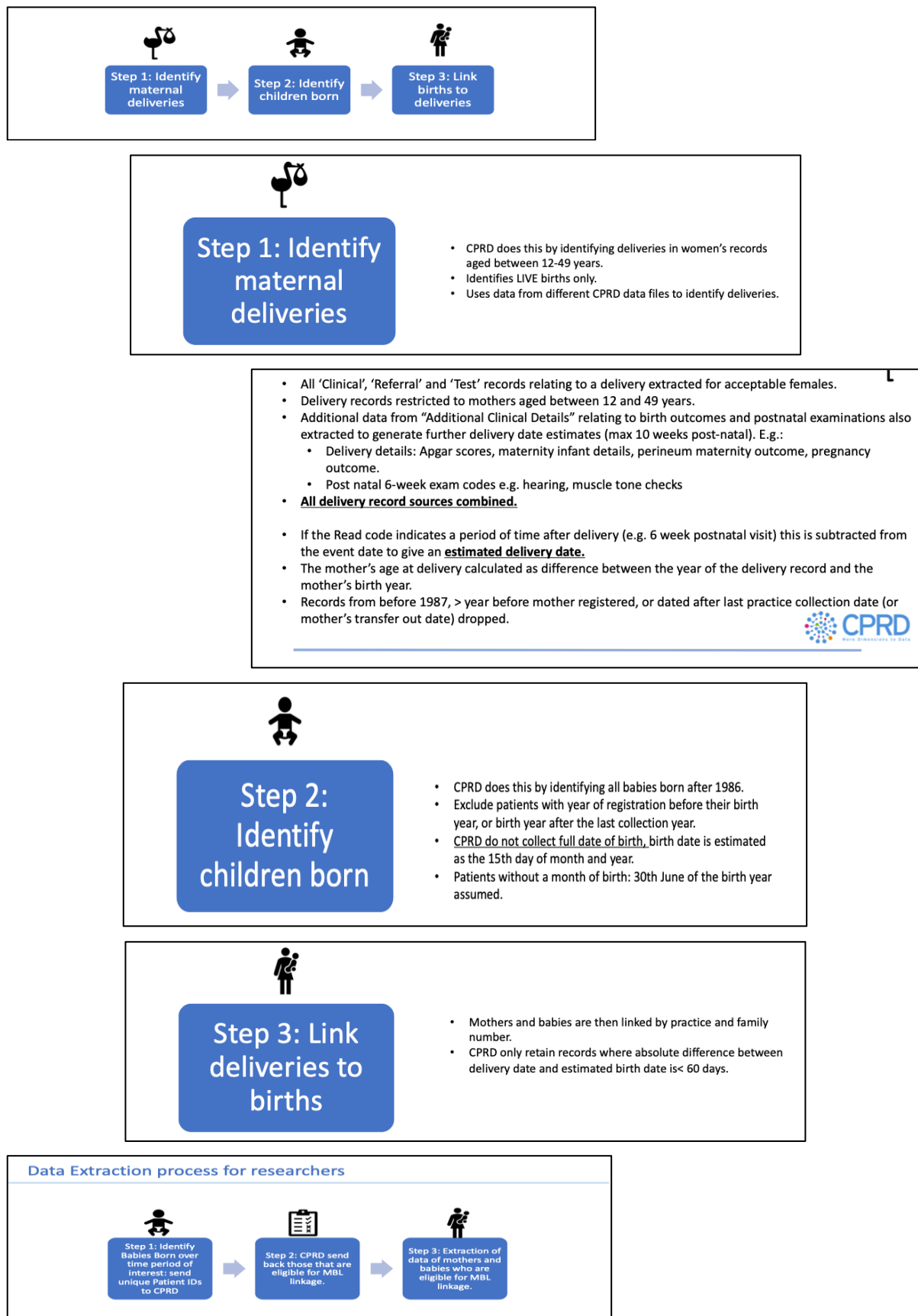
- *The ‘mother and baby link’ file* (which contains the practice ID which both mother and baby are registered, the mother’s unique patient id, the baby’s unique patient id, the assumed delivery date of the baby, mother’s birth year, baby’s birth year, child’s gender and the number of children linked to that specific mother in CPRD).
- *The ‘baby’ files* (separate files covering clinical, test, therapy, immunisation etc)
- *The ‘mother’ files* (separate files covering clinical, test, therapy, immunisation etc).

2.5 Data linkage – the Indices of Multiple Deprivation

Data linkage was also requested for the babies in the cohort ‘Indices of Multiple Deprivation (IMD)’.¹⁴³ IMD in the UK is used as a relative measure of deprivation and combines several separate indicators across seven different variables: *Income, Employment, Health and disability, Education, Skills and training, Housing and Services, Living environment and Crime*. These indicators are combined to create an overall, weighted, deprivation score for every Lower Layer Super Output Area (LSOA) in England. This does not directly relate to children but to the adults living in these small areas. There are several versions of IMD score which range from 2000 onwards - with 2019 used for this study. IMD data are available for the English population only, though even for the English babies IMD data was not available to be linked for 120,729 (23.2%)¹ of the babies in the cohort, which was a significant limitation of the data. For each baby with IMD linkage I received a file with an assigned IMD score based on their geographical location (though not their actual postcode which is unavailable for researchers).

¹ This was double checked by the Imperial CPRD fob holder who extracted the data from CPRD, including the linked IMD data.

Figure 1: The CPRD Methodology used to generate the Mother-Baby Link



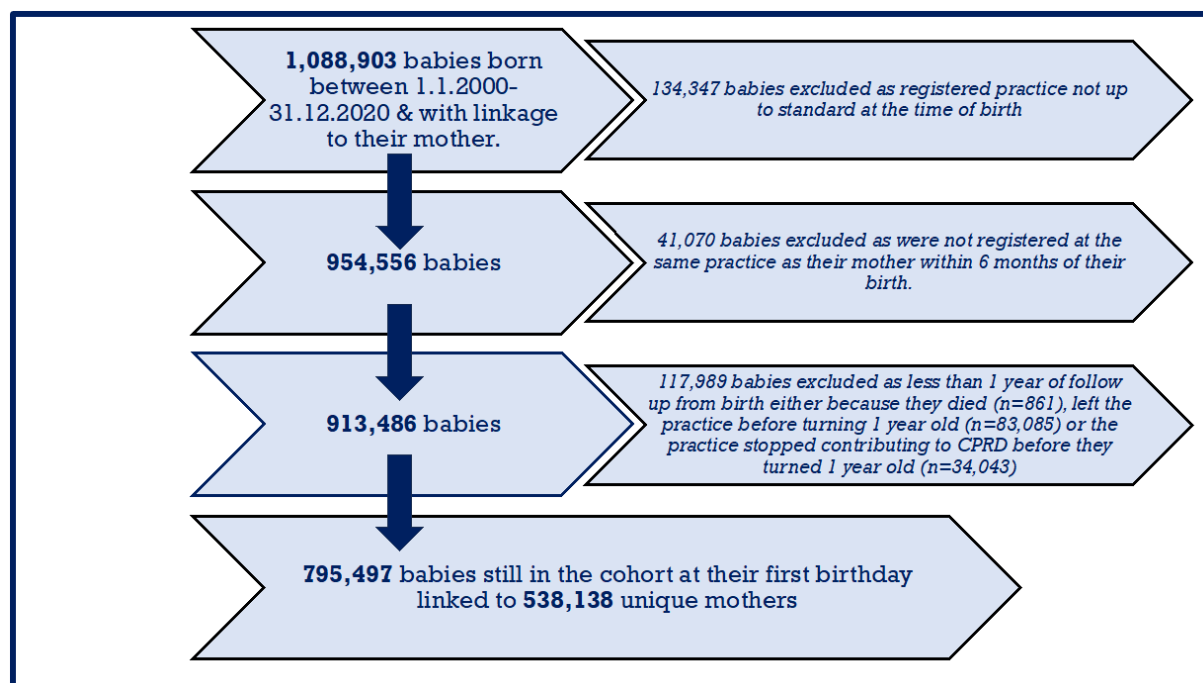
2.6 Cohort construction

To create the birth cohort the CPRD GOLD March 2021 release was used.¹³⁶ This CPRD release contained a total of 19,723,490 research acceptable patients of all ages (including transferred out or deceased patients), from a total of 952 practices (both current and historic).¹³⁶ There were 1,088, 903 children identified from this March 2021 release who were born between January 1, 2000, and December 31, 2020 and who were able to be linked to their mother via the CPRD mother-baby link (figure 2). The child's date of birth was derived from the estimated date of delivery provided in the CPRD mother-baby link.¹⁴² Only children registered at an 'up to standard' CPRD-participating practice at birth and registered within 6 months of their birth were included. 'Up to standard' is where a GP practice is deemed to have continuous high-quality data that is fit for use in research. This 'up to standard' indicator is based on analysing the total data in the practice in terms of 'continuity of recording' and minimising data usage of patients who have either died or left the practice.¹³⁷ The 'up to standard' indicator is refreshed every time a new collection for a practice is processed into CPRD.¹³⁶ Children with less than one year of follow up were excluded as they were not eligible for their first MMR vaccine until one year of age. Children were followed up from birth until the end of the study period (December 31, 2020), or to the date they left the practice (deregistered), or died or the practice stopped collecting data, whichever came first.

We created a sub-cohort of children who were still in the cohort when they became eligible for their second MMR vaccine at age 3 years, 4 months (n=557,050) and another sub-cohort of children who were born after 2013 (n=207,531) for the analysis of maternal

pertussis vaccine uptake. Children were then also linked to the Indices of Multiple Deprivation (IMD).¹⁴³

Figure 2: Cohort Construction



Children born between January 2000 and December 2020, with a link to their mother and registered at CPRD Gold participating practices. *Children leave the cohort at the end of the study period (31/12/2020). Consequently, children leave the cohort at varying ages. Children may also leave the cohort before the end of the study period if the last practice data collection date was prior to the end of the study period or if they leave their registered practice.*

2.7 Outcomes

The main outcomes for this study were the proportion of children receiving their first MMR vaccine by age 2 years and proportion of children vaccinated with both first and second

MMR vaccines by age 5 years, in line with reported national childhood vaccine coverage statistics of MMR uptake.³ The estimated age of receipt of MMR vaccines could be calculated from the estimated date of delivery in CPRD from the mother-baby link. To determine whether children were vaccinated with MMR vaccines, and when, involved developing code lists and examining data from different CPRD files which will now be outlined.

2.8 Code List Development

To develop Read code lists for MMR vaccines I used a systematic process. First, my main source for the code lists was the full 2021 official vaccine Read code lists used by the Child Health Information Systems (CHIS),² to extract vaccination uptake data from GP records in the UK.¹⁴⁴ Secondly, I then cross checked these codes against published code lists,¹⁴¹ and then used the CPRD code browser¹³⁷ to validate my code lists (appendix 2) and ensure none had been missed.

2.9 Determining vaccination status in CPRD

Vaccination data were taken from the CPRD immunisation, therapy and clinical files with duplicate vaccine events (e.g. on the same day or same child) being removed as data from these different files were merged. The immunisation file also includes several different types of data relating to the type of immunisation event in addition to the unique corresponding Read code (appendix 2). For example, there is a 'status' variable that can be 'given' or 'refused'. Infants or children under 5 with a code for 'MMR vaccine refusal' or

² From personal correspondence with a senior CHIS commissioner in NHS England, London region, January 2021

‘vaccine refused’ they were not classified as being vaccinated, even if there was MMR vaccine code for a vaccine event on the same day. Additionally there is a ‘compound’ variable and in this study if the corresponding Read code was for a mumps or rubella vaccine code, but the immunisation ‘compound’ was MMR then the vaccine event was considered to be an MMR vaccine event, consistent with previous studies.¹⁴¹ If a baby had individual measles, mumps and rubella coded vaccine events on the same day they were determined to have had an MMR vaccination. Other data from the immunisation file about the type of immunisation was not considered relevant to the study such as the location where the vaccine was administered and the route of administration.

2.10 Covariates

I examined the relationship between several covariates reported to be associated with childhood vaccine uptake from previous studies including ethnicity,¹⁴ deprivation⁶⁹, birth order⁵⁶ and maternal age,⁵⁶ as discussed in the introduction. I assigned each child in England to one of five deprivation groups using English IMD quintiles, (5 the most deprived, 1 the least deprived).¹⁴³ However, data on IMD was only available for children in England so multivariable analysis including deprivation was conducted for England only children.

I identified mothers with only one child linked to their record as a proxy of being first or only children. Twin or multiple births were not looked at as a separate variable. A study of pregnancies in CPRD found that <1% of deliveries identified were multiple births¹⁴⁵ and a recent German study reported that twins were similarly vaccinated for all vaccines apart from influenza and RSV.¹⁴⁶ Therefore, adjusting for multiple births is unlikely to have altered the findings of this study of MMR vaccination uptake. I used maternal age at birth of the child to

assign children to maternal age groups: under <20 years, 21-30 years, 31-40 years and 41 years or older. Children's ethnicity was determined using code lists developed from previous ethnicity studies.¹⁴⁷ Each child was assigned to one of the higher-level classification ethnicity groups: 'Asian', 'Black', 'Mixed', 'White', 'Other' and 'Unknown'.¹⁴⁸ If the child's record was missing any record of ethnicity then an ethnicity code from the mother's record was used. If a baby was missing data on deprivation or ethnicity they were allocated to an unknown category. I also used the region of CPRD practice to assign the child's UK nation of residence.

2.11 Calculating childhood MMR vaccine uptake

I estimated MMR vaccine uptake in the cohort by calculating the number of children who had one MMR vaccine dose by age 2 years and 5 years. I estimated second dose uptake from the number of children who were still in the cohort by age 3 years 4 months and therefore eligible for their second dose and calculating the number who had two doses of MMR vaccines recorded. I then calculated first and second dose MMR uptake by different socio-demographic groups based on deprivation, ethnicity, maternal age, birth order or family size and nation by the same ages – age 2 and 5 years for first dose and by 5 years for second dose.

2.12 Calculating maternal pertussis uptake

Maternal vaccination was determined from the immunisation, clinical and therapy files using codes to indicate a pertussis vaccine had been given to a mother, including pertussis vaccine booster codes and specific codes for pertussis vaccine in pregnancy (appendix 2). For a mother to be considered vaccinated during pregnancy the code for the

vaccination event had to have been recorded within the 1 year prior to the baby's estimated date of delivery.

2.13 Examining socio-demographic determinants of MMR Vaccine uptake

I plotted inverse Kaplan-Meier survival curves for each predictor variable (deprivation quintile, ethnicity, maternal age, birth order and UK nation of baby's residence) to compare uptake among different socio-demographic determinant groups. Children were censored before 5 years, if they died, left their practice or the practice stopped contributing to CPRD. I checked whether the predictors met the proportional hazard assumptions using Kaplan-Meier survival curves.

I then used Cox proportional hazard models to estimate hazard ratios (HR) for MMR first dose vaccination by 2 and 5 years of age and second dose MMR vaccination by 5 years of age for predictors that met assumptions. I first carried out univariate analysis followed by multivariable analyses adjusting for deprivation, maternal age, and ethnicity. Covariates were included in the adjusted multi-variable model if they were associated in the univariate analysis. I considered an association of $p < 0.05$ as statistically significant. I used Stata version 17 (Stata Corp, College Station, Texas, USA) for the analyses.

2.14 Sensitivity Analyses

I performed sensitivity analyses to understand how associations with socio-demographic determinants might be affected by missing data. I examined the association of

socio-demographic determinants among children without known deprivation and then without recorded ethnicity.

CHAPTER 3: STUDY 1:

What are the characteristics of children at risk of missing out on routine vaccines or being vaccinated late before age 5 years in the UK?

Do children whose mothers are not vaccinated in pregnancy have a higher risk of being vaccinated late or missing vaccines before 5 years old in the UK?

RESULTS

3.1 Publication

The published version of this study is available from Vaccine¹³² and is also appended in Appendix 39.

Skirrow H, Foley K, Bedford H, Lewis C, Whittaker E, Costelloe C, Saxena S. *Impact of pregnancy vaccine uptake and socio-demographic determinants on subsequent childhood Measles, Mumps and Rubella vaccine uptake: a UK birth cohort study.* Vaccine. 2024 Jan 12;42(2):322-31. <https://doi.org/10.1016/j.vaccine.2023.11.063>

3.2 Cohort demographics

The study cohort included 795,497 children who were born and registered with CPRD practices between January 2000 and December 2020, with records linked to their mothers. At 3 years 4 months of age—when the second dose of the MMR vaccine is due according to the current UK schedule—there were 557,050 children remaining in the cohort. By the time children reached 5 years of age, this number had decreased to 446,476. Table 2 summarises the key characteristics of the cohort. The largest ethnic category consisted of children with unknown ethnicity (329,215 out of 705,497; 41.38%), followed by children with White ethnicity (279,574 out of 795,497; 35.14%). Additionally, 6% of the cohort (47,993 out of 795,497) were born to mothers aged 20 years or younger. Most of the cohort were children

whose mothers had just one child matched to them (330,038, 41.5%) or were one of two children matched to the same mother (323,998, 40.7%).

The cohort was mostly from England (n=520,874, 65.5%) though among English children, a higher proportion lived in the least deprived areas (18%; 92,532 out of 520,874) compared to those living in the most deprived areas (14%; 73,595 out of 520,874-table 2). Information on deprivation status was missing for 23% (120,729 out of 520,874) of English children. More than half of the children (435,776 out of 795,497; 54.79%) were born in or before 2009, while 88% (699,957 out of 795,497) were born before 2015 (appendix 3).

Table 2: Characteristics of the Birth Cohort

Characteristic	Number (%)
Children	795,497^a
Boys	407,840 (51.3)
Deprivation^b	
<i>Quintile 1 (least deprived)</i>	92,532 (17.8)
<i>Quintile 2</i>	80,236 (15.4)
<i>Quintile 3</i>	78,819 (15.1)
<i>Quintile 4</i>	74,936 (14.4)
<i>Quintile 5 (most deprived)</i>	73,595 (14.1)
<i>Unknown</i>	120,729 (23.2)
Ethnicity	
<i>White</i>	279,574 (35.1)
<i>Mixed</i>	138,269 (17.4)
<i>Asian or British Asian</i>	27,985 (3.5)
<i>Black or Black British</i>	13,816 (1.7)
<i>Other Ethnic Group</i>	6,538 (0.8)
<i>Unknown</i>	329,215 (41.4)
Maternal age at birth of child (years)	
<i>≤20</i>	47,993 (6.0)
<i>21–30</i>	355,663 (44.7)
<i>31–40</i>	368,438 (46.3)
<i>41+</i>	23,403 (2.9)
Family size/number children matched to mother	
<i>First or only children</i>	330,038 (41.5)
<i>Two children</i>	323,998 (40.7)
<i>Three or more children</i>	141,461 (17.8)
Country	
<i>England</i>	520,874 (65.5)
<i>Scotland</i>	139,277 (17.5)
<i>Wales</i>	90,139 (11.3)
<i>Northern Island</i>	45,207 (5.7)

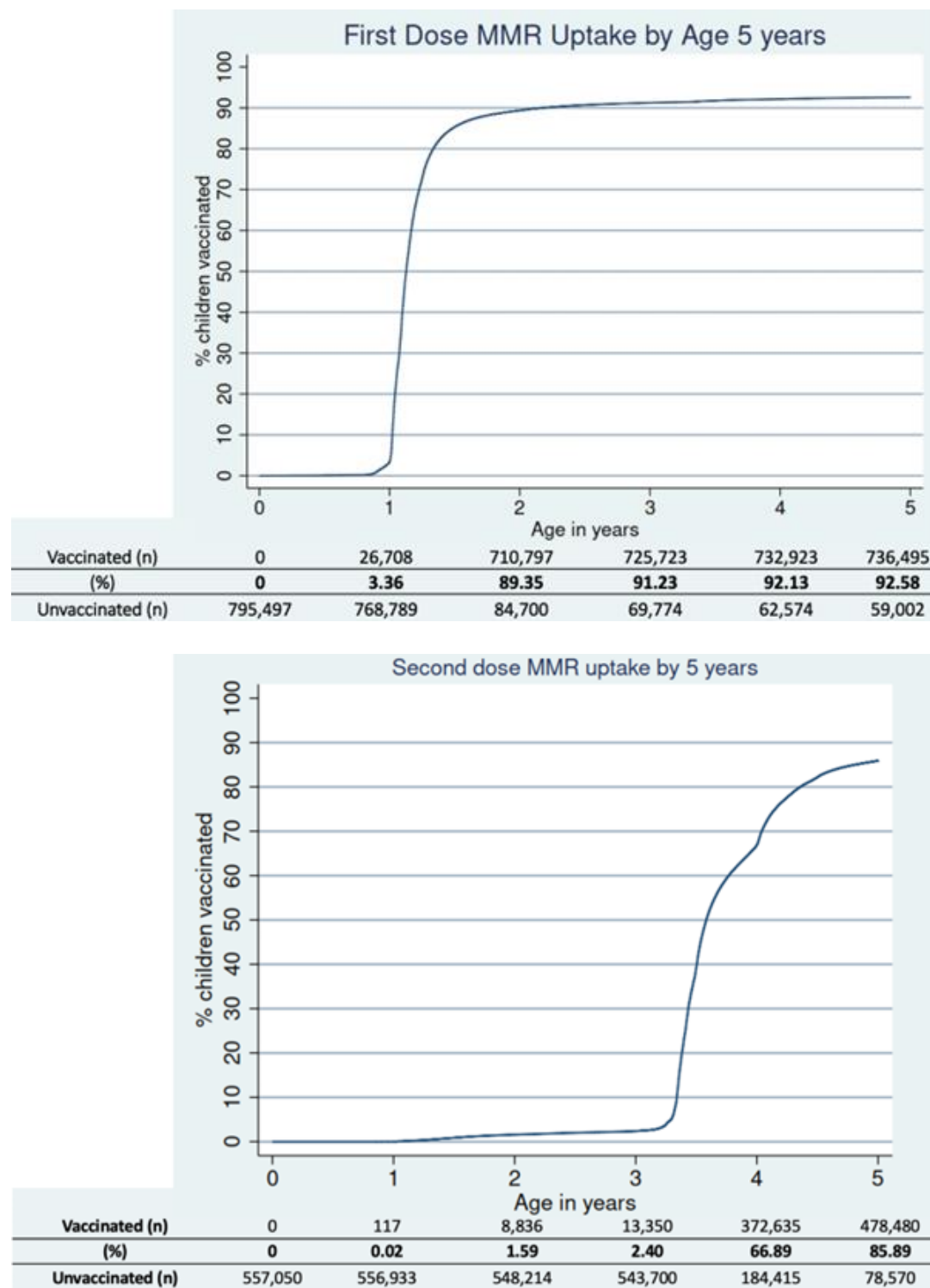
^a Born between 01/01/2000 and 31/12/2020 registered to UK Clinical Practice Research Datalink practices.

^{b*} IMD data only available for English children (n=520,874). Index of multiple deprivation quintiles (5 the most deprived, 1 least deprived)

3.3 MMR vaccine uptake

In the cohort, 89.4% of children (710,797 out of 795,497) received their first dose of the MMR vaccine by the age of 2, increasing to 92.6% (736,495 out of 795,497) by the age of 5 (figure 3). The median age for receiving the first dose was 13.3 months (equivalent to 1 year and 1 month). For the second dose, uptake was 85.9% (478,480 out of 557,050) among children who remained in the cohort at 3 years and 4 months, the age at which they became eligible (figure 3). The median age for receiving the second dose was 42.2 months (or 3 years and 6 months).

Figure 3: First and Second Dose MMR Vaccine Uptake by 5 years of Age



- i. First Dose MMR Vaccine uptake over the cohort shown by inverse Kaplan–Meier curve. ($n = 795,497$).
- ii. Second Dose MMR Vaccine uptake over the cohort shown by inverse Kaplan–Meier curve. ($n = 557,050$).

3.4. MMR vaccine uptake by socio-demographic determinants

Deprivation

Uptake of first dose MMR at 2 years was lowest (85.5%) in the most deprived areas of England compared with 91.1% uptake in the least deprived areas (table 3). Similarly, at 5 years of age, lowest uptake was for first dose (90.1%) and second dose (81.5%) of MMR vaccine in the most deprived areas compared to 93.9% (first dose) and 88.0% (second dose) in the least deprived areas (tables 3 & 4 & appendix 4). After the most deprived areas the children with lowest uptake were those with unknown deprivation who had first dose MMR uptake at 2 years and 5 years of 87.6% and 90.6% compared to 91.1% and 93.9% in the least deprived areas. For second dose MMR vaccine uptake among children with unknown deprivation was 82.7% by age 5 years compared to 88.0% in the least deprived areas (tables 3 & 4 & appendix 4).

Ethnicity

Children of Black or Black-British ethnicity had lowest MMR vaccine uptake for their first dose of MMR vaccine by 2 and 5 years and their second dose by 5 years (84.1% vaccinated with first dose by age 2 years, 87.7% vaccinated by age 5 years & 79.7% vaccinated with two doses by age 5 years) compared to 90.7%, 93.7% and 87.5% uptake among White ethnicity children at 2 years, 5 years (first dose) and 5 years (second dose) respectively, (tables 2 & 3 & appendix 5). Children recorded as 'Other ethnicity group' had the second lowest uptake with 86.5% having their first dose by age 2 years and 88.2% by 5 years compared to 90.7% and 93.7% among children of White ethnicity. Only 83.7% children in the

‘Other ethnicity group’ had two doses of MMR by age 5 years compared to 87.5% of White ethnicity children, (tables 2 & 3 & appendix 5).

Table 3: MMR 1st dose vaccine uptake by age 2 & 5 years for all children and adjusted by socio-demographic group for England only children

	Uptake first dose MMR by age 2 years					Uptake first dose MMR by age 5 years				
	n (%)	HR	95% CI	HR*	95% CI	n (%)	HR	95% CI	HR*	95% CI
All Children*	710,797 (89.4)					736,495 (92.6)				
Deprivation**										
<i>Quintile 1</i>	84,324 (91.1)					86,895 (93.9)				
<i>Quintile 2</i>	72,452 (90.3)	0.99	0.98-1.00	0.99	0.98-1.00	74,731 (93.1)	0.99	0.98-0.99	0.98	0.98-0.99
<i>Quintile 3</i>	69,980 (88.8)	0.95	0.94-0.96	0.94	0.93-0.95	72,466 (91.9)	0.95	0.94-0.95	0.94	0.93-0.95
<i>Quintile 4</i>	65,835 (87.8)	0.93	0.92-0.94	0.93	0.92-0.94	68,481 (91.4)	0.93	0.92-0.94	0.93	0.92-0.94
<i>Quintile 5 (most deprived)</i>	62,908 (85.5)	0.85	0.84-0.86	0.85	0.84-0.86	66,269 (90.1)	0.86	0.85-0.87	0.86	0.85-0.87
<i>Unknown</i>	105,752 (87.6)	0.95	0.94-0.96	0.95	0.94-0.96	109,385 (90.6)	0.94	0.94-0.95	0.94	0.93-0.95
Ethnicity*										
<i>White</i>	253,656 (90.7)					262,051 (93.7)				
<i>Mixed</i>	126,346 (91.4)	0.99	0.98-0.99	1.03	1.02-1.03	130,223 (94.2)	0.99	0.98-0.99	1.03	1.02-1.04
<i>Asian or British Asian</i>	16,062 (90.3)	1.01	0.99-1.02	1.08	1.06-1.09	25,880 (92.5)	0.99	0.98-1.00	1.07	1.05-1.08
<i>Black or Black British</i>	11,615 (84.1)	0.80	0.79-0.82	0.87	0.85-0.89	12,117 (87.7)	0.79	0.78-0.81	0.87	0.85-0.88
<i>Other Ethnic Group</i>	5,742 (86.5)	0.95	0.92-0.97	1.01	0.98-1.04	5,854 (88.2)	0.92	0.89-0.94	0.98	0.95-1.01
<i>Unknown</i>	288,182 (87.5)					300,375 (91.2)				
Maternal age (years)*										
<i>≤20</i>	41,115 (85.8)	0.84	0.83-0.85	0.88	0.87-0.89	43,400 (90.4)	0.85	0.85-0.86	0.89	0.88-0.90
<i>21–30</i>	316,537 (88.9)	0.98	0.98-0.99	1.00	0.99-1.00	328,260 (92.2)	0.98	0.98-0.99	0.99	0.99-1.00
<i>31-40</i>	332,387 (90.2)	-	-	-		343,280 (93.2)	-	-	-	-
<i>41+</i>	20,718 (88.5)	0.95	0.94-0.97	0.94	0.92-0.96	21,555 (92.1)	0.96	0.94-0.97	0.94	0.93-0.96

Proportion of children vaccinated by socio-demographic determinant and univariate and multivariable Cox regression analyses. HR=Hazard Ratios are of first dose MMR uptake by age 2 and 5 years HR*=Adjusted hazard ratios. *795,497 **Only English children n=520,874. Reference categories: Quintile 1 (least deprived), White Ethnicity, Mothers aged 31-40 years.

Table 4: MMR 2nd dose vaccine uptake by age 5 years for all children and adjusted by socio-demographic group for England only children

	Uptake second dose MMR by age 5 years				
	n (%)	Hazard Ratio	95% CI	Hazard Ratio Adjusted*	95% CI
All Children*	478,480 (85.9) *				
Deprivation**					
<i>Quintile 1</i>	58,947 (88.0)				
<i>Quintile 2</i>	48,146 (86.9)	0.96	0.95-0.97	0.96	0.94-0.97
<i>Quintile 3</i>	44,965 (85.4)	0.91	0.90-0.92	0.90	0.89-0.92
<i>Quintile 4</i>	41,098 (84.4)	0.91	0.90-0.93	0.90	0.89-0.91
<i>Quintile 5 (most deprived)</i>	38,345 (81.5)	0.84	0.82-0.85	0.82	0.81-0.83
<i>Unknown</i>	65,678 (82.7)				
Ethnicity*					
<i>White</i>	173,816 (87.5)				
<i>Mixed</i>	86,520 (88.7)	1.08	1.07-1.08	1.09	1.08-1.10
<i>Asian or British Asian</i>	15,134 (86.1)	0.99	0.98-1.01	1.08	1.06-1.10
<i>Black or Black British</i>	6,400 (79.7)	0.84	0.82-0.86	0.93	0.90-0.95
<i>Other Ethnic Group</i>	3,066 (81.6)	0.91	0.88-0.95	0.98	0.94-1.02
<i>Unknown</i>	193,544 (83.7)				
Maternal age at birth of child (years)*					
<i>≤20</i>	27,043 (83.2)	0.88	0.86-0.89	0.92	0.90-0.93
<i>21–30</i>	209,072 (85.7)	0.98	0.98-0.99	1.00	0.99-1.01
<i>31-40</i>	228,123 (86.5)				
<i>41+</i>	14,242 (84.3)	0.97	0.95-0.99	0.94	0.92-0.96

*n=557,050. Univariate and multivariable Cox regression analyses for Hazard Ratios of second dose MMR uptake by age 5 years.

**Only English children n=297,179. Reference categories: Quintile 1 (least deprived), White Ethnicity, Mothers aged 31-40 years.

Maternal age

Children born to mothers aged 20 years or younger had a lower uptake of the first dose of MMR vaccine uptake at 2 and 5 years compared with mothers aged 31-40 years (85.8% by 2 years & 90.4% by 5 years compared with 90.2% by 2 years and 93.2% by 5 years respectively) (tables 3&4 & appendix 6). Uptake of the second dose of MMR vaccine at 5 years among children of mothers aged 20 years or younger was 83.2% compared with 86.5% uptake for children of mothers aged 31-40 years (tables 3&4 & appendix 6).

Family size

Children born to mothers with only one child linked to them in the birth cohort had lower first MMR vaccine uptake by 5 years (89.6%) compared with children born to mothers with either two (94.9%) or three or more children (93.7%) (appendix 7). For second dose of MMR vaccine uptake by age 5 years, children who were born to mothers with only one child linked to them had uptake of 82.9% compared to 88.2% uptake among those with two or more children or 85.5% uptake among those with three or more children (appendix 7).

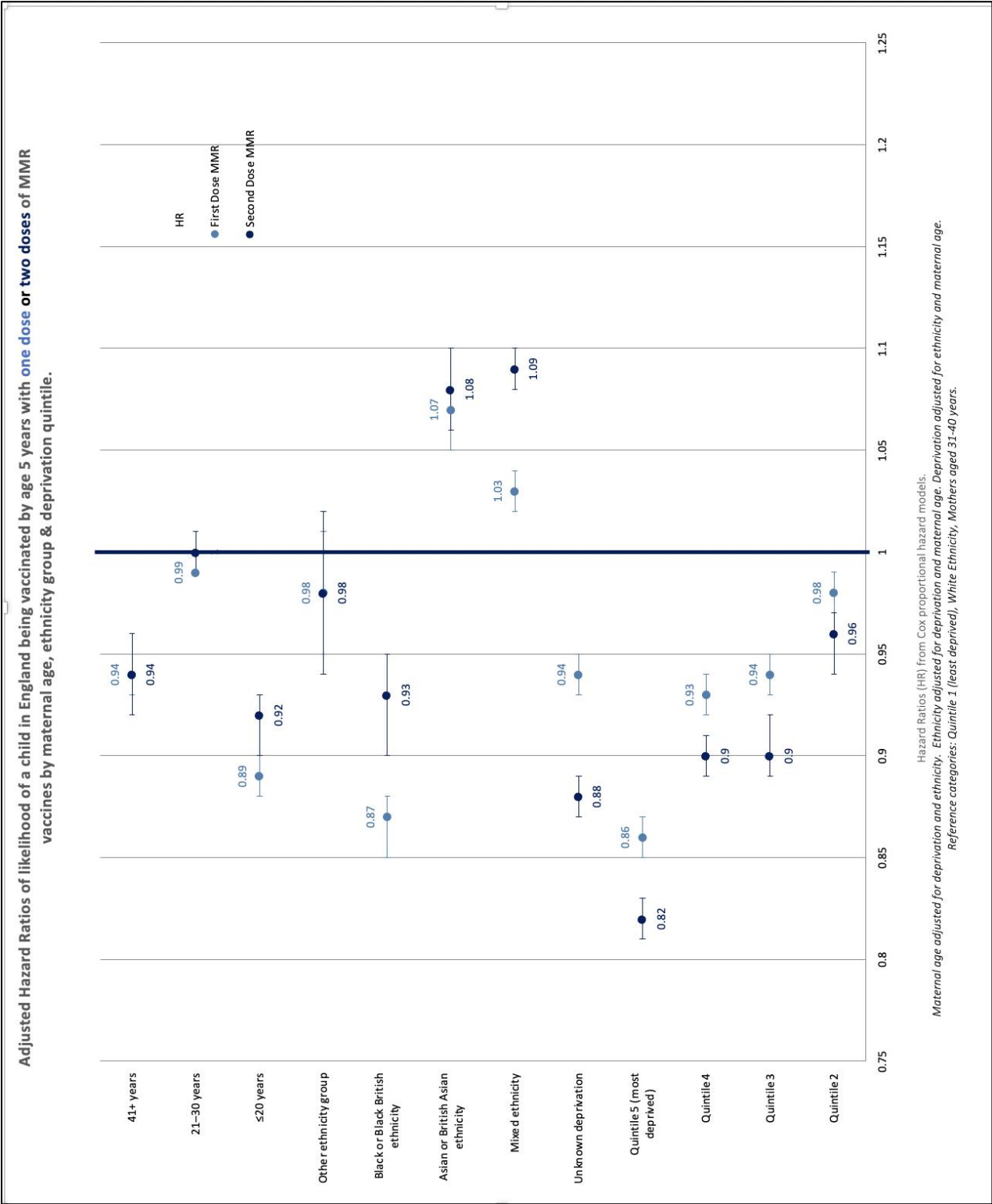
UK nation

Uptake in England was lower than in other UK nations with first dose MMR uptake by 5 years 91.8%, compared with 95.4% in Northern Ireland (appendix 8). For second dose MMR uptake in England was 84.6%, compared again to the highest uptake in Northern Ireland of (91.2%) (appendix 8).

3.5 Univariate and multivariable effects of deprivation, ethnicity and maternal age on MMR vaccine uptake

Babies living in the most deprived areas of England were less likely to have their MMR vaccines compared to children living in the least deprived areas in both the univariate and multivariable adjusted models. In the adjusted Cox proportional hazard model, English children born in the most deprived areas were less likely to have their first MMR vaccine by age 2 years and 5 years (adjusting for ethnicity and maternal age): first dose MMR uptake by 2 years adjusted hazard ratio (HR) 0.85, (95% CI:0.84-0.87) & first dose MMR uptake by 5 years adjusted hazard ratio (HR) 0.86 (95% CI:0.85-0.87) (table 3, figure 4). This association was strongest for second MMR vaccine dose by age 5 years with children born in the most deprived areas least likely to be vaccinated (adjusted HR 0.82 (95%CI: 0.81-0.83) compared with children born in the least deprived areas (table 4, figure 4).

Figure 4: Likelihood of a child in England being vaccinated by age 5 years with one dose or two doses of MMR vaccines by socio-demographic group



Adjusted Hazard Ratios of likelihood of a child in England being vaccinated by age 5 years with one dose or two doses of MMR vaccines by maternal age, ethnicity group & deprivation quintile.

In the Cox proportional hazard model English children of Black or Black-British ethnicity were less likely to be vaccinated with MMR vaccines compared with children of White ethnicity, though the strength of this association was reduced after adjusting for deprivation and maternal age. First dose of MMR vaccine by 2 years of age adjusted hazard ratio (HR) 0.87, 95% CI: 0.85-0.89 and adjusted hazard ratios of first and second dose MMR by age 5 years: HR 0.87, 95% CI: 0.85-0.88 & 0.93, 95% CI: 0.90-0.95 (table 4, figure 4). There were also a higher percentage of children of Black or Black British ethnicity living in the most deprived regions of England (3,985, 32.0%) compared to the percentage of White ethnicity children living in the most deprived areas of England (21,543, 14.8- appendix 9). Hazard ratios of the unknown ethnicity group from the Cox proportional hazard model are not reported as the unknown ethnicity group did not have a proportional relationship with other ethnicity groups (appendix 5).

Children of mothers aged 20 years or younger were also less likely to have MMR vaccines compared to children of mothers aged 31-40 years, first dose MMR adjusted HR by 2 years 0.88, 95% CI: 0.87-0.89 and 5 years 0.89, 95% CI: 0.88-0.90 and second dose MMR adjusted HR by 5 years, 0.94 95%, CI: 0.92-0.96 (table 4, figure 4). There was also a higher percentage of children born to mothers aged under 20 years living in the most deprived areas of England (9,320, 30.5%) compared to the percentage of mothers aged 31-40 years living in the most deprived areas of England (21,817, 8.9%) (appendix 10). Family size and nation were not included in the Cox models as assumptions were not met.

Directions of associations and conclusions of the relationship between first and second dose MMR vaccine uptake and socio-demographic determinants were robust to sensitivity analyses excluding missing data (appendix 11).

3.6 Maternal Pertussis and MMR Uptake

Overall uptake of pertussis vaccine among pregnant women was 61.1% (126,846 mothers of 207,531 children born from 2013 onwards were vaccinated against pertussis in their pregnancies). Among the children born to vaccinated mothers 94.8% (n=120,200) had one dose of MMR vaccine by age 5 years. Uptake was lower among children born to the 80,685 unvaccinated mothers: 87.9% (n=70,961) children had one dose of MMR vaccine by 5 years (Figure 5). Of the mothers of children still in the 2013 cohort when eligible for their second MMR vaccine (n=98,838), 65.6% (n=65,109) were vaccinated against pertussis. Of children born to vaccinated mothers 89.5% had two MMR vaccines by age 5 years (n=58,292). This compares with uptake among children of unvaccinated mothers of 79.4% (n=26,777) for two doses of MMR vaccines by 5 years (figure 5).

In the Cox proportional hazard model of the 2013 cohort, children born in the most deprived areas of England were least likely to be vaccinated with their MMR vaccines by age 5 years (appendix 12). Children in England who were born to mothers vaccinated in pregnancy were more likely to have their first and second dose MMR vaccines by the age of 5 years, HRs: 1.43, 95% CI:1.41-1.45, 1.49, 95% CI:1.45-1.53 after adjusting for Ethnicity, deprivation and maternal age (table 5).

Table 5: MMR uptake by age 5 years by maternal pertussis vaccination status and adjusted by socio-demographic group for England only children

Uptake first dose MMR by age 5 years						Uptake second dose MMR by age 5 years					
Children with mothers vaccinated in pregnancy n (%)	Children with mothers unvaccinated in pregnancy n (%)	HR	95% CI	HR Adjusted*	95% CI	Children with mothers vaccinated in pregnancy n (%)	Children with mothers unvaccinated in pregnancy n (%)	HR	95% CI	HR Adjusted**	95% CI
120,201 (94.8)	70,961 (87.9)	1.38	1.37 - 1.40	1.43	1.41- 1.45	58,292 (89.5)	26,777 (79.4)	1.37	1.35 - 1.39	1.49	1.45 - 1.53

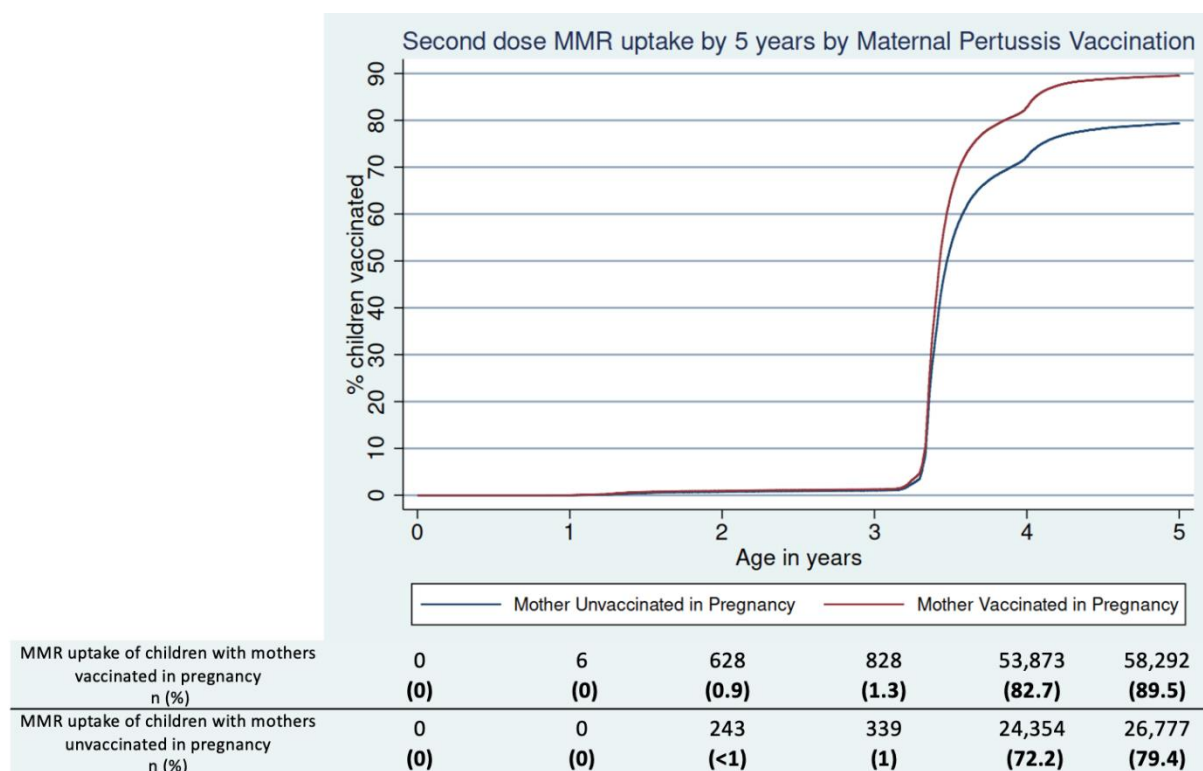
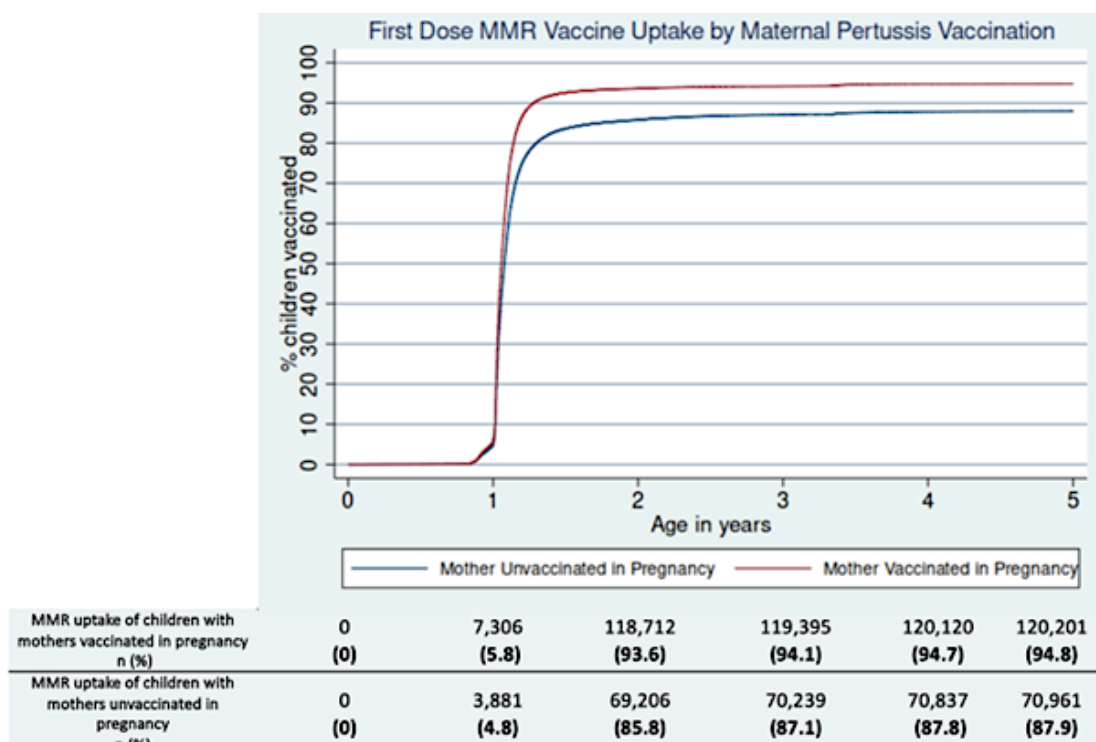
Univariate and multivariable Cox regression analyses for Hazard Ratios of first and second dose MMR uptake by age 5 years by maternal pertussis vaccination status.

Reference category: mothers unvaccinated against pertussis in pregnancy.

*n=96,865 children (only England children in 2013 cohort).

**n= 35,433 (only England children in 2013 cohort & still in cohort when eligible for second MMR)

Figure 5: MMR vaccine uptake by maternal pertussis vaccination



- i. First Dose MMR Vaccine uptake over the 2013 cohort shown by inverse Kaplan–Meier curve. (n=207,531).
- ii. Second Dose MMR Vaccine uptake over the 2013 cohort eligible for second MMR shown by inverse Kaplan–Meier curve. (n=98,838).

3.7 Key findings from study 1

In this retrospective birth cohort study, I found socio-demographic disparities in MMR uptake among children consistent with previous research as outlined in this thesis's introduction. Children residing in deprived areas were found to be over 10% less likely to receive MMR vaccinations compared to their counterparts in less deprived areas. Additionally, children of Black ethnicity and those born to mothers under the age of 20 were at increased risk of being unvaccinated.

Novel to this thesis I found that maternal uptake of pertussis vaccine during pregnancy is a significant predictor of childhood MMR vaccination. Children born to mothers who received vaccinations during pregnancy were 40% more likely to receive MMR vaccines during childhood, even after adjusting for deprivation, ethnicity and maternal age.

CHAPTER 4: STUDIES 2A and 2B:

Why do parents and families think some children are vaccinated late or miss out on routine vaccines?

How has the COVID-19 pandemic influenced parents' attitudes towards and experiences of accessing routine childhood vaccines?

METHODS

4.1 Publication

The published version of this study is available from Vaccine and is also in Appendix 40.

Skirrow H, Lewis C, Haque H, Choudary-Salter L, Foley K, Whittaker E, Costelloe C, Bedford H, Saxena S. 'Why did nobody ask us?': A mixed-methods co-produced study in the United Kingdom exploring why some children are unvaccinated or vaccinated late. Vaccine. 2024 Sep 17;42(22):126172.

4.2 Ethical Approval

Ethics approval was granted on 26th January 2022 by the Imperial College Research Ethics Committee (study reference: 22IC7458).

4.3 Community partners: The Mosaic Community Trust

The Mosaic Community Trust are my public partners and Lena Choudary-Salter, the Chief Executive of The Mosaic Community Trust named the study 'Why has nobody asked us?!'. This name came about as I initially partnered with The Mosaic Community Trust (Mosaic) in pre-doctoral public involvement work into low maternal vaccine uptake in and around Westminster, London.¹⁴⁹ A member of the local authority met with Lena and me following this work to ask how to address historically low childhood vaccine uptake in the

local area. Lena replied, *“Why has nobody asked us?!”* – *why* hadn’t the local community been asked their opinion before about why not enough children are getting vaccinated in North-West London.

Mosaic is a registered charity and women’s community support group. It was founded in 2005 to support the local community in and around Church Street, one of the most deprived areas of Westminster in London.¹⁵⁰ Their mission is to empower diverse, socially and economically marginalised and disadvantaged communities and promote community cohesion and integration.¹⁵⁰ This is achieved through promotion of health and economic wellbeing, community leadership and a rights-based approach to community support. This enables active participation in strategic decision making at the community level and the ability to access mainstream services and economic opportunities. Mosaic has also trained local women to become community outreach workers/advocates who run biweekly drop-in sessions, as well as other initiatives for local community members to provide mental health and wellbeing support. To facilitate their integral role in the community, Mosaic has also built strong partnerships with local service providers and other voluntary sector organisations. These partnerships enable women to be directed from Mosaic to other support services as well as the ability for local women to be referred by third parties directly to Mosaic sessions. These strong stakeholder relationships enable Mosaic to act as advocates for the local ethnic minority community.

4.4 Co-production methods

The National Institute for Health Research (NIHR) sets out the five key principles of co-production,¹⁵¹ namely:

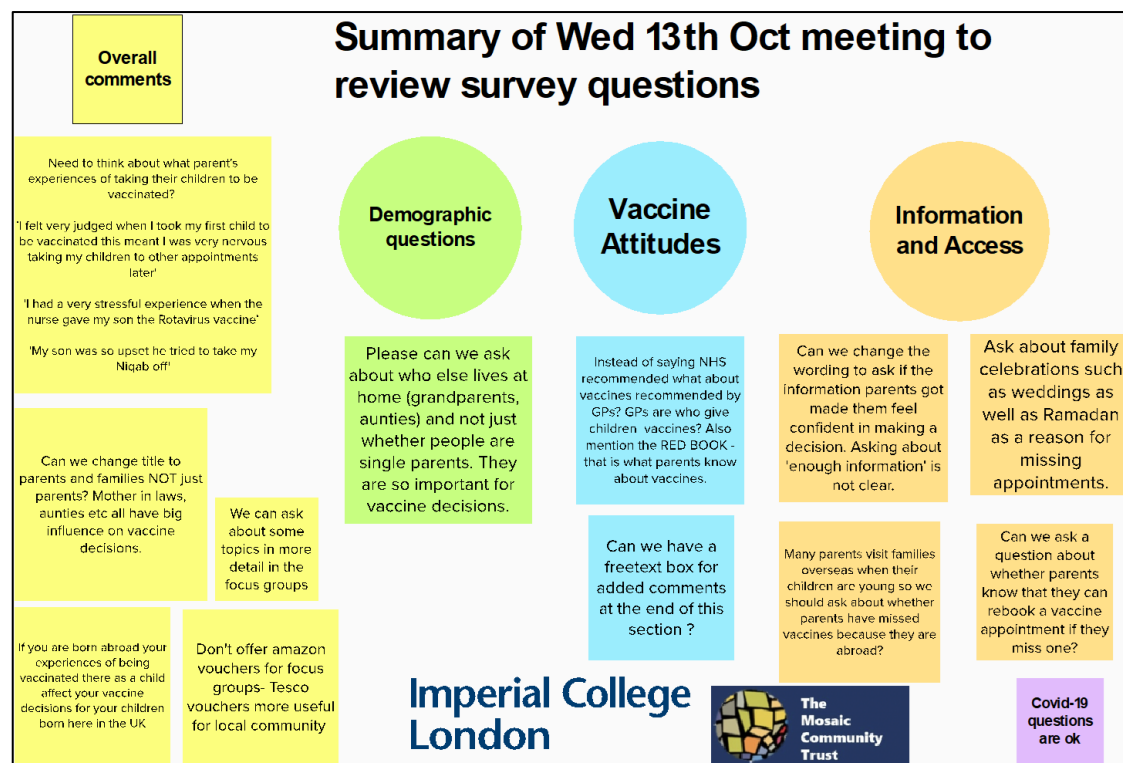
- Sharing of power – the research is jointly owned, and people work together to achieve a joint understanding.
- Including all perspectives and skills – the research team includes all those who can make a contribution.
- Respecting and valuing the knowledge of all those working together on the research – everyone is of equal importance.
- Reciprocity – everybody benefits from working together.
- Building and maintaining relationships – an emphasis on relationships is key to sharing power. There needs to be joint understanding and consensus and clarity over roles and responsibilities. It is also important to value people and unlock their potential.

Table 6 below demonstrates below how these principles of co-production relate to this project. Initial study meetings involved agreeing practices and procedures for the conduct of the study. Brainstorming meetings were held in 2021: see figure 6 for examples of co-produced outputs of ideas for the study and questionnaire development. A multi-methods approach was agreed upon using a questionnaire to survey parents followed by focus groups to both quantify different parental experiences of accessing routine vaccines for children under 5 years and then explore in greater depth barriers and facilitators to accessing routine vaccines.

Table 6: Principles of Co-production used during study

Sharing of power	Including all perspectives and skills	Respecting and valuing the knowledge of all those working together on the research	Reciprocity – everybody benefits from working together	Building and maintaining relationships
- Partners in developing the NIHR research fellowship application that secured funding for the project. - Co-creating the methods and designing the questionnaire. - Mosaic community health advocates acting as co-researchers, - Mosaic as co-authors on the research outputs. - Co-leading dissemination events with the local community and stakeholders.	When developing the questionnaire, we incorporated different members of Mosaic viewpoints on what topics should be included.	- Before sessions with community members Lena & the Mosaic community health advocates and I always meet for briefings - Agree common terms, ensure understanding of the topic, agree the aims and address any questions from community health advocates. - Mosaic have also run a session on how to effectively involve members of the public in research for an 'away day' for the Imperial Child Health Unit.	- Increased vaccine knowledge among Mosaic & some have become vaccine advocates. - Learnt skills that are transferable to other professional and personal areas. - Training the Mosaic community health advocates on facilitating focus groups was delivered for example by CL. - Mosaic have won the President's award for societal engagement at Imperial College London.	- From initial work together in 2018-19 on maternal vaccine uptake, to work during the pandemic on COVID-19 vaccine uptake, to this study and now further research collaborations being planned for post-doctoral research. - I am also a specialist advisor to Mosaic.

Figure 6: Examples of Co-production Meeting Outputs from 2021



4.5 Questionnaire design

A questionnaire was co-developed based on both co-production meetings using Mosaic's ideas but was also informed by previous surveys on vaccine parental attitudes and hesitancy.^{96 100 152 153} For example, a report prior to the COVID-19 pandemic, by the Royal Society of Public Health on childhood vaccination in the UK, included a survey of 2,622 parents.¹⁰⁰ The Royal Society of Public Health was contacted over email for the full survey questions and results however these are not publicly available.³ Themes including access barriers to vaccination in the UK were included as well as attitudinal themes as well.

Other stakeholders in NW London such as the Maternity Champions,¹⁵⁴ Community Champions,¹⁵⁵ local public health departments and local commissioners were also involved in informing question topics at meetings such as the Westminster Immunisation Partnership Board. Some question topics were also considered to be better suited to be explored in the subsequent focus groups to allow further exploration.

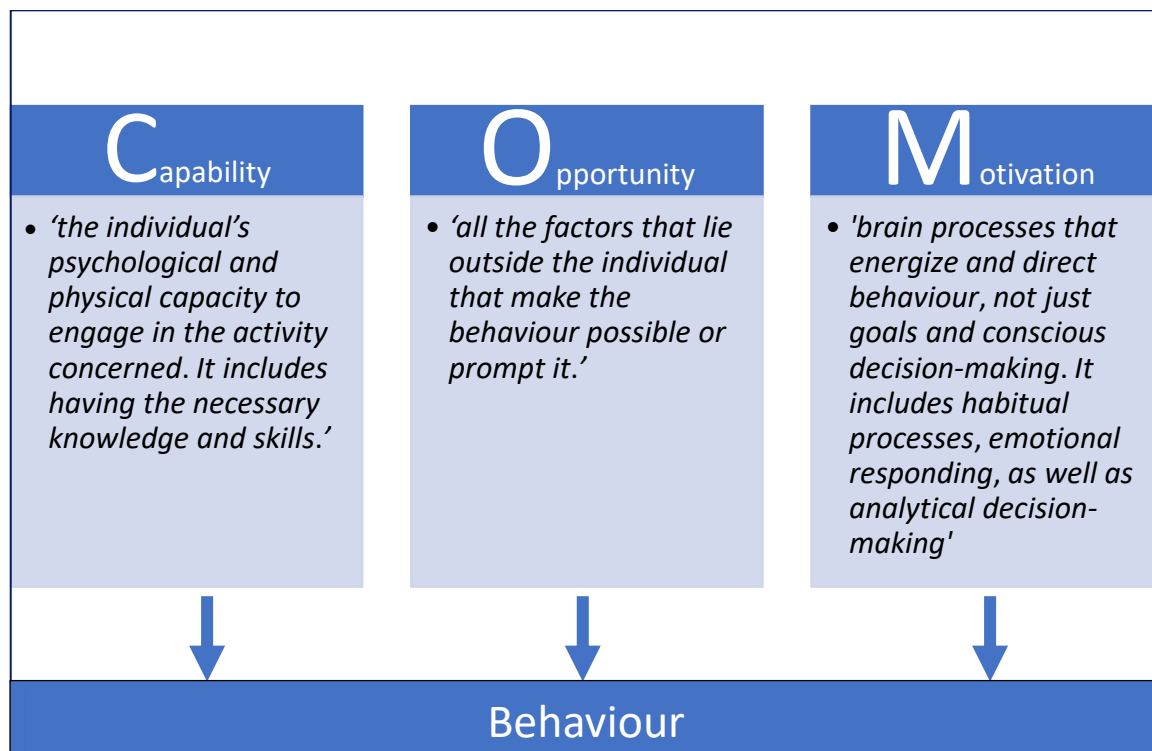
At meetings and over subsequent email discussions question topics were agreed with Mosaic with themes agreed including: access to appointments, availability of time to ask questions, religious and cultural commitments and parents travelling overseas to visit family agreed. Questions on the impact of the COVID-19 pandemic and subsequent COVID-19 vaccination program, on routine childhood vaccine attitudes and access were also agreed on to be included.

³ Personal Email Correspondence. Helen Skirrow to Royal Society of Public Health. 26th July 2021

4.6 The COM-B Model

The COM-B model,^{156 157} that has been previously applied to vaccination behaviour,¹⁵⁸ was additionally used as a framework to inform the questionnaire. Questions arising from the brainstorming sessions with Mosaic, and from previous surveys were mapped to the COM-B framework. Then the final questionnaire reviewed to ensure different factors from the model that can influence vaccine behaviours were encompassed. The COM-B model suggests that capability (C), opportunity (O) and motivation (M) are needed to perform a certain behaviour such as vaccination (B) and the elements of the model are outlined below in Figure 7.¹⁵⁶

Figure 7: The Com-B Model



Adapted from: Michie S, Van Stralen MM, West R. The behaviour change wheel: a new method for characterising and designing behaviour change interventions. *Implementation science*. 2011 Dec;6:1-2.¹⁵⁷

The final developed questionnaire comprised the following four sections: demographics; routine vaccines for children; experiences of accessing information about routine vaccines for children and, routine vaccines for children and the COVID-19 pandemic. Within each section of the questionnaire, parents were asked about their attitudes and experiences. For each question or statement respondents indicated their level of agreement on a 7-point Likert scale between Strongly disagree to Strongly agree. There was also a free-text response option for some sections so that responders had the opportunity to elaborate on their responses. Questionnaires were available online or on paper. See appendix 13 for the full approved questionnaire.

4.7 Questionnaire recruitment

The questionnaire was available to be completed online or in paper versions provided to Mosaic. The questionnaire was promoted by Mosaic locally in North-West London, through local networks of parents and families that attended Mosaic meetings. The questionnaire was also promoted via other local community organisations including Maternity Champions,¹⁵⁴ Community Champions,¹⁵⁵ Connecting Care for Children¹⁶⁰ and Maternity Voices Partnerships¹⁶¹ who were e-mailed and invited to share the questionnaire. By approaching a range of community groups embedded among local peer support networks our recruitment strategy especially sought to recruit from grass roots organisations and therefore reflect a representative sample. The questionnaire was also advertised and promoted using Instagram paid for promotion with a cross post to Facebook with a targeted audience of parents in North-West London. The paid promotion feature was used from 12th August 2022 to 28th September 2022, reached 27,352 accounts and achieved 317 link click engagements. The

questionnaire was also shared and distributed via the research team's personal twitter accounts, including linking to other researchers and organisations with vaccine uptake interests.

Eligible participants were required to be residents in the UK be aged 18 years or over and have children aged 10 years or younger at the time of completing the questionnaire. The questionnaire was live online and promoted from 7th June 2022 until 6th November 2022. The questionnaire was prefaced by an information page explaining the study, and how the data were to be used (appendix 13). Participants were informed that by taking part they agreed for their responses to be used for research purposes. Participants were required to confirm (by tick-box) at the start that they met the eligibility criteria and that they consented to participate in the study. Apart from the question confirming they were eligible, answers to the questions were optional for parents completing the questionnaire. There were discrete answer options as well as freetext response options to several questions. At the end of the questionnaire participants were invited to take part in a follow-up focus groups by leaving their contact details.

4.8 Questionnaire analysis

Descriptive statistics of question responses were summarised, and chi-square analyses were conducted to test for significant associations between ethnicity and agreement or disagreement with statements. Respondents were split into two ethnicity groups as we were underpowered to analyse by different ethnicity subgroups. Parents who answered which of the following best describes your ethnicity? As *'White, White Irish or Other White*

background' were compared to those that answered any of 'Any Mixed background, Black or Black British or any Black background, Asian or British Asian or any Asian background, Chinese or other or prefer not to say'. Likert responses were also dichotomised into 'Agreed' (Strongly Agree, Agree or Somewhat Agree) and 'Disagreed' (Neither Agree or Disagree, Somewhat Disagree, Disagree or Strongly Disagree). Parents who left the question about ethnicity blank were not included in the chi-square analyses.

Free text responses to the questionnaire were analysed in Microsoft Excel using a codebook thematic analysis. The codebook was developed using an inductive and deductive process based on the content of the open-text comments and also the focus group transcripts. Deductive codes were based on the COM-B model¹⁵⁷ as well as the study objectives and previous literature, while inductive codes were developed from both the questionnaire freetext comments and the focus group data. To enhance the rigour of the analysis, coding approaches and data interpretations were discussed between myself, HH, HB, CL, and EW.

4.9 Focus group topic guide development

The topic guide (appendix 14) was informed by the questionnaire responses and included topics such as attitudes to vaccination, vaccine information and experiences of accessing childhood vaccinations.

4.10 Focus group recruitment

Respondents who included their details at the end of the questionnaire were contacted later and invited to take part in focus groups. They were given a choice of taking part in either in-person or online focus groups. Written informed consent was obtained from each participant. Depending on the preference of the participant, the consent form was sent and returned completed via email or in person. For the final fourth focus group, participants were recruited from local parents among Mosaic's network, as data saturation had not been reached by recruiting from the questionnaire respondents alone after three focus groups.

4.11 Focus group data collection

Four focus groups were conducted in total, two in person at a community room in the Church Street Library, Westminster, that is regularly used by Mosaic for meetings and two were online via Zoom. Participants received a £10 gift voucher in recognition of their time and contribution. Focus groups were conducted between the 15th March and 24th May 2023 and lasted between 60 and 90 minutes. All the four focus groups, both online and in person, were conducted by me and Habiba Haque (HH- Learning and Development Co-ordinator at The Mosaic Community Trust) acting as facilitators with one of three supervisors (Helen Bedford (HB), Celine Lewis (CL) and Elizabeth Whittaker (EW)) acting as co-facilitators at different focus groups.

4.12 Focus group analysis

Focus group recordings were transcribed verbatim by an external professional transcription service '*Way With Words*¹⁶²' that is used by Imperial College London. Both the

questionnaire free-text responses and the data collected in the focus groups were analysed using a codebook thematic analysis,^{163 164} following an inductive and deductive coding scheme. Deductive codes were based on the COM-B model¹⁵⁷ as well as the study objectives and previous literature, while inductive codes were developed from the data. To enhance the rigour of the analysis, coding approaches and data interpretations were discussed between myself, HH, HB, CL, and EW, with CL also double coding one transcription to check for agreement.

CHAPTER 5: STUDY 2A

Why do parents and families think some children are vaccinated late or miss out on routine vaccines?

RESULTS

5.1 Publication

The published version of this study is available from Vaccine and is also in Appendix 40.

Skirrow H, Lewis C, Haque H, Choudary-Salter L, Foley K, Whittaker E, Costelloe C, Bedford H, Saxena S. 'Why did nobody ask us?': A mixed-methods co-produced study in the United Kingdom exploring why some children are unvaccinated or vaccinated late. Vaccine. 2024 Sep 17;42(22):126172.

5.2 Questionnaire sample

A total of 518 parents completed the questionnaire, 476 online and 42 on paper. The total number of parents answering each question differed. Characteristics of parents are shown in Table 7. Of the 72 respondents who gave a postcode outside London, 70 were from England and two from Scotland. Demographic characteristics between paper and online respondents differed. The average age of all respondents was 37 years (median and mean) and ranged between 19 and 57 years though paper respondents had a lower median age of 35 years. Among all respondents, 25% were from ethnic minority groups, though among paper respondents, the majority (83%, 35/42) were from ethnic minorities.

The 14 paper respondents who described themselves as 'Other ethnicity group' gave their ethnicity as 'Arab'. Among paper respondents the majority were Muslim (88%, n = 37/42).

Only 31% (n = 13) of paper respondents were university educated with the majority completing secondary school education to either 16 years (29%, n = 12) or 18 years (26%, n =

11). Paper respondents also differed from online respondents with respect to family size: over a third of the paper respondents who answered the question had 3 or more children (36%, n = 15/42) compared with only 7% (n = 33) of on-line respondents. Very few respondents answered that they were living with extended family members 7% (n = 35)- though among paper respondents this was higher (17%, n = 7/42).

5.3 Focus group sample

In total 19% (n = 100) of all parents surveyed provided their details to be contacted for a follow-up focus group and were either contacted by myself, or by phone by HH, to participate. Twenty-two responded to the invitation, with 16 taking part in one of the first three focus groups. The remaining six parents opted out prior to the focus groups. Mosaic recruited a further six women to take part in the final focus group from among the local parents who use Mosaic services but who had not completed the questionnaire. The characteristics of focus groups' participants are outlined in Table 8, (100% were women) of whom 10 were from ethnic minority groups. The focus groups included parents who had chosen to delay or decline some childhood vaccinations (Table 8).

Table 7: Characteristics of Questionnaire Respondents

	Respondents (n)	%
Gender		
Female	456	88
Male	11	2
Not given	51	10
Geographical location		
North-West London	203	39
All London	330	64
Outside London	72	14
Not given	116	22
Country of birth		
United Kingdom (UK)	267	51
Non-UK	149	29
Not given	102	20
Ethnicity		
White or White British	320	62
Mixed	28	5
Black or Black British	21	4
Asian or Asian British	43	9
Other, ethnic group	38	7
Not given	68	13
Religion		
No religion	219	42
Christian	164	32
Muslim	71	14
Hindu	8	2
Jewish	8	2
Not given	48	9
Education		
Educated to primary school level, secondary school up to 16 years or 18 years	48	9
Educated beyond 18 years at college, university or to post-graduate level	415	80
Not given	55	11
Household structure		
Raising children with partner	428	83
Single parent or other	47	9
Not given	43	8
Number of children		
1	206	40
2	206	40
3 or more	48	9
Not given	58	11

Demographic characteristics of both paper (n=42) and online (n=476) questionnaire respondents (total n=518).

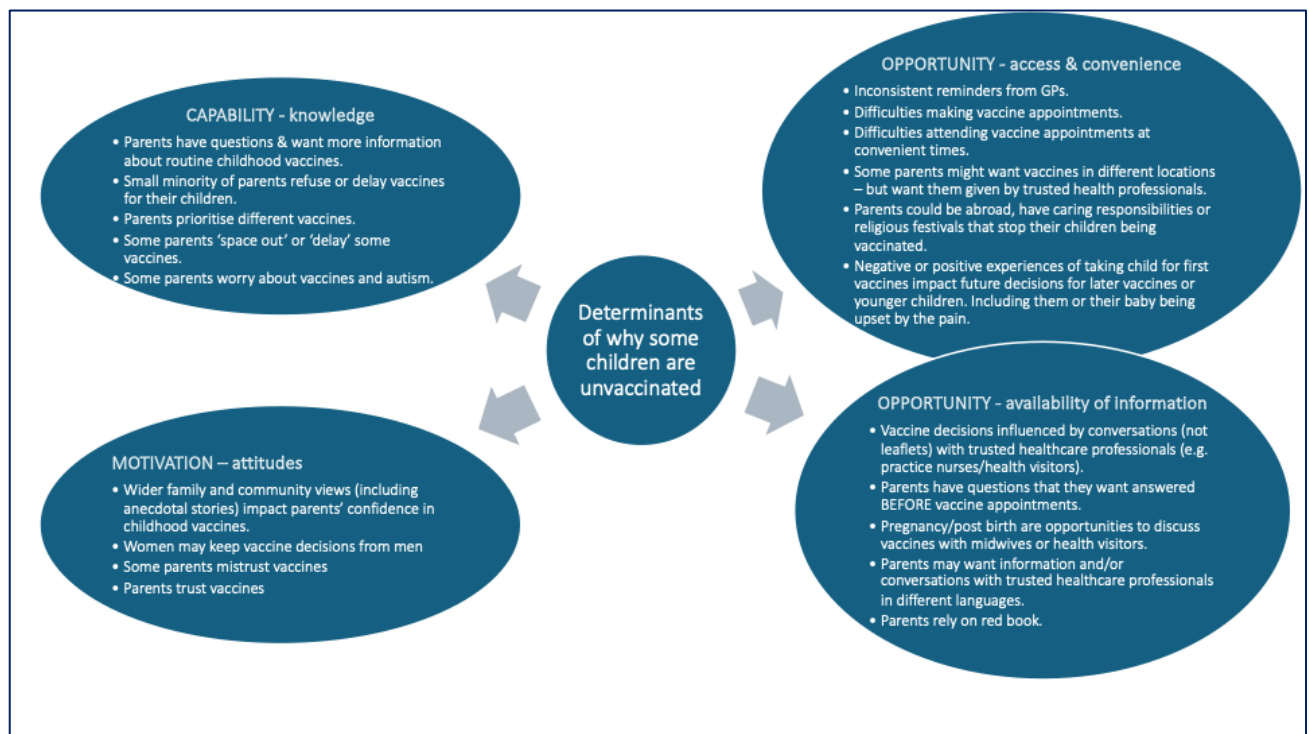
Table 8: Characteristics of Focus Group Participants

No	Ethnicity	Online or in person focus group in North-West London	Vaccines ever delayed or refused for the child/ren (not including childhood COVID-19 vaccine)
1	White (other)	In person (FG1)	None
2	White (British)	In person (FG1)	Flu, whooping cough & additional polio booster
3	Asian or Asian British	In person (FG1)	None
4	Asian or Asian British	In person (FG1)	None
5	Other ethnic group (Arab)	In person (FG1)	MMR
6	White (British)	Online (FG2)	None
7	White (British)	Online (FG2)	Paid for some vaccines separately.
8	Mixed	Online (FG2)	None
9	White (Other)	Online (FG2)	None
10	White (Other)	Online (FG2)	Delayed MMR and paid privately for other vaccinations to be spaced out.
11	White (British)	Online (FG2)	None
12	White (British)	Online (FG2)	None
13	White (British)	Online (FG3)	None but chose to have 1 year old vaccines at separate appointments.
14	White (Other)	Online (FG3)	Preschool booster
15	Asian or Asian British	Online (FG3)	MMR- both 1 year and preschool booster declined.
16	White (British)	Online (FG3)	None
17	White (British)	In person (FG4)	None
18	Asian or Asian British	In person (FG4)	MMR vaccine
19	Asian or Asian British	In person (FG4)	None
20	Asian or Asian British	In person (FG4)	None
21	Other ethnic group (Arab)	In person (FG4)	MMR vaccine
22	Other ethnic group (Chinese)	In person (FG4)	None

5.4 Findings according to the COM-B Model: study 2A

The following sections present data according to the COM-B model,^{156 157} which was used to guide analysis. The themes draw on a combination of questionnaire responses, free-text questionnaire answers and data from the focus groups (appendix 15 for number of free-text responses). Given the variation in the number of respondents per question, descriptive statistics and chi square analysis report on the percentages among those who chose to answer each question. Quotes from focus group participants and free-text responses are provided in appendix 16 to illustrate key themes while figure 8 shows the summary of key finding within each sub-theme of the COM-B model. Themes were developed from either deductive codes based on the a priori study objectives and some were inductive either developed from the questionnaire responses or from the focus group data.

Figure 8: Summary of study-specific findings within each sub-theme of the COM-B model (study 2A)



5.5 Capability

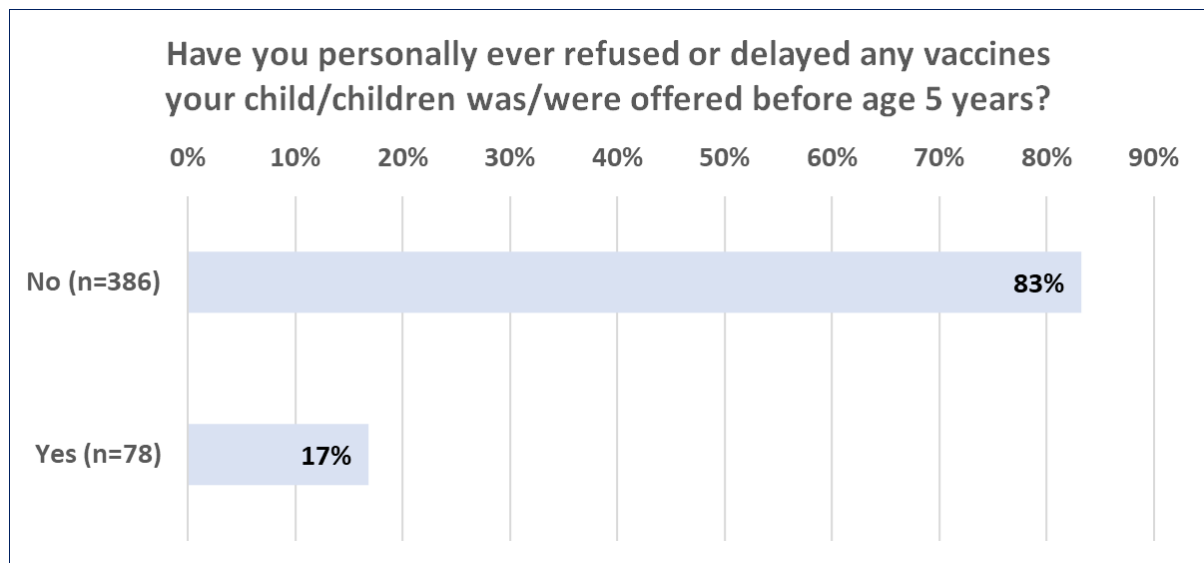
Normal for parents to have questions or want more information about routine childhood vaccines.

In both the questionnaire and the focus groups, parents talked about having questions about childhood vaccines that they wanted answering (figure 8, appendix 16). One parent said: *'I have a lot of questions, and I feel like I don't know that many information'* (FG1 participant) while another said *'I will not do anything until I'm given the full (information)...can you please explain to me what is the benefit? What is this? What's the side effects?'* (FG4 participant). A lot of the questions were linked with parents wanting more information about ingredients and side-effects of routine childhood vaccines. One parent said: *'Information about risk and benefit needs to be more available'*, (qu. n41) while another said, *'share information on how the vaccines work, and that the ingredients are safe and have been tested.'* (qu. n142). While several parents mentioned wanting more information specifically about vaccine ingredients and side effects the desire for more information was probably linked to the other theme of parents wanting greater opportunity to discuss vaccines with healthcare providers.

Delaying or refusing some routine childhood vaccines.

Only 15% of all parents (n = 78/518) said that they had ever refused or delayed a vaccine (though only 464 parents surveyed chose to answer that question, figure 9). Among those who had delayed or refused a vaccine, the majority answered that their child had the vaccine later or they planned to get them vaccinated later (63%, n = 49/78). Among parents who gave written details of which vaccines they had refused or delayed (n = 45), the most common was the MMR vaccine (n = 10) or the 1 year (n = 6) and preschool booster vaccines (n = 5), (which in the UK includes the first and second MMR doses). A very small minority of parents had refused all their children's vaccines (n = 8) and <5 parents specifically mentioned refusing the flu vaccine. A smaller percentage of parents who identified as White ethnicity said that they had refused or delayed vaccines (13%, n = 41) compared to parents who identified as an ethnic minority group (21%, n = 29, p value = 0.03, (appendix 17)). The majority (>90%) of parents also answered that they thought it was important for their child to be vaccinated (figure 10), though this was higher among parents who identified as White ethnicity (97%, n = 301) compared to those who identified as ethnic minority (89%, n = 119, p value = 0.002, appendix 17).

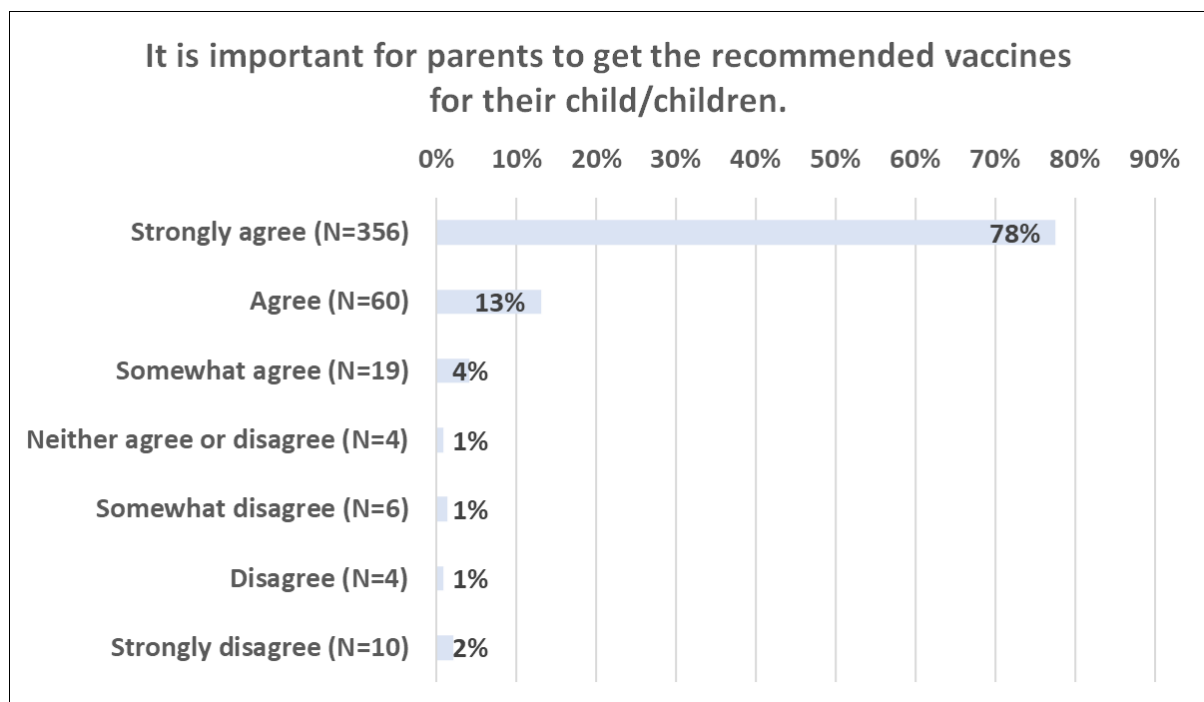
Figure 9: Parental refusal or delay of routine childhood vaccines under the age of 5 years



Total respondents answering question n=464.

Percentage of total parents who did the questionnaire n=78/518, 15%

Figure 10: Importance of getting children vaccinated.



Total respondents answering question n=459

Prioritising different childhood vaccines.

Parents discussed prioritising some vaccines over others (figure 8, appendix 16), with both the flu and polio booster vaccinations offered in London in 2023^{165 166} mentioned. One parent talked about having seen effects of polio first hand and prioritising the vaccine (appendix 16). While another parent chose to decline the additional booster polio vaccine: *'when there was a big, massive polio vaccination for all children...I refused to give my son the polio injection'* (FG4 participant) while another said they *'chose not to get my son the flu vaccine'* (qu. n435).

Choosing to space out or delay vaccines due to concerns about too many vaccines being given at the same time.

Linked with the decisions some parents made to prioritise certain vaccines over others, some parents talked about being concerned about too many vaccines being given at once (appendix 16). One parent said: *'The NHS vaccine programme is too much too young and I have chosen a more spaced-out vaccine programme that I mostly do privately as the NHS don't offer single doses for most vaccines. I also chose not to have one vaccine and delay some of them'* (qu. n479). However, the ability to choose to pay for single dose vaccines privately requires parents to have disposable income which lower income families may not be able to afford. Nonetheless this was still a concern among different parents as another parent said they thought that there were: *'Too many jabs in 1 go, especially 1yo vaccination - creates an overload'* (qu. n417). A few parents reported choosing to have their children's vaccines given at different spaced-out appointments, one parent said: *'so I think she did three, and then we went back for the other two'* (FG3 participant).

Parents worry that vaccines are associated with the development of autism.

Though the issue was not specifically raised and only mentioned by a few parents (n ≤10) in the questionnaire, in every focus group parents brought up concerns about the link between vaccines, specifically MMR, and autism (figure 8, appendix 16). One parent said: *'Personally I still question whether it is good for them to be vaccinated a number of diseases at the same time. Even though it's disproven I still question aluminium/autism'* (qu. n210). A couple of parents whose children had been diagnosed as autistic brought up that they now thought that this could have been caused by vaccination. A parent described how her son: *'was vaccinated on time. I had no problem with that, even though there was on the back of my mind, is it. He ended up having autism at a younger age. I thought could be from the vaccination?'* (FG4 participant)

5.6 Opportunity

Conversations with trusted healthcare professionals.

Parents discussed having conversations with healthcare professionals – including doctors, practice nurses and health visitors as key influences on getting their children vaccinated (figure 8, appendix 16). One said: *'I think that's a really important thing to be able to talk to people about ... (them) with the right information and the right support.'* (FG1 participant). Parents wanted these conversations to be with someone they trusted, who was informed and who would know the medical answers to their vaccine questions. One mother said: *'I prefer just speaking to someone, and I think for me, I like the information. And that's probably why I go to the GP and I'm comfortable to just ask them before they do anything, that's what I would prefer to do.'* The same mother went on to describe *'I've had fairly good experiences....so they've built my trust'*. (FG3 participant).

One parent described differing experiences at vaccine appointments. At one they felt they had not been given an opportunity to have a conversation resulting in them choosing to delay some vaccines and go privately; at a different appointment they felt a practice nurse took the time to talk to them (figure 8, appendix 16). Another parent mentioned how their health visitor had spoken to them about vaccines first, followed by their doctor and nurse who knew them personally and so were able to give them the information they wanted about their child's vaccines clearly (figure 8, appendix 16).

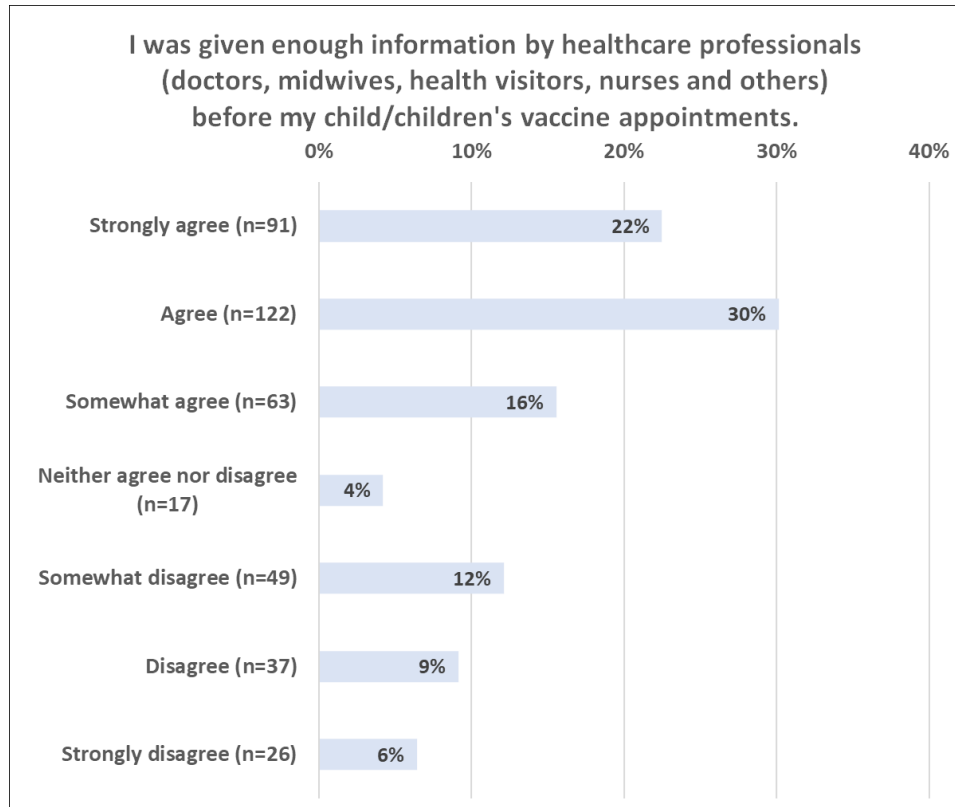
Parents have questions that they want answered before the vaccination appointment.

Parents wanted both vaccine information and information about vaccine appointment logistics before appointments (figure 8, appendix 16) delivered through a conversation with a trusted health professional. One parent said: *'want the information before.....ideally, so I've got time to process it. And then also, because I might want to go away and then do some digging around, okay, well, they've mentioned this, let me research this by myself and come up with all the things that I need to ask. ... I don't think I'm really selective about who... So long as they were someone who was knowledgeable, so I think a nurse, even a health visitor, a GP, anyone'* (FG3 participant). Most parents (68%, n = 276) strongly agreed, agreed, or somewhat agreed that they had been given enough information by healthcare professionals beforehand (figure 11). However, over a quarter (28%, n = 122) did not agree they had been given enough information before their child's vaccine appointment (figure 11).

Around two thirds of parents (63%, n = 259) agreed to differing degrees that they had had enough opportunity to ask questions before their vaccine appointments (figure 12). However, over a quarter (27%, n = 111) did not agree with this statement (figure 12). More parents, (84%, n = 337) agreed to differing extents that they understood the information they were given before their child's vaccine appointment (appendix 18). There was no difference between ethnic minority or White parents as to whether they had received enough information before their child's vaccine appointment or whether they understood the information (appendix 17). However, slightly fewer parents who identified as belonging to an ethnic minority other than White agreed that they had had enough opportunity to ask

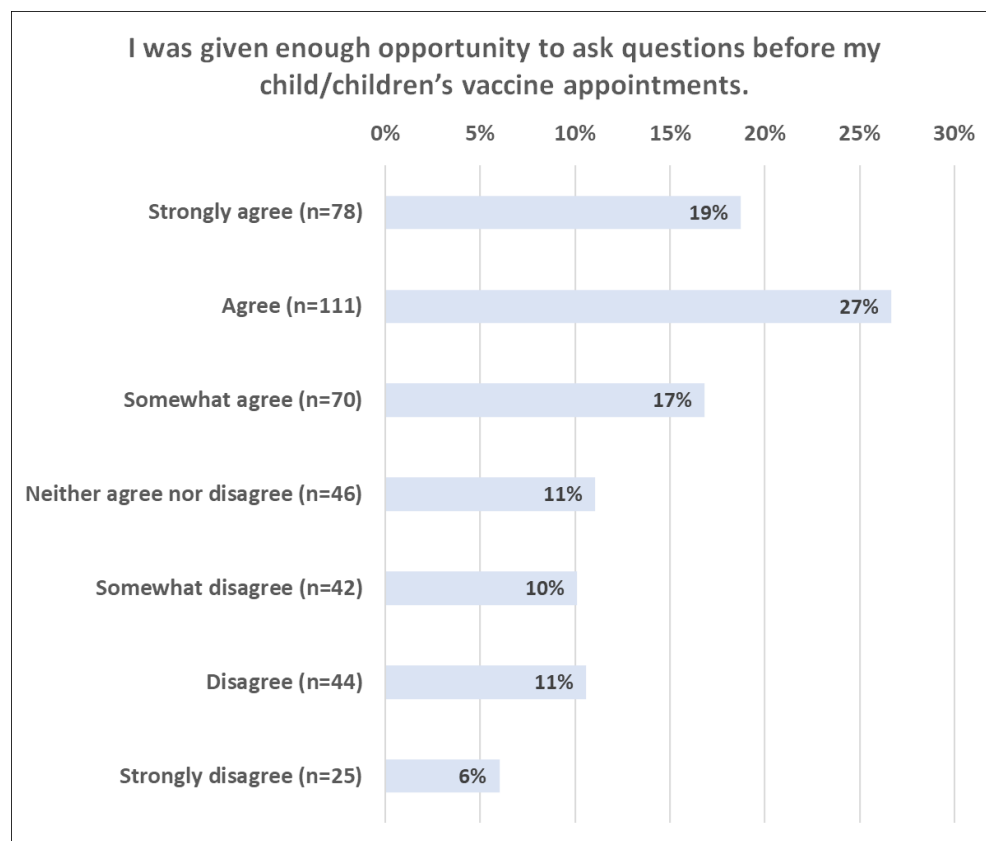
questions before their child's vaccine appointments (64% (n = 180) White ethnicity parents versus 51% (n = 51, p = 0.02) ethnic minority parents (appendix 17).

Figure 11: Information from healthcare professionals before vaccine appointments



Total respondents answering question n=405.

Figure 12: Opportunity to ask questions before vaccine appointments



Total respondents answering question n=416

Pregnancy offers opportunity to provide more information/discuss childhood vaccines with midwives or immediately post birth with health visitors.

Parents discussed wanting more information about childhood vaccines during their pregnancy or immediately after their babies' birth from health visitors. One mother said: *'I don't think I received any information about childhood vaccines when I was pregnant.....And I probably would have liked it, because it would have been part of the thinking about having a baby, what that meant, and what I'm putting in my own body.'* (FG2 participant). Again, parents wanted the information to be given via a conversation with a healthcare professional and not just a pamphlet (figure 8, appendix 16). Parents mentioned the information in pregnancy about childhood vaccines could be provided in birth preparation courses: *'Maybe,*

more information could be given in preparation to birth courses. For example, explaining ...how the illnesses can impact children' (qu. n89).

Parents want information and/or conversations with trusted healthcare professionals in different languages.

Some parents felt that there should be better information about vaccines for parents who were from ethnic minority backgrounds or who spoke languages other than English. One parent said that there needed to be: *'Better information for parents of ethnic backgrounds. Translated ingredients list, up to date responses to all worries that they may hear by word of mouth or social channels. What the vaccine does and doesn't do in the language they understand. E.g. address issues some might fear' (qu. n51).* One mother who was born outside the UK described how helpful she found a health visitor who spoke the same language as her (Arabic) when she gave birth in the UK and would have liked to have a conversation with her in Arabic about her child's vaccinations (appendix 16). Again, as with previous themes, it was felt the conversation in a different language was more important than a leaflet (figure 8, appendix 16). Only 142 parents answered the question about wanting vaccine information provided in their own language (appendix 19). Of these the most common answer was to 'neither agree or disagree' (32%, n = 45) and only 27% (n = 39) agreed to different extents that they wanted information translated. A higher proportion of ethnic minority parents (47%, n = 29) who answered the question would have preferred the information translated compared to White parents (10%, n = 7, $p \leq 0.0001$) who answered (appendix 17).

Relying on the red book to track vaccinations.

Parents mentioned the importance of their child's red book (personal child health record) in keeping track of their vaccinations (figure 9, appendix 16) – one said: *'I relied on my red book to know when to book my child's vaccines.'* (qu. n267). Parents also described how they used the red book when they did not get reminders from their GP: *'I was expecting to get reminders for the vaccinations from our GP and that wasn't the case. So we had the one you do at 1 year old and around 3 years old delayed by months because I randomly remembered to check the red book'* (qu. n157).

Inconsistent receipt of reminders from GP surgeries about childhood vaccines.

Parents did not consistently receive reminders or notifications from their GP to book children's vaccinations meaning children were unvaccinated or vaccinated late (figure 9, appendix 16). One parent said: *'our surgery are not sending notifications automatically'* (qu. n111). Variation between different GP surgeries (and even different siblings) about reminders was reported. One parent said: *'Reminders would be useful, but everyone seemed to get one but me.'* (FG4 participant). While another said: *'I have 3 kids within 4 years & you.... invite one child and the others not... doesn't give me confidence.... I got a letter for...vaccination for one child and not others'* (qu. n123).

Difficulties in making vaccine appointments – parents struggle to get through to doctors' surgeries to make vaccine appointments for their children.

A key theme was parents having difficulties in making vaccine appointments at GP surgeries. One parent said: *'arranging them with the GP is not easy. You often have to wait a*

long time to speak to a receptionist and if you call too early the appointments are not available to book and when you call again you have missed the chance to get an appointment when required. It should be easier to book' (qu. n14). Many mentioned difficulties in getting through to GP surgeries by telephone to book appointments and wanted an easier way to book appointments (appendix 16). One parent implied that having to call to make an appointment was an extra barrier to being able to vaccinate your child conveniently: *'Having to book separate appointments at the GP for vaccinations is a bit of a faff - long phone queues' (qu. n72).* The majority (88%, n = 368) of parents knew how to book their children's vaccine appointments (appendix 20), so the difficulties faced were booking appointments rather than a lack of understanding about how to book them; there was no difference in booking knowledge by ethnicity (appendix 17). The majority also understood they could rebook vaccine appointments if they missed them (87%, n = 356, appendix 21) with no difference by ethnicity (appendix 17).

Difficulties in attending vaccine appointments.

Many parents mentioned difficulties in attending their children's vaccine appointments as they were only available on one day or they had to take time off work (appendix 16). One parent said: *'surgery...just need to provide more appointments than every-other Wednesday' (qu. n186).* Another parent described how her child was late being vaccinated as the nurse at their surgery was only able to offer vaccine appointments one day a week: *'the nurse that does the vaccinations is only there one day a week. And if you've missed your chance to get in then it's delayed a week and another week and another week....*

Months.' (FG4 participant). Parents talked about difficulties in taking time off work: *'With preschool children, it is a pain getting them to the surgery.... Finding an appointment slot when I could take time out of work, go and get her from nursery, get her vaccinated, take her back to nursery etc just proved impossible... especially when clinics were only 1-2x weekly'* (qu. n143). Three quarters of parents agreed to different extents that they were able to book vaccine appointments at convenient times (75%, n = 306, appendix 22), with no differences by ethnicity (appendix 17). Around a quarter (28%, n = 118, appendix 23) of parents also agreed to different extents that they found it difficult to take their children to vaccine appointments due to work, with no differences by ethnicity (appendix 17). Parents did not report difficulties in travelling to vaccine appointments at the GP surgeries (appendix 24). Over two thirds (69%, n = 278, appendix 25) of parents surveyed said that drop-in clinics would make it easier for their children to be vaccinated with no difference found between ethnic minority or White parents (appendix 17). Similarly, 74% (n = 277) of parents agreed to different extents that more appointments after school hours would make it easier to get their children vaccinated (appendix 26) with no difference by ethnicity (appendix 17).

Negative or positive experiences of taking child for first vaccines impact future decisions for later vaccines or younger children. Including them or their baby being upset by the pain.

Parents described how their first experiences of taking their children to be vaccinated often influenced how comfortable they felt taking their children to future vaccine appointments (figure 9, appendix 16). Some parents also mentioned not liking needles and wanting more nasal vaccines like the flu vaccine. One parent said: *'My daughter had a terrible reaction to her very first vaccinations and that scared us.... That first experience has shaped my subsequent thoughts and certainly made me hesitate about vaccines. Fortunately, I have a*

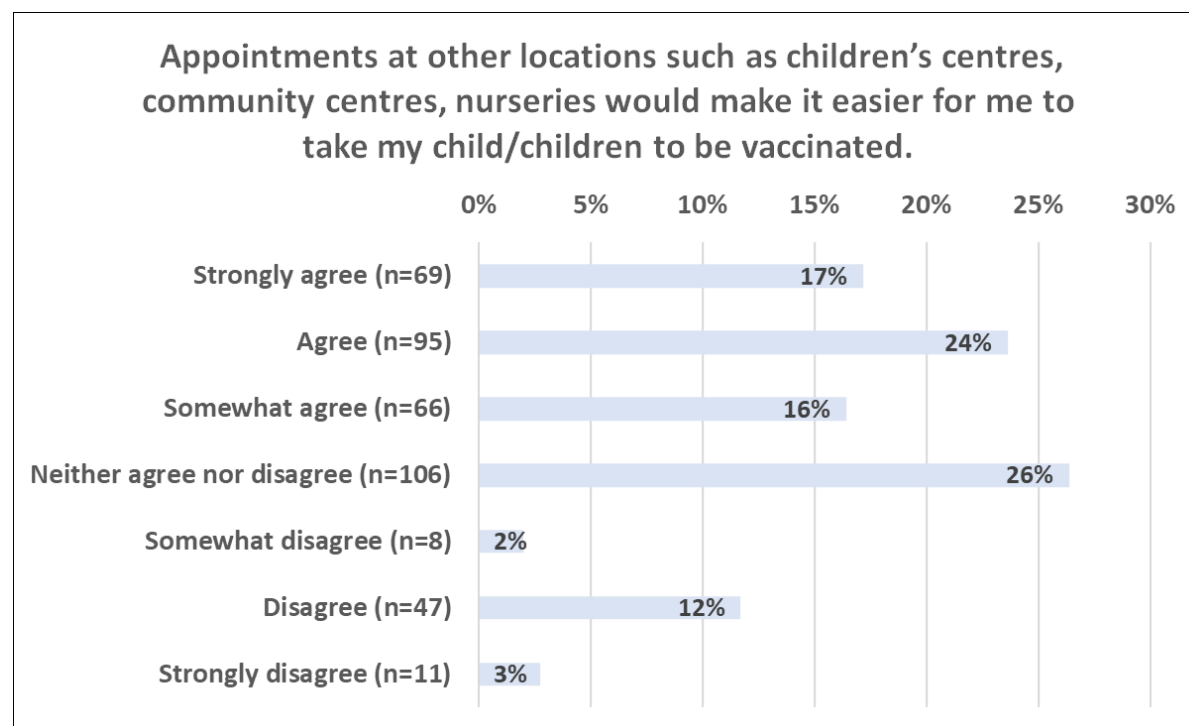
partner who was willing to do the appointment. I wish more funding was put into how vaccines are administered and it would be great to see more alternatives to needles like the flu vaccine....' (qu. n190). Also mentioned by some focus group participants who were Muslim was that they wanted somewhere more private after vaccinations to breastfeed their children (appendix 16). This went with the feeling that *'very often appointments can be rushed'* (FG1 participant) when parents felt that they had to leave the nurse's room quickly but didn't feel comfortable about breastfeeding in the waiting room. However, 90% (n = 368) of parents surveyed agreed to some extent that they felt comfortable taking their children to their GP surgery to be vaccinated (appendix 27), with no difference by ethnicity (appendix 17).

Offering vaccines in different locations- but wanting them to be given by trusted known healthcare staff to answer questions.

Parents discussed how comfortable they would feel about getting their children vaccinated at different locations including one mother describing how easy it had been to get her child vaccinated at her local children's centre (appendix 16). Some parents wanted vaccines to be offered in more locations one said: *'more appointments and options on where to receive the immunisations should be available.....Can't pharmacies administer them?'* (qu. n14). However, in the focus groups while some parents said they would be happy to go to a health centre as opposed to their own GP, some mentioned that they would not want to go somewhere 'random' and that they would want someone they knew, trusted and who was knowledgeable to vaccinate their child (figure 9, appendix 16). One parent said: *'I remember having my Covid vaccine in a leisure centre and, yes, I don't know that I would want to take X to a leisure centre.... if it's not somebody that I know that's vaccinating him either.'* (FG3 participant). Over half of parents surveyed (57%, n = 230, figure 13) agreed to different

extents that appointments in other locations would make it easier to get their children vaccinated, with no difference by ethnicity (appendix 17).

Figure 13: Vaccine appointments in other locations



Total respondents answering question n=402

Other reasons for missing vaccines: being abroad or child being ill or in hospital.

Parents discussed several other reasons for their children sometimes missing their routine vaccines such as children being ill, caring responsibilities or them being overseas visiting family (appendix 16). A small minority of parents mentioned vaccinating their children abroad, one parent said: *'Sometimes... had them vaccinated abroad to be on track with their schedule'* (qu. n128). However, <5% of parents surveyed agreed that visiting relatives overseas made it difficult to vaccinate their children (appendix 28). One fifth of parents surveyed agreed to different extents that caring responsibilities made it harder to get their children

vaccinated (21%, n = 46) (appendix 29) with one parent commenting *'has to take all her children with (me)'* (qu. n21) to get one child vaccinated. Religious and cultural events were not given as a reason parents found it difficult to vaccinate their children (appendix 30).

5.7 Motivation

Family and wider community perceptions and anecdotal stories from local community impact whether parents feel confident in getting child vaccinated.

Among parents surveyed 62% (n = 280) agreed to different extents that wider family members influenced their vaccine decisions (appendix 31), though there was no variation by ethnicity (appendix 17). This was similarly reflected in the free text responses and the focus group discussions where mothers discussed their wider community influencing their vaccination choices sometimes more than medical establishment (appendix 16). One parent said: *'it can be very scary to parents especially if, for example religion or grandparents do not approve of vaccines'* (qu. n142). These conversations were particularly prominent in the in-person focus group discussions though among all parents surveyed, over 90% (n = 423) thought that parents in their local community had their children vaccinated (appendix 32), with no difference by ethnicity (appendix 17).

Women keeping vaccine decisions from men

Some mothers discussed the role their husband's views had on vaccine decisions for their children. A mother who was against vaccination herself described how she reached a compromise with her 'pro-vaccine' husband: *'I have no plans to have my child vaccinated (if she chooses to catch up as a teenager or adult that's her choice), but I agreed a compromise with my pro-vaccine husband that he could take her for the 6-in-1 vaccine, however he hasn't*

done anything about it.' (qu. n258). Some mothers in the focus groups described keeping their own vaccine decisions from their partner and family for fear of being judged, one mother said: *'I didn't tell my family until I was vaccinated (referring to COVID-19 vaccine).'* (FG4 participant).

Mistrust of vaccines

A minority of parents discussed their distrust of vaccination in both the questionnaire and the focus groups. One parent said in the questionnaire: *'Big pharma money making business not necessary and I no trust whatsoever in the system'* (qu. n164). The mistrust of vaccination was often mentioned as mistrust of the pharmaceutical industry in general as well as mistrust of medical professionals and research (figure 9, appendix 16). One parent said: *'Where there is obvious financial gain for a few I don't trust the research'* (qu. n159).

Trust in vaccines

Parents also talked about their belief and trust in vaccination overall. One parent said: *'I believe that all vaccines are appropriate and have willingly ensure my children are vaccinated'* (qu. n158). Parents felt vaccines were important to protect their children and mentioned that the vaccines routinely offered to children in the UK as part of the schedule were established and therefore, they trusted them (figure 9, appendix 16).

5.8 Key findings from study 2A

This mixed-methods co-produced study included a higher proportion of ethnic minority parents' views, from London, compared to previous studies of parent vaccine attitudes in the UK. I found that parents want to speak to trusted, known health professionals about their children's vaccines, often before their children's vaccine appointments. I found that access barriers such as difficulties in booking and attending appointments at GP surgeries can influence whether children are vaccinated or vaccinated late in the UK.

CHAPTER 6: STUDY 2B

How has the COVID-19 pandemic influenced parents' attitudes towards and experiences of accessing routine childhood vaccines?

RESULTS

6.1 Publication

The published version of this study is available from PLOS One and in Appendix 41:

Skirrow H, Lewis C, Haque H, Choundary-Salter L, Foley K, Whittaker E, Costelloe C, Bedford H, Saxena S. *The impact of the COVID-19 pandemic on UK parents' attitudes towards routine childhood vaccines: A mixed-methods study.* PLoS One. 2024 Aug 13;19(8):e0306484. doi: 10.1371/journal.pone.0306484. PMID: 39137199; PMCID: PMC11321586.

6.2 Questionnaire and focus group sample – see sections 5.2 and 5.3

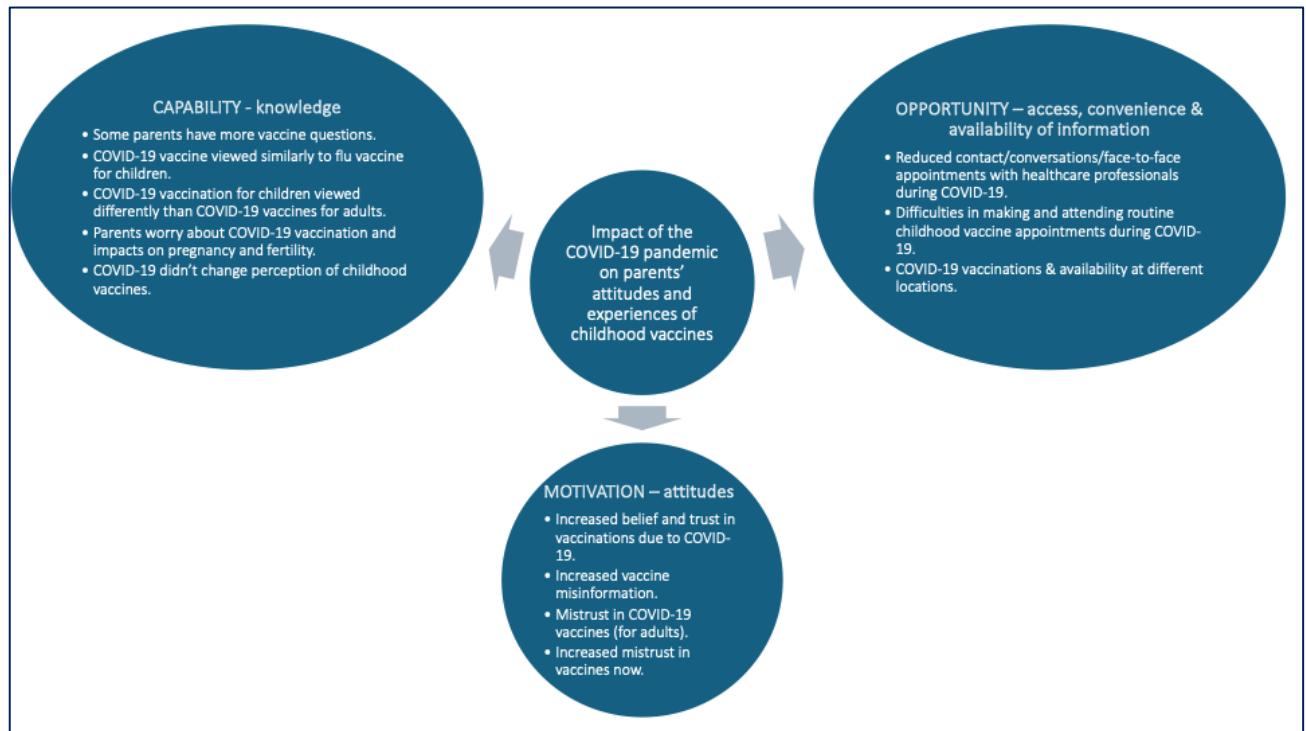
Please see chapter 4 for the methods concerning the questionnaire and the focus groups. Different sections of the research findings were written up separately. Chapter 5 reports on the reasons why some children are unvaccinated and this, chapter 6, reports on the sections related to the impact of the COVID-19 pandemic on childhood vaccine attitudes among parents. Please see section 5.2 and 5.3 for the questionnaire and focus group sample and tables 7 and 8.

6.3 Findings according to the COM-B Model: study 2B

The following sections present data according to the COM-B model,^{156 157} used to guide analysis. The themes draw on a combination of questionnaire responses, free-text questionnaire answers and data from the focus groups (see appendix 33 for number of free-text responses to the COVID-19 questions). Given the variation in the number of respondents

per question, descriptive statistics and chi square analysis report on the percentages among those who chose to answer each question. Quotes from focus group participants and free-text responses are provided in appendix 34 to illustrate key themes. A summary of study-specific findings within each sub-theme of the COM-B model is provided in figure 14. Themes were developed from either deductive codes based on the a priori study objectives and some were inductive either developed from the questionnaire responses or from the focus group data.

Figure 14: Summary of study-specific findings within each sub-theme of the COM-B model (study 2B)

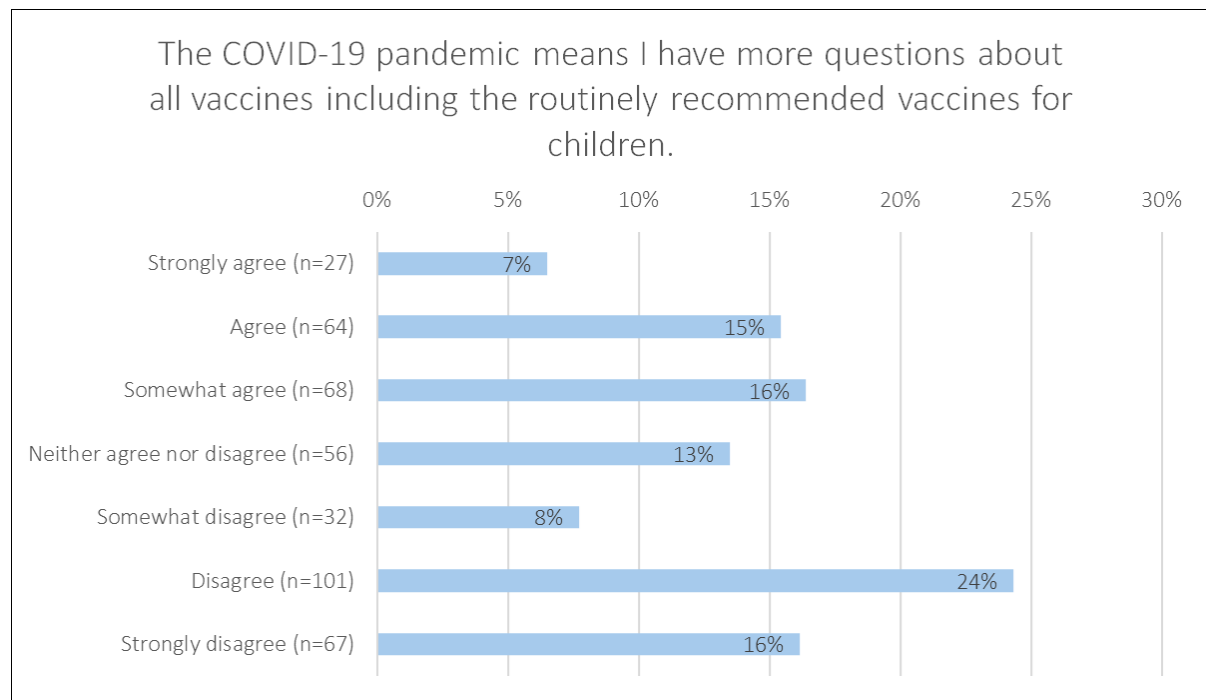


6.4 Capability

Increased questions about vaccines

Over a third of questionnaire respondents (38%, n=159/415) agreed to some degree that they had more questions about routine childhood vaccines since COVID-19 (figure 15). Parents who described their ethnicity as *“Any Mixed background, Black or Black British or any Black background, Asian or British Asian or any Asian background, Chinese or Other or Prefer not to say”* were more likely to have questions following COVID-19 - 59% (n=71/120) agreed that they had more questions since the pandemic about routine childhood vaccines compared to 30% (n=84/281) of parents who identified as White ethnicity ($p<0.0001$, appendix 35). Among paper respondents 63% (n=26/41) agreed to some extent that the pandemic had increased their questions about routine vaccines compared to only 36% (n=133/374) of online respondents.

Figure 15: COVID-19 and parents' questions about routine childhood vaccines



Total respondents answering question: n=415

Over a half (52%) of respondents agreed to some extent that their knowledge about routine vaccines had been increased by the pandemic (appendix 36). However, just over a quarter (26%) disagreed, with the remainder (23%) neither agreeing nor disagreeing (appendix 36). There was no difference between responses by ethnicity (appendix 35).

In the focus groups some parents reported having more questions about routine childhood vaccines since the COVID-19 pandemic (appendix 34). Parents might now see vaccination as a choice compared with before the pandemic when they viewed it as something they did automatically for their children- *'I think the impact of Covid, for me, has made me think that vaccinations are a choice. So, you're actively choosing to do something, or you're choosing not to do something. And it's made it less compulsory and more voluntary'* (FG 2 participant).

COVID-19 vaccine viewed similarly to flu vaccine.

Although not specifically questioned about COVID-19 vaccines for their children, several questionnaire respondents and focus group participants discussed this and in doing so drew parallels with the childhood nasal flu vaccine (figure 14, appendix 34). Both were seen as additional or optional by some parents and not viewed as being part of the routine childhood vaccination offered in the UK. For example, one questionnaire respondent (*qu. n122*) commented *‘I chose not to get my son the flu vaccine or the current Covid vaccine. I feel both are not essential.’* Another parent felt that getting the flu vaccine during the pandemic was not needed *‘Getting flu nasal was an unnecessary outing during lockdown and risks from it are minimal compared to other illnesses vaccines are offered for’* (*qu. n40*).

COVID-19 vaccination for children viewed differently.

Several parents mentioned their attitudes to COVID-19 vaccination for their children in either the questionnaire’s free-text responses or during the focus groups. COVID-19 vaccination was not viewed as important or necessary for children compared to adults, and parents often cited less severe symptoms of COVID-19 in children compared to adults as their rationale for not wanting the vaccine for their children (figure 14, appendix 34). For example, one parent reported, *‘The Covid 19 jab was never needed for children as children were not even getting bad symptoms so why did they need a vaccine for covid if it didn't even affect them much in the first place?’* (*qu. n26*).

COVID-19 vaccine and pregnancy and fertility.

In the questionnaire, a few parents expressed their own or other parents in their circle concerns about COVID-19 vaccines impacting on fertility and this issue was also raised in the focus groups (figure 14, appendix 34). Additionally, in the focus groups, several participants mentioned their confusion about whether to have the COVID-19 vaccines during pregnancy. For example, one focus group participant said: *'Had both COVID vaccines whilst I was pregnant, which was a huge decision for me. Because at the time, they were like we don't know what it's going to do to you if you're pregnant.'* (FG3 participant). Another commented on midwives not recommending COVID-19 vaccine strongly enough for pregnant women *'most midwives didn't advocate strongly enough for pregnant women to have the covid vaccine'* (qu. n24).

COVID-19 did not change perception of childhood vaccines.

Several respondents to the online questionnaire commented that the pandemic had no impact on their views and attitudes to childhood vaccines and that they had the same beliefs as pre-pandemic (figure 14, appendix 34). For example, one questionnaire respondent wrote directly after the COVID-19 questions: *'Hasn't changed my view'* (qu. n3).

Discrete choice answers indicated that most respondents felt that the pandemic had made them think it was more important for children to receive the routine vaccines (total 62% (n=250/405) either strongly agreed, agreed, or somewhat agreed – appendix 37) with only a minority of total respondents (13%, n=57/405) disagreeing to any extent with this statement (appendix 37). There was no difference between the different ethnicity groups

about whether the pandemic had made them think routine vaccines were more important (appendix 35).

6.5 Opportunity

Reduced contact/conversations/face-to-face appointments with healthcare professionals during COVID-19

Questionnaire respondents and focus group participants both mentioned that the reduction in face-to-face appointments with different healthcare professionals during the pandemic – including midwives, health visitors and general practice staff- had given them fewer opportunities than they would have liked, to ask questions about routine childhood vaccines (figure 14, appendix 34). *'I had my baby during the end of COVID, so - so I felt like I didn't get that much information and I was left out.'* (FG1 participant). That parent went on to describe the questions they wanted answering including: *'There's so many vaccines and I feel like it's too much.... Why does a baby need to have all of these?'* (FG1 participant).

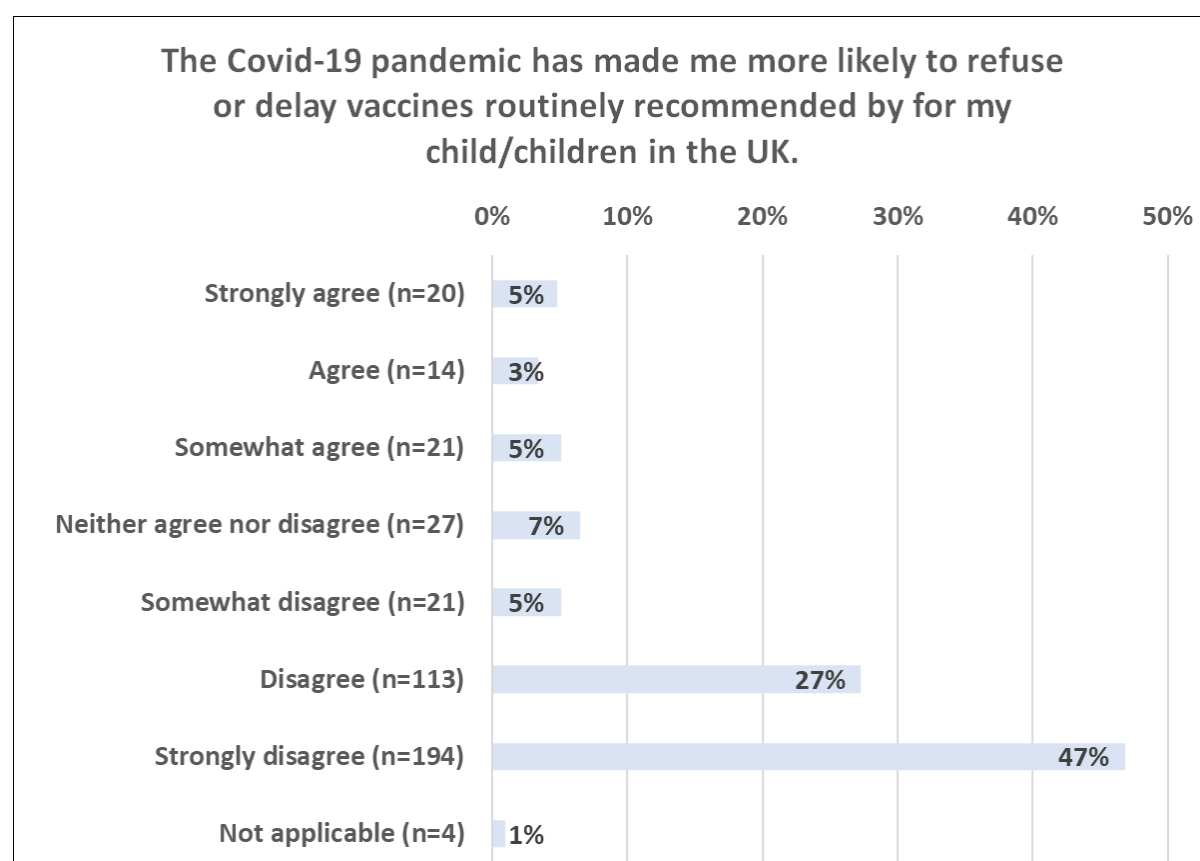
Difficulties in making/attending routine childhood vaccine appointments during pandemic.

In the free-text questionnaire responses, many respondents reported their children's routine vaccines had been delayed due to COVID-19 and finding it difficult to either schedule or attend an appointment (figure 14, appendix 34). Access difficulties during COVID-19 were more frequently cited as a reason for a delayed vaccination than choosing to delay the vaccine because the pandemic made them question or doubt vaccines. For example, one parent commented: *'For me personally in the height of the pandemic my GP services made it difficult to book any appointments so there was a lot of confusion on whether I could book*

vaccinations, my children missed the vaccinations they were due to have during the lockdown' (qu. n28).

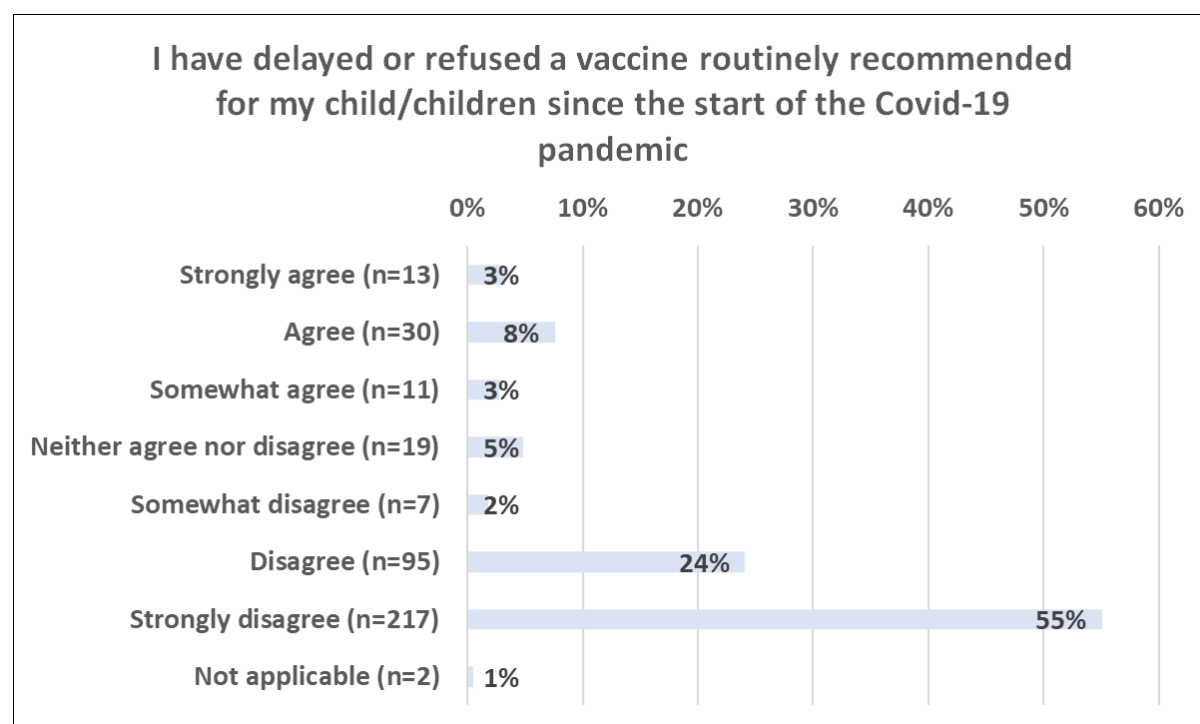
The majority (47% n=194/414) strongly disagreed that following COVID-19 they were more likely to refuse or delay a vaccine for their child (figure 16), with a further 32% (n=134/414) disagreeing or somewhat disagreeing and only 13% (n=55/414) agreeing (figure 16). Similarly, 81% (n=319/394) disagreed to some degree that the pandemic had made them refuse or delay a vaccine for their child (figure 17). Chi-square analyses however suggested that parents who answered that they belonged to an ethnicity group other than White ethnicity were more likely to refuse a vaccine ($p < 0.0001$) or had actually refused a vaccine for their child since the pandemic ($p = 0.0031$) compared to parents in the White ethnicity group (appendix 35).

Figure 16: COVID-19 pandemic and likelihood of refusing or delaying routine vaccines.



Total respondents answering question n=414.

Figure 17: COVID-19 pandemic and having refused or delayed routine vaccines.



Total respondents answering question n=394.

COVID-19 vaccinations and availability at different locations.

Several parents reported via the free-text comments that although they wanted their children to have the COVID-19 vaccine, they had struggled to get an appointment. This was also raised in the focus groups where parents discussed the lack of availability of COVID-19 vaccines as well as not wanting to have routine childhood vaccines in some of the locations where COVID-19 vaccines had been offered (figure 14, appendix 34). For example, *'With covid, ...we all get jabbed by some randomest people in some random locations. We had ours in Westminster Abbey. Nice location but I wouldn't take my child for his first vaccination there' (FG1 participant)*. This was generally perceived to be because they would rather go to a healthcare setting, including pharmacies, with a trusted healthcare professional giving their children's vaccines. For example, one parent commented *'it's reassuring that when you're at the GP you have it, because then you can ask any questions that you think of there and then...I remember having my Covid vaccine in a leisure centre and, yes, I don't know that I would want to take (them) to a leisure centre to... not somebody that I know that's vaccinating him either. Whereas even if it's a nurse that I'm not familiar with at the GP surgery, at least this is my GP surgery that I go to, they reassure me, I ask them questions. I've got that bit of a relationship' (FG3 participant)*.

6.6 Motivation

Increased belief and trust in vaccinations due to COVID-19

Some parents discussed how the pandemic had made them believe vaccinations were more important than they had previously thought and that getting their children vaccinated

was an even greater priority (figure 14, appendix 34). This is linked to the theme about the pandemic having not changed their mind about vaccines – one parent commented after the COVID-19 section of the questionnaire *'I was already a strong proponent for vaccines' (qn4)*.

Most respondents (66%) somewhat disagreed, disagreed, or strongly disagreed that the pandemic had made them question the safety of routine vaccinations for children (appendix 38) though 28% somewhat agreed, agreed, or strongly agreed that it had. There were some differences between paper and online responses to this question with more paper respondents, 63% (n=26/41) agreeing to some degree that the pandemic had made them question the safety of routine vaccines compared to only 24% of online respondents (n=89/374). Chi-square analyses suggests that parents who identified as ethnicity groups other than White ethnicity were more likely to question routine vaccine safety post covid (51% n=61/120) compared to those of White ethnicity ((18%, n=50/330), p value=<0.0001, appendix 35). Qualitative data revealed concerns such as about side effects to explain why vaccine safety has been questioned (appendix 34).

Increased vaccine misinformation

In both the free-text questionnaire responses and the focus groups, parents discussed seeing an increase in vaccine misinformation and feeling that they had to try and make sense of this post-covid (figure 14, appendix 34). For example, a parent discussed the impact of social media information on their ideas about vaccines during Covid-19 *'media leave us to change our ideas about vaccinations in Covid...Because when I heard a lot of Misinformation*

or right information or wrong information from the media...but because in the phone media everywhere...Facebook. So now we...Confused. Yes' (FG4 participant). Parents cited 'misinformation on the internet.... which is then repeated and shared among some peer groups' as being a reason for some people not agreeing with vaccines (qu. n71).

Mistrust in COVID-19 vaccines for adults

In the focus groups, particularly the in-person ones, participants discussed actively declining COVID-19 vaccines for themselves and their wider family due to scepticism about COVID-19 vaccines for adults. Some questionnaire respondents mentioned similar feelings. This was despite no specific questions about COVID-19 vaccines for adults or children. They reported not trusting COVID-19 vaccines as they were 'new' and been developed quickly. For example, one questionnaire respondent said they are *'afraid of any new vaccines including covid 19. So, we didn't have it. Nobody knows it's long-term effect' (qu. 240)*. There was also a sentiment expressed by some that they regretted getting the COVID-19 vaccines for example *'Since the pandemic we hear so much about the effects of vaccines. I wish I hadn't got the covid vaccine'. (qu. n330)*.

Increased mistrust in vaccines now

A very small minority of focus group participants and a few questionnaire respondents discussed the COVID-19 pandemic having increased their mistrust towards all vaccines (and not just specifically routine childhood ones), (figure 14, appendix 34). They cited mistrust in pharmaceutical companies and vaccination being promoted for financial gain for example *'There is a loud silence about conflict of interests of those flag bearing for vaccine production*

and their financial gain. The research and results done is/was minimal especially during the Covid era and very questionable' (qu. 138)

6.7 Key findings from study 2B

The COVID-19 sections of my mixed methods co-produced study of a questionnaire followed by focus groups found that most parents remain confident in routine childhood vaccines since the pandemic. However, I found that parents may want more information since the pandemic and may have more questions about their children's vaccinations. This maybe particularly the case for parents who belong to ethnic minority groups.

CHAPTER 7: DISCUSSION

7.1 Summary of findings

Study 1 main findings

In the birth cohort study of 795,497 children born since 2000, MMR vaccine uptake did not meet national targets and broadly reflects the nationally reported MMR vaccine uptake figures over the same time-period: MMR uptake is sub-optimal in the UK and below the national 95% target by 5 years of age.^{5 167} In the birth cohort, there was 89.4% uptake of first dose of MMR vaccine by 2 years of age. UKHSA reports similar coverage of first MMR dose: below 90% between 2000-2010 and then increasing to slightly above 90% between 2011-2020.⁵ First dose MMR uptake by 5 years of age was higher than at 2 years with 92.6% children vaccinated, this is again in line with national estimates which reported uptake of 92.4-94.3% between 2010-2020.⁵

Uptake of second dose MMR vaccine was also lower, again in line with nationally reported figures: in the cohort 85.9% of children were vaccinated with two MMR doses by age 5 years compared to national coverage estimates of 86.0-86.6%.⁵ Uptake of second dose of MMR vaccination increased at age 4 years (figure 3). This could be due to either unvaccinated 4-year-old children being invited for their second MMR, or parents taking children to be vaccinated when they are due to start school after receiving reminders to check their child's vaccination status.⁵⁹

Children living in more deprived areas had lower MMR vaccine uptake, compared to children living in least deprived areas. Children of Black ethnicity were less likely to be

vaccinated with MMR compared to children of White ethnicity. Being born to mothers aged under twenty years was also associated with lower vaccine uptake compared to mothers aged 31-40 years.

Among mothers of babies born since 2013, 61.1% were vaccinated in pregnancy against pertussis, also broadly in line with nationally reported estimates, though uptake varies geographically.⁴ After adjusting for ethnicity, deprivation and maternal age, which are all associated with both maternal and childhood vaccine uptake,^{18 20 23} children born since 2013 to mothers vaccinated against pertussis in pregnancy were 40% more likely to have their first and second dose MMR vaccines by age 5 years. To my knowledge, at the time of writing, this is the first study to assess the association between pregnancy vaccine uptake and childhood vaccine uptake in a UK birth cohort.

Study 2a main findings

The mixed-methods co-production study exploring parents' views of why some children are unvaccinated found that most parents vaccinate their children – only 15% (n=78) reported that they had ever refused or delayed a routine childhood vaccine, with the MMR vaccine the most commonly delayed or refused.

Using the COM-B model,¹⁵⁷ the questionnaire and focus groups identified the highest number of themes related to '*Opportunity*' as reasons for why children were unvaccinated (figure 9). This included different aspects of opportunity including physical access, convenience and availability of information. Parents reported inconsistent reminders about their children's vaccines, inadequate information, and physical difficulties in booking and attending their children's vaccine appointments. Over half of parents (57%) thought that vaccinations offered in different locations might make it easier to vaccinate their children, however some parents were more reluctant about going anywhere other than their own general practice and wanted their children to be vaccinated by someone they knew and trusted. Though over two thirds of parents (69%) thought drop-in clinics would make vaccinating their children easier.

Parents '*Capability*' and knowledge about vaccinating their children often related to them having questions about routine childhood vaccines, including some parents believing that it was better to delay or space out vaccines as well as a very small minority worrying that vaccines were associated with autism. Over a quarter (27%) of parents felt they had not been given enough opportunity to ask questions, nor given enough information before their

children's vaccine appointments. Parents wanted more information provided through conversations with trusted and knowledgeable health professionals, often before appointments, which parents often felt were rushed and not the right opportunity to ask questions.

Ethnic minority parents were slightly more likely to have refused a vaccine for their child compared to White ethnicity parents and nearly a half of parents (47%) from ethnic minorities would have preferred to have information about their children's vaccinations translated into their own language, by someone they knew, before appointments.

Parents' experiences of getting their child vaccinated often influenced future vaccine decisions – if parents felt they were listened to or not rushed they remembered and valued that interaction. Some parents wanted more conversations about childhood vaccinations in pregnancy or with health visitors after they had just given birth.

Parents were '*Motivated*' to get their children vaccinated because of positive attitudes among their local communities, though some mothers reported vaccine beliefs that differed from those of their family members. For example, some mothers discussed that their attitudes to the MMR vaccine differed from their child's father. Most parents (95%) thought it was important to get their children vaccinated, though among ethnic minority parents this was slightly lower (89%). A very small minority of all parents mistrusted vaccination.

Study 2b main findings

The majority (95%) of parents surveyed post pandemic continue to consider routine childhood vaccination to be important. A smaller majority (62%) reported feeling the pandemic had made them think childhood vaccination was even more important. However, while most parents still have confidence in routine childhood vaccines, some may have more questions about vaccines post COVID-19; over a third of parents reported that they had more questions post-pandemic. To my knowledge, this is the first published UK study conducted since the pandemic to examine specifically its impact on parents' vaccine attitudes, with a key finding being that parents may have more questions about vaccination as a result of the pandemic. Some parents felt the pandemic had made them question the safety of routine childhood vaccines, though the majority (66%) did not. A very small minority of parents (<10%) reported that the pandemic had made them more likely to refuse or delay a vaccine, and again a very small minority reported that their mistrust in all vaccinations has increased since the pandemic. Parents reported finding the pandemic had made booking and attending vaccination appointments harder; these difficulties were reported to be a more common reason for their children not being vaccinated or vaccinated late during or since the pandemic than COVID-19 prompting concerns about routine childhood vaccination.

COVID-19 vaccines were not asked about specifically in the questionnaire and focus groups, however many parents made unsolicited comments about them. Some parents viewed COVID-19 vaccines for children as non-essential in a similar way to the childhood nasal flu vaccine and therefore 'different' from other routine childhood vaccines. Some parents expressed negative views towards COVID-19 vaccines for children while some, particularly

those who completed the online questionnaire, felt that the UK should have recommended COVID-19 vaccines for children earlier as other countries such as the United States had done.¹⁶⁸ Some parents surveyed discussed feelings of mistrust towards COVID-19 vaccines for pregnant women or concerns over impacts on fertility.

The study was underpowered to report differences between different ethnicity sub-groups though parents who identified as belonging to ethnicity groups other than White may have more questions about childhood vaccines since the pandemic. More parents who completed the questionnaire on paper were from ethnic minorities (83% compared to 25% of all respondents), which may explain why 63% of paper respondents agreed to some extent that they had more questions since the pandemic compared to only 36% of online respondents. This difference in ethnicity between the online and paper respondents may also explain the differences with regards to other questions, such as more (63%) paper respondents reporting that the pandemic had made them question the safety of routine childhood vaccines compared to online respondents (24%).

7.2 Overall findings

Figure 18 below outlines the key findings mapped to the original research questions of the thesis.

Figure 18: Original Research Questions Mapped to Main Findings

Late or missed childhood vaccination in the United Kingdom: Identifying the determinants.	
<i>Background: What is the problem with vaccine uptake in the UK?</i>	• <i>Not enough children in the UK get vaccinated and MMR vaccine uptake is a particular problem – this has led to increasing measles outbreaks.</i>
What are the characteristics of children at risk of missing out on routine vaccines or being vaccinated late before age 5 years in the UK?	• <i>In a large birth cohort study, in keeping with previous studies, socio-demographic determinants such as whether children live in poorer areas, belong to an ethnic minority or have a teenage mother were associated with them being less likely to be vaccinated with MMR.</i>
Do children whose mothers are not vaccinated in pregnancy have a higher risk of being vaccinated late or missing vaccines before 5 years old in the UK?	• <i>A novel finding is that whether a mother gets vaccinated during pregnancy is associated with whether her child subsequently receives the MMR vaccine.</i>
Why do parents and families think some children are vaccinated late or miss out on routine vaccines?	• <i>In a mixed-methods co-produced study parents reported that access to vaccine appointments or difficulties booking appointments were barriers to their children being vaccinated. Parents also wanted more information from or discussions with health professionals before vaccine appointments to answer their vaccine questions. Some parents thought these conversations could happen in pregnancy or shortly after delivery as well.</i>
How has the COVID-19 pandemic influenced parents' attitudes towards and experiences of accessing routine childhood vaccines?	• <i>Most parents vaccinate their children and trust vaccines and only a minority refuse to vaccinate their children, even since the COVID-19 pandemic, but some parents, particularly from ethnic minorities may have more questions since the pandemic.</i>

7.3 Comparison to previous literature

Study 1

Consistent with previous smaller or regional studies,^{17 69-73} in this cohort, children born in the most deprived areas of England were 14% less likely to have the first dose of MMR vaccine by age 5 years compared to children in the least deprived areas. The association between deprivation and MMR vaccine uptake was even stronger for the second dose of MMR, with children in the most deprived areas 18% less likely to have their second MMR by age 5 years, compared to children in the least deprived areas. Children of Black or Black-British ethnicity were less likely to be vaccinated with MMR vaccines at ages 2 and 5. This finding is consistent with previous work in childhood vaccine uptake with Black or Black-British ethnicity children being less likely to be vaccinated in the UK.^{18 75} Similarly, children born to mothers aged under 20 years were less likely to be vaccinated than older mothers, as reported from previous studies.⁵⁶ Following adjustment in the multi-variable models the association between ethnicity and maternal age and vaccine uptake reduced, with deprivation remaining the greatest predictor of being unvaccinated with first and second dose MMR. Further studies since the pandemic and the endpoint of this birth cohort study in 2020 support the finding that living in a more deprived area remains a strong predictor of being unvaccinated.^{13 15}

The association between pregnancy vaccine uptake and subsequent MMR vaccination in the UK is supported by previous studies from Australia,¹¹³ where antenatal interventions to improve both maternal and childhood vaccination are already being piloted.¹¹⁴ Given that sociodemographic determinants for both pregnancy and childhood vaccine uptake in the UK are similar,¹⁸ this finding is not surprising. However, there is increasing evidence that

pregnancy vaccine intentions relate to subsequent childhood vaccine attitudes and uptake.¹¹⁵⁻

¹¹⁷ For example, COVID-19 vaccine acceptance among UK pregnant women was associated with likelihood of also accepting a COVID-19 vaccine for their children.¹¹¹

Study 2a

The mixed-methods study of parental views found that parents find it difficult to book and access vaccine appointments meaning that *opportunity* and practical barriers impact whether children are vaccinated in the UK. This finding is supported by previous research. For example, prior to the pandemic, in 2019, the Royal Society of Public Health (RSPH) surveyed UK parents and found that access to appointments was a primary factor in children missing vaccinations.¹⁰⁰ The RSPH survey, echoes this study with over 90% of parents reporting vaccinating children was important.¹⁰⁰ However, the RSPH survey included 95% respondents from White ethnicity backgrounds compared to this study which included 25% parents from ethnic minority backgrounds. More recently a smaller qualitative cohort study of sequential interviews, with 22 parents in one English city, found that accessibility issues such as difficulties booking vaccine appointments at GP surgeries were important barriers for children being vaccinated or vaccinated on time.¹⁶⁹

One in four parents in this study were unhappy with the information they were given or wanted more opportunity to ask questions of health professionals before vaccinations, which is in keeping with UKHSA attitudinal surveys.⁹⁸ The UKHSA reported that, in 2022, 32% of parents who were unsatisfied by their children's vaccine appointments felt that they were not given enough information before the vaccinations.⁹⁸ Previous studies have also found that

recommendation by healthcare providers is an important driver of vaccine uptake.^{48 100 105 170}

171

The UKHSA found parents thought appointments were too rushed, which is consistent with this study's findings and supports parents' experiences of vaccine appointments impacting future vaccine decisions. In this study over half of parents surveyed thought vaccines in alternative locations might make it easier to get their children vaccinated. However, parents in the focus groups discussed a strong preference for their children to be vaccinated by known, trusted health professionals even if they were going to alternative locations. In comparison, the UKHSA reported parents have a strong preference to having their children vaccinated at their own GP surgery. This could reflect that GP staff are known trusted health professionals.

This study highlights that access and availability of information are more important causes of UK children not being vaccinated than anti-vaccination sentiment. This is also supported by Edelstein et al who found that anti-vaccination sentiment was not the primary driver of declining childhood vaccine uptake.¹⁰⁶ Focusing on ensuring high vaccine confidence among parents and reducing vaccine misinformation¹⁷² should remain a public health priority, particularly post COVID-19.¹⁷³ However, this mixed methods study of parents' views suggests UK children are more likely to be unvaccinated due to programmatic issues as opposed to parents' anti-vaccination views. This is also the case globally – children tend to be unvaccinated due to service delivery inequities affecting underserved populations.¹⁷⁴

Study 2b

This mixed-methods study found that parents continue to think childhood vaccination is important (95%) - supporting studies conducted pre-pandemic,^{96 100} in the early phase of the pandemic in 2020¹²¹ and subsequently.⁹⁸ For example, the UKHSA 2022 parental attitudes survey found that over 90% of parents trust vaccines, think they are safe, and that they work to protect children.⁹⁸ Studies in the USA have also found parental vaccine confidence remains high as in this study, however in the United States vaccine hesitancy, defined as indecisiveness about vaccination,¹⁷⁵ may have increased since COVID-19.¹²³ In one US study the impact of the pandemic on routine vaccine attitudes is highly correlated to attitudes towards COVID-19 vaccines – parents' experiences and beliefs about COVID-19 vaccines relate to their childhood vaccine beliefs.¹²⁴ A study (not yet peer reviewed) reporting on a survey of 14,720 UK parents conducted in 2020, 2021 and 2022 also found that parents who did not receive at least three doses of a COVID-19 vaccine were less positive about vaccinating their children.¹⁷⁶

The high number of responses mentioning COVID-19 vaccines in this study, though they were not specifically asked about, highlights the heightened public discourse about vaccination during COVID-19.^{173 177} This also likely reflects the timing of the questionnaire in 2022 which coincided with the JCVI making a non-urgent recommendation of COVID-19 vaccines for 5-11 year olds.¹⁷⁸ In this study, parents reported feeling that COVID-19 vaccines were 'non-essential' for children which is also in keeping with other studies - parents may be less willing to accept COVID-19 vaccines for their children compared to themselves.^{179 180} A study in the USA found that parents' main reason for not wanting to

vaccinate their children against COVID-19 was due to concerns about vaccine safety and side-effects.¹⁸¹

Parents reported uncertainty and confusion around the advisability of COVID-19 vaccines for women of reproductive age which is in keeping with previous research reporting women's concerns about vaccination in pregnancy and fertility concerns.^{111 182} These themes related to vaccination and pregnancy also support the findings from study 1 of this thesis: the attitudes towards, and the uptake of, vaccines in pregnancy are associated with subsequent childhood vaccine uptake.^{113 132}

The impact of the pandemic worldwide has been that fewer children overall are getting vaccinated due to logistical or programmatic barriers caused by health service disruption,¹⁸³ more than due to changing attitudes. The findings from this mixed-methods study in the UK support this – parents may have more questions and want to talk to health professionals about vaccines more since the pandemic, but children were less likely to be vaccinated in the UK due to the pandemic impacting access to vaccinations as opposed to increasing vaccine mistrust. A UK survey of parents (not yet peer reviewed) has also reported that parental refusal of routine childhood immunisations decreased between 2020 and 2022.¹⁷⁶

7.4 Strengths and limitations

Study 1

The main strength of this retrospective cohort study using CPRD is the large, representative sample,¹³⁷ which reduces the possibility that the findings are due to chance and means the analysis was highly powered. Though with any observational cohort study, there may be important biases relating to medical coding accuracy, data completeness and loss to follow-up that need consideration. Almost all vaccinations occur in primary care in the UK, with the primary care record the data source for nationally reported vaccine uptake figures, so the vaccination estimates are likely to be reliable. However, the CPRD database would not capture vaccinations received in other settings such as hospitals, but this is likely to be the case for only a very small minority of children. Some pregnant women may be vaccinated in hospital maternity units and not be recorded in the GP records so we may have underestimated pregnancy vaccine uptake.⁴ I also did not examine influenza vaccine uptake among pregnant women in addition to the pertussis vaccine as an indicator of mothers who take up maternal vaccines. This is due to the seasonality of the influenza vaccine programme making it difficult to identify eligible pregnancies. Pertussis vaccine in contrast is offered to all pregnant women year round.

A main source of bias in the findings could arise from children being lost to follow-up, however by using survival analysis methods, and only analysing second MMR uptake among children still in the cohort when their second MMR was due, this was minimised. Children who deregistered from their practice before the age of 1 year were excluded from the cohort, as they were never eligible for their first dose of MMR. However, moving during

pregnancy and early childhood has been found to be associated with lower vaccine uptake.⁸⁵ The CPRD cohort could be biased and include families less likely to move and thus more likely to vaccinate their children. This bias may explain the finding that first born or only children had lower vaccine uptake compared to larger families, which is not consistent with previous studies, in which larger family sizes have been found to be associated with increased chance of missing childhood vaccines.^{56 74} The families in the cohort may have been more likely to have their children vaccinated anyway due to being less likely to have moved, or using their knowledge and experience of having older children vaccinated. For example, research during COVID-19 found that mothers often relied on knowledge from previous pregnancies when accessing childhood vaccinations.¹²² The findings from the mixed-methods co-produced study in this thesis also support parents' experiences of getting their children vaccinated influencing future vaccine attitudes and decisions. Multiple births were also not looked at as a separate variable however these are likely to have been a very small (<1%) proportion of the cohort¹⁴⁵ and not influenced the findings.¹⁴⁶

Incompleteness of ethnicity and deprivation data is the main limitation of the birth-cohort study and likely arose as the cohort is historical, extending back to 2000, when medical coding and in particular ethnicity coding was less complete.^{137 184} In the cohort 40% were missing ethnicity coding. The proportion of children in the ethnic minority groups was small, for example, only 13,816, (1.7%) of children in the cohort were Black or Black-British compared to 4% of the population of England and Wales.¹⁴⁸ Though 17% of my cohort were Scottish where only 1% of the population are Black or Black-British according to census data.¹⁸⁵ As a result, the study lacked the power to identify associations between different smaller ethnicity groups which may have given more granular detail than the higher order

ethnicity groupings used in the analysis. There was deprivation data for the majority (77%) of the England cohort though deprivation data for other UK nations is not available for CPRD data linkage.

I was not able to account for confounding factors that may have influenced both maternal and childhood uptake such as maternal education,⁵⁶ as this information is not routinely recorded in the primary care record. In the final multi-variable models, nation and family size were not included, however these are unlikely to have influenced the finding that deprivation is the greatest predictor of whether a child is vaccinated with MMR as this is consistent with previous studies on the predictors of childhood vaccine uptake.¹⁶ It has been previously reported that once deprivation is adjusted for, the association of other factors such as ethnicity or having a child with a developmental disability and childhood vaccine uptake is reduced.^{16 90}

Another limitation is the historical nature of this cohort as fewer practices have contributed to CPRD Gold in more recent years. However, the trends in MMR vaccine uptake are relevant for the UK today as MMR vaccine uptake has fallen further since, exacerbating existing inequalities and leading to increasing outbreaks of measles.^{7 59 186}

Study 2a & 2b

This mixed methods co-produced study's main strength is that partnering with Mosaic enabled targeted recruitment in an area of North-West London with an historically low vaccine uptake. A quarter of parents surveyed were from ethnic minority groups which is a

higher proportion than previous UK parental vaccine surveys.^{98 100 121} The study also included more parents from London compared to previous surveys⁹⁸ which is another strength given London's historically lower vaccine uptake and rising measles cases.⁷ The mixed-methods approach of a questionnaire followed by focus groups also allowed richer insight into parents' attitudes and experiences.

In the UK, children belonging to ethnic minorities are less likely to be vaccinated,¹⁴ however the study was underpowered to describe parental attitudes and experiences by ethnicity subgroup. The aggregation of non-White ethnicity into one group is a significant limitation and fails to appreciate the heterogeneity of groups classified as ethnic minorities in the UK and the multi-dimensional concept of ethnicity.¹⁸⁷ There were also varying numbers of parents completing each question in the questionnaire; those that chose not to answer certain questions may be different to those that did, thus biasing the results.

The parents were not asked their attitudes pre-pandemic therefore a limitation is that the study cannot directly compare the impact of the pandemic on the study participants' individual vaccine attitudes. Also, due to eligibility, the parents questioned included both those who had children pre-pandemic, whose pre-existing attitudes may have been changed by the pandemic, and parents who had children during the pandemic, whose vaccine attitudes may have been influenced by giving birth during COVID-19. The questionnaire was live in 2022, and the focus groups took place in 2023 so parents may also have inaccurately recalled the impact of the pandemic on their access to vaccinations. However, researching attitudes two years after the start of the pandemic enabled its longer-term implications on routine vaccine attitudes to be explored.

7.5 Overall Strengths and Limitations

The findings from this thesis may have been more relevant if the cohort study and mixed-methods co-produced study had studied similar populations and complimented each other further. The retrospective cohort study examined babies born up until 2020 and their characteristics, as well as how maternal vaccination impacted subsequent childhood MMR vaccine uptake among babies born since 2013. However, the mixed-methods study examined attitudes among parents in 2022 and 2023. It may have been more complimentary to the cohort study if the questionnaire and focus groups had included pregnant women and questions about their pregnancy vaccination and subsequent children's vaccination. However, overall, the cohort study describes *which* children are missing out on their vaccines and the mixed-methods co-produced study offers insight into *why* those children may not be getting vaccinated, including the impact of the COVID-19 pandemic.

CHAPTER 8: RECOMMENDATIONS AND CONCLUSION

Implications for policy, practice and future research

8.1 Target Resource and Interventions in More Deprived Areas

My 20-year birth-cohort study found being born in a more deprived area is the strongest predictor of not getting two doses of the MMR vaccine. This supports targeting interventions and resource to increase childhood MMR uptake towards the poorest areas. To reduce the MMR vaccine uptake inequalities the current inequities in general practice resource allocation need addressing,¹⁸⁸ particularly as inequalities have increased since the COVID-19 pandemic.¹³ For example, populations in more deprived areas tend to have more complex health and social care needs compared to less deprived areas,¹⁸⁹ as well as less primary care staff.¹⁹⁰ GPs in more deprived areas therefore may need to use greater resource to increase vaccine uptake among their local population or have less time and resource available compared to practices in less deprived areas. The National Institute of Health and Care Excellence (NICE), 2022 guidelines to increase vaccine uptake advised that interventions should be tailored to local population needs.¹⁷⁰ My findings from study 2 supports focussing interventions in more deprived areas, with low vaccine uptake, primarily on improving access to vaccinations as well as access to healthcare professionals who can answer parents' vaccine questions - as outlined below.

8.2 Prioritise Facilitating Access to Routine Childhood Vaccine Appointments

My findings provide further evidence that UK parents have confidence in vaccination, and that anti-vaccination sentiment is not the main driver of parents delaying or not

vaccinating their children, even since COVID-19. MMR vaccines were the most commonly delayed or refused, which reflects the low national uptake and current resultant outbreaks.^{5 7}

My research supports interventions focusing on improving access to vaccinations as is recommended in NICE guidance and the National Vaccine Strategy.^{130 170} Interventions to increase MMR and other vaccines uptake will need to be multi-component.¹⁷⁰ For example by improving availability of vaccination appointments through increasing after school appointments, as well as providing consistent reminders and recall and possibly opportunistic vaccination services.^{101 102 170} However, while opportunistic vaccine clinics in locations such as schools, are often set up in response to outbreak situations,⁷ my findings suggest parents may prefer trusted, known health professionals to vaccinate their children, which may be difficult to offer at vaccine clinics set up in alternative locations. However, over two thirds of parents surveyed thought drop-in clinics would make it easier to vaccinate their children.

8.3 Provide Easy Opportunities for Parents to ask Questions

My research supports conversations with health professionals as key factors influencing parents' attitudes and confidence in taking their children for vaccinations, as opposed to health information online or leaflets. This suggests that as well as more convenient vaccine clinics, parents need easier access to trusted health professionals to answer vaccine questions. This is particularly the case since COVID-19, and ethnic minority parents may have more questions. All healthcare workers that see families therefore need to have the training and skills to be able to confidently answer parents' vaccine questions.^{105 191} For example, I found some parents still have concerns about the MMR vaccine and autism so

healthcare workers must be equipped with the knowledge and skills to address these concerns when raised by parents.

Parents reported valuing conversations with health visitors^{192 193} or midwives,¹⁹⁴⁻¹⁹⁶ so education of these staff groups also needs to be prioritised. Supporting midwives and health visitors to opportunistically raise and discuss vaccinations with families, at any appointment, also links to targeting both pregnancy and childhood vaccine uptake together as outlined below.

8.4 Consider Research into Antenatal Interventions that Target both Maternal and Childhood Vaccinations

My findings that pregnancy and childhood vaccine uptake are related suggest that interventions to increase vaccine uptake could start much earlier when parents are first expecting a baby. Pregnancy offers a unique opportunity to promote, inform and support new parents in accessing routine maternal and childhood vaccines.¹¹⁵ Healthcare professionals should opportunistically promote vaccination at any encounter with parents,¹⁰⁰ across the life-course, to reduce maternal and childhood vaccine uptake inequalities in the UK.¹³¹ The addition of the RSV vaccine for pregnant women to the routine schedule,⁴⁹ so pregnant women are now being offered RSV, pertussis and seasonal influenza vaccines makes maternal vaccination an even larger component of the routine vaccination schedule in the UK and an increasingly important factor in protecting children's future health. A maternal vaccination against Group B Streptococcal infection may also be added in the future.¹⁹⁷ Initial RSV maternal vaccine uptake figures from UKHSA suggests pre-existing inequalities based on ethnicity are persisting,¹⁹⁸ thus maximising maternal vaccine uptake remains a priority.¹⁷⁰

In Australia a pilot maternal intervention to address both maternal and childhood vaccination targeted three aspects of pregnant women's healthcare encounters: changing 'practice' by having vaccine champions, improving 'providers' knowledge of vaccines and also giving 'parents' reminders and resources.¹¹⁴ However, whether maternal interventions to increase childhood vaccine uptake, such as the Australian pilot, would be applicable and effective in a UK setting is unknown and should be explored in further research. Given the importance of access to vaccines, maternal interventions in the UK could explore not just promoting childhood vaccines to pregnant women but also help families access vaccine appointments. This could be by enabling health visitors or midwives to book vaccination appointments for families or direct families to opportunistic vaccination services if available. A life course approach that maximises access could also consider older siblings when health visitors or midwives visit families- is there an older sibling in the family who hasn't been vaccinated against MMR whom the midwife or health visitor can support in getting vaccinated. However, such interventions would need strong integration between different NHS services as well as robust underlying data systems.

8.5 Tailor Interventions to Consider Multiple Dimensions of local Ethnicity and Cultural Networks in Areas of Low Vaccine Uptake.

Interventions to increase vaccine uptake need to be tailored to consider the multiple dimensions of local religious, cultural and ethnicity networks.^{84 104} For example, my findings suggest the importance of using trusted, known local community translators, where appropriate, to deliver vaccine information to ethnic minority parents through conversations in different languages. My research also suggests that this maybe even more important since

the pandemic. Future research should seek to unpick variation between different ethnic minority groups' attitudes and experiences of childhood vaccination and how interventions can be tailored to address inequalities which is also supported by the NICE guidance.¹⁷⁰

Religion, ethnicity and deprivation have been found to intersect with regards to childhood vaccination attitudes and access in the UK.^{80 100 199} For example, Muslim parents in the UK may refuse the childhood nasal influenza vaccine due to concerns about porcine gelatine content,⁹⁷ however co-producing research with Mosaic has emphasised the importance of being cautious about associations between vaccine acceptance and religion. Over 80% of the paper respondents to the questionnaire were from ethnic minorities and gave their religion as Muslim, of whom 63% thought the pandemic had made them more likely to question the safety of routine childhood vaccines compared to 24% of online respondents.

Future research could consider how local religious networks can be utilised to increase childhood vaccine uptake among predominantly Muslim communities such as where the Mosaic Community Trust is based. For example, targeted interventions to address attitudes and access to childhood vaccinations among UK orthodox Jewish families who have low vaccine uptake have been previously developed.¹⁵⁸ To address declining vaccine uptake tailored interventions must consider intersecting religious, cultural and ethnicity dimensions in areas of low vaccine uptake.

8.6 Implications for a UK Accelerated MMR vaccination schedule

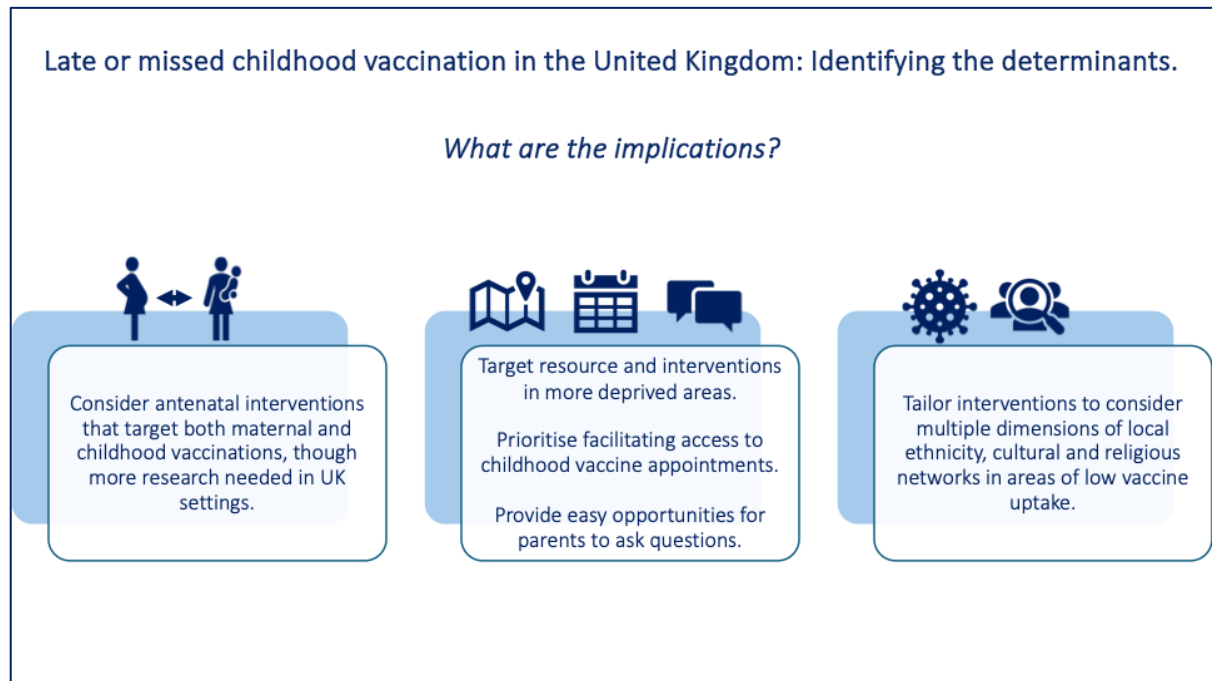
In a statement on the childhood immunisation schedule in the UK, in 2022, the JCVI advised that the NHS should consider offering the second dose of MMR vaccine at 18 months instead of at the current 3 years 4 months to improve coverage.²⁰⁰ It is now expected that an additional vaccination appointment will be added to the schedule at 18 months in 2025/early 2026 to deliver this second MMR dose and a booster Hib dose in the form of the hexavalent vaccine.²⁵

Second dose MMR uptake has been historically lower in the UK, as I also found, so new considerations to increase uptake are needed. An ecological study of the impact of an accelerated, earlier second MMR dose in an area of London on vaccine uptake found that it increased uptake, but more research is needed to understand the impact on particular demographic groups.²⁰¹ My findings support such a change to the schedule as the majority of children who get vaccinated with one MMR vaccine do so by age 2 years (89.4%), with coverage only increasing slightly to 92.6% by age 5 years. This suggests that families are more likely to engage with preventive vaccinations at earlier ages, which is also supported by the higher uptake of primary vaccines at 2, 3 and 4 months of age in the UK.⁵ Delays in childhood vaccine have been found to increase with age as well, with later vaccinations more likely to be missed.⁹²

Overall Recommendations from Thesis

These are shown in figure 19 below.

Figure 19: Recommendations



Personal Reflections

Cohort study using CPRD

I initially found using CPRD for the first time very challenging – mainly in terms of how to approach cleaning the dataset and linking the different files. I felt there was a gap in the department for peer-to-peer support for researchers using CPRD. Therefore, in 2021, I set up the Department of Primary Care and Public Health's, Clinical Practice Research Datalink (CPRD) User group. I led the group for three years until 2024 which included arranging external expert speakers. I am grateful it is now embedded as a peer support group within the School of Public Health to hopefully assist future projects and researchers with studies.

Co-production research

In the methods chapter for study 2 of this thesis I discussed how I had tried to adhere to the principals of co-production in my research. Partnering with Mosaic has enabled this research to ensure the voices of ethnic minority parents, living in a more deprived area, with low vaccine uptake were considered. Reflecting on this experience is important. Working with Lena, Habiba, Fahmida and Louise and the wider Mosaic team has been a valuable and rewarding experience and it has been a pleasure to get to know an inspiring and interesting group of women. I hope to take forward co-production methods into my post-doctoral work using what I have learnt as outlined below.

I have learnt that co-production **relies on strong community relationships**, and these cannot be developed quickly, which is often out of step with some smaller, short-term patient and public involvement grants. I have invested in my relationship with Mosaic since 2018 and

even just attending community meetings and listening to people's views and ideas have all informed and helped this research.

I appreciate that Mosaic and all the women whose views I was interested in, have busy schedules and demands like everyone else. I have learnt to **be flexible and adapt my schedule** to theirs. For example, coinciding my meetings with Mosaic's community group's regular bi-weekly sessions was much easier than trying to arrange separate meetings. Mosaic made sure events were informal and relaxed which helped members of the public, particularly for whom English is not their first language and/or who may have been born abroad, feel comfortable in sharing their ideas. I am incredibly grateful for all the time and energy Mosaic and their members gave.

I have tried to make sure that I have **never expected Mosaic to give any time for free**. I paid Mosaic for any time they spent on the project-even quick telephone calls or meetings. I have also tried to **mutually help** Mosaic with small jobs such as helping them with briefing notes or tidying up PowerPoint presentations. For example, throughout our partnership I have tried to help arrange external speakers. For example, I and Professor Beate Kampmann ran question and answer sessions for Mosaic on COVID-19 vaccines alongside local GPs and Imams. Celine Lewis, one of my supervisors also ran an education session for Mosaic on running focus groups. Mosaic were also always co-authors on my academic outputs relating to the project.

I was lucky that my research topic of vaccination was a **priority for the community** even when we were developing the funding bid in 2019 – many mothers had questions.

However, the pandemic, made my research become even more important to community members. In my post-doctoral work, it will be important to ensure that my work stays **relevant and important to community partners**. However, I think we were too ambitious with the length of the questionnaire and tried to cover every topic around vaccinating children. Even though we piloted the questionnaire among Mosaic it was too long when they did it with mothers and in further research, I would aim to be more focused. By providing an alternative format of paper questionnaires that Mosaic Community Health Workers completed with some parents alongside the online format, also increased representativeness- a higher proportion of ethnic minority parents completed the paper questionnaire.

I have also learnt that as a researcher you must be **willing to change your own preconceived ideas** on topics. An example of this is from our brainstorming sessions in summer 2021, which came just after a lot of the Mosaic mothers had first been invited to have the COVID-19 vaccine. However, many of them had chosen not to get vaccinated during Ramadan. I had thought this was due to their religious beliefs and thought we needed to do more sessions on the COVID-19 vaccines alongside local Imams, as we had done previously. I was astonished that in fact they knew that getting vaccinated during Ramadan was fine from a religious perspective but that it was the practical impact of Ramadan on their lives that stopped them wanting to either get the COVID-19 vaccine for themselves or for example indeed an MMR vaccine for their child. Mothers were waking before dawn to prepare food and then staying up late again cooking for their families. They did not have the time or energy to deal with even potentially mild side-effects following getting vaccinated and that was why they waited until the end of Ramadan. A lot of time and resource during COVID-19 was spent for example in trying to ensure different religious groups understood the importance of

vaccines, for example, but for the mothers I was working with, the practicalities of their lives were more important. This is I think is echoed in my overall findings: – practical barriers stop children being vaccinated in the UK more than a lack of vaccine confidence.

Conclusion

The majority of parents in the UK vaccinate their children and are confident in routine childhood vaccinations. However, uptake of both childhood and maternal vaccines has been declining since before the pandemic. Living in a more deprived area is the greatest determinant of whether children are likely to be vaccinated before age 5 years with their two doses of MMR vaccines.

Access barriers such as difficulties booking and attending vaccine appointments determine whether some children are unvaccinated in the UK, more than parents holding anti vaccination views. However, some parents who want to vaccinate their children would prefer more information or more opportunities to ask questions before their children's vaccine appointments. Ideally, parents want this information delivered by having a conversation with a trusted, known, health professional. Parents, particularly those from ethnic minority families, may also have more questions about childhood vaccines since COVID-19.

Health professionals need time, resource, and training to be able to confidently answer parents' questions about routine vaccinations, at every contact with families. This includes midwives and health visitors who see women during pregnancy and shortly after birth, as maternal vaccine uptake is an independent predictor of MMR vaccine uptake in the UK. Healthcare professionals and services could therefore consider developing and evaluating antenatal interventions to promote and facilitate access to both maternal and childhood vaccines.

To address declining uptake and prevent outbreaks of infectious diseases such as measles it needs to be easier and more convenient for parents to get their children vaccinated and ask health professionals questions, particularly in more deprived areas of the UK.

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Appendices

Appendix 1: The Complete Routine Immunisation Schedule January 2025



The complete routine immunisation schedule				From January 2025
Age due	Diseases protected against	Vaccine given and trade name		Usual site ¹
Eight weeks old	Diphtheria, tetanus, pertussis (whooping cough), polio, <i>Haemophilus influenzae</i> type b (Hib) and hepatitis B	DTaP/IPV/Hib/HepB	Infanrix hexa or Vaxelis	Thigh
	Meningococcal group B (MenB)	MenB	Bexsero	Thigh
	Rotavirus gastroenteritis	Rotavirus ²	Rotarix ²	By mouth
Twelve weeks old	Diphtheria, tetanus, pertussis, polio, Hib and hepatitis B	DTaP/IPV/Hib/HepB	Infanrix hexa or Vaxelis	Thigh
	Pneumococcal (13 serotypes)	Pneumococcal conjugate vaccine (PCV)	Prevenar 13	Thigh
	Rotavirus	Rotavirus ²	Rotarix ²	By mouth
Sixteen weeks old	Diphtheria, tetanus, pertussis, polio, Hib and hepatitis B	DTaP/IPV/Hib/HepB	Infanrix hexa or Vaxelis	Thigh
	MenB	MenB	Bexsero	Thigh
One year old (on or after the child's first birthday)	Hib and MenC	Hib/MenC	Menitorix	Upper arm/thigh
	Pneumococcal	PCV booster	Prevenar 13	Upper arm/thigh
	Measles, mumps and rubella (German measles)	MMR	MMRvaxPro ³ or Priorix	Upper arm/thigh
	MenB	MenB booster	Bexsero	Thigh
Eligible paediatric age groups ⁴	Influenza (each year from September)	Live attenuated influenza vaccine LAIV ^{5,6}	Fluenz ^{3,6}	Both nostrils
Three years four months old or soon after	Diphtheria, tetanus, pertussis and polio	dTaP/IPV	Boostrix-IPV	Upper arm
	Measles, mumps and rubella	MMR (check first dose given)	MMRvaxPro ³ or Priorix	Upper arm
Boys and girls aged twelve to thirteen years	Cancers and genital warts caused by specific human papillomavirus (HPV) types	HPV ⁵	Gardasil 9	Upper arm
Fourteen years old (school Year 9)	Tetanus, diphtheria and polio	Td/IPV (check MMR status)	Revaxis	Upper arm
	Meningococcal groups A, C, W and Y	MenACWY	MenQuadfi	Upper arm
65 years old	Pneumococcal (23 serotypes)	Pneumococcal Polysaccharide Vaccine (PPV23)	Pneumovax 23	Upper arm
65 years of age and older	Influenza (each year from September)	Inactivated influenza vaccine	Multiple	Upper arm
65 from September 2023 ⁷	Shingles	Shingles vaccine	Shingrix	Upper arm
70 to 79 years of age (plus eligible age groups and severely immunosuppressed) ⁷	Shingles	Shingles vaccine	Zostavax ^{3,7} (or Shingrix if Zostavax contraindicated)	Upper arm
75 years of age	Respiratory syncytial virus (RSV)	RSV vaccine	Abrysvo	Upper arm

1. Intramuscular injection into deltoid muscle in upper arm or anterolateral aspect of the thigh.
 2. Rotavirus vaccine should only be given after checking for SCID screening result.
 3. Contains porcine gelatine.
 4. See annual flu letter at: www.gov.uk/government/collections/annual-flu-programme
 5. See Green Book HPV Chapter 18a for details on immunising immunocompromised young people who will need 3 doses.

6. If LAIV (live attenuated influenza vaccine) is contraindicated or otherwise unsuitable use inactivated flu vaccine (check Green Book Chapter 19 for details).
 7. See Green Book Shingles Chapter 28a for details on eligible age groups including severely immunosuppressed individuals from age 50.



For vaccine supply information for the routine immunisation schedule please visit portal.immform.ukhsa.gov.uk and check Vaccine Update for all other vaccine supply information: www.gov.uk/government/collections/vaccine-update



The safest way to protect children and adults



immunisation schedule From January 2025

plete routine

Selective immunisation programmes			
Target group	Age and schedule	Disease	Vaccines required
Babies born to hepatitis B infected mothers	At birth, four weeks and 12 months old ^{1,2}	Hepatitis B	Hepatitis B (Engerix B/HBvaxPRO)
Infants in areas of the country with TB incidence $\geq 40/100,000$	Around 28 days old ⁴	Tuberculosis	BCG
Infants with a parent or grandparent born in a high incidence country ³	Around 28 days old ⁴	Tuberculosis	BCG
Children in a clinical risk group	From 6 months to 17 years of age	Influenza	LAIV or inactivated flu vaccine if contraindicated to LAIV or under 2 years of age
Pregnant women	At any stage of pregnancy during flu season	Influenza	Inactivated flu vaccine
	From 16 weeks gestation ⁵	Pertussis	Tdap (ADACEL)
	From 28 weeks gestation	RSV	RSV vaccine (Abrysvo)

1. Take blood for HBsAg at 12 months to exclude infection.

2. In addition hexavalent vaccine (Infanrix hexa or Vaxelis) is given at 8, 12 and 16 weeks.

3. Where the annual incidence of TB is $\geq 40/100,000$ – see www.gov.uk/government/publications/tuberculosis-tb-by-country-rates-per-100000-people

4. Check SCID screening outcome before giving BCG.

5. Ideally before 32 weeks gestation but may still be given after 32 weeks.

Additional vaccines for individuals with underlying medical conditions		
Medical condition	Diseases protected against	Vaccines required ¹
Asplenia or splenic dysfunction (including due to sickle cell and coeliac disease)	Meningococcal groups A, B, C, W and Y Pneumococcal Influenza	MenACWY MenB PCV13 (up to 10 years of age) ² PPV23 (from 2 years of age) Annual flu vaccine
Cochlear implants	Pneumococcal	PCV13 (up to 10 years of age) ² PPV23 (from 2 years of age)
Chronic respiratory and heart conditions (such as severe asthma, chronic pulmonary disease, and heart failure)	Pneumococcal Influenza	PCV13 (up to 10 years of age) ² PPV23 (from 2 years of age) Annual flu vaccine
Chronic neurological conditions (such as Parkinson's or motor neurone disease, or learning disability)	Pneumococcal (only if the individual is also at increased risk of aspiration) Influenza	PCV13 (up to 10 years of age) ² PPV23 (from 2 years of age) Annual flu vaccine
Diabetes	Pneumococcal Influenza	PCV13 (up to 10 years of age) ² PPV23 (from 2 years of age) Annual flu vaccine
Chronic kidney disease (CKD) (including haemodialysis)	Pneumococcal (stage 4 and 5 CKD) Influenza (stage 3, 4 and 5 CKD) Hepatitis B (stage 4 and 5 CKD)	PCV13 (up to 10 years of age) ² PPV23 (from 2 years of age) Annual flu vaccine Hepatitis B
Chronic liver conditions	Pneumococcal Influenza Hepatitis A Hepatitis B	PCV13 (up to 10 years of age) ² PPV23 (from 2 years of age) Annual flu vaccine Hepatitis A Hepatitis B
Haemophilia	Hepatitis A Hepatitis B	Hepatitis A Hepatitis B
Immunosuppression due to disease or treatment ⁴	Pneumococcal Shingles vaccine Influenza	PCV13 (up to 10 years of age) ^{2,3} PPV23 (from 2 years of age) Shingrix – over 50 years of age ⁵ Annual flu vaccine
Complement disorders (including those receiving complement inhibitor therapy)	Meningococcal groups A, B, C, W and Y Pneumococcal Influenza	MenACWY MenB PCV13 (up to 10 years of age) ² PPV23 (from 2 years of age) Annual flu vaccine

1. Check relevant chapter of the Green Book for specific schedule: www.gov.uk/government/collections/immunisation-against-infectious-disease-the-green-book

2. If aged 2 years to under 10 years of age and unimmunised or partially immunised against pneumococcal infection, give one PCV13 dose.

3. To any age in severely immunosuppressed.

4. Consider annual influenza vaccination for household members and those who care for people with these conditions.

5. Check Green Book Shingles Chapter 28a www.gov.uk/government/publications/shingles-herpes-zoster-the-green-book-chapter-28a

immunisation

The safest way to protect children and adults

NHS

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https://assets.publishing.service.gov.uk/media/677ff43f22A085c5ff5c0548/UKHSA_13197_Complete_Immunisation_schedule_01A_WEB.pdf

Appendix 2: Code lists for MMR & Maternal Pertussis Vaccination

MMR Vaccination

Read Codes	Product codes for therapy files
<i>Measles Vaccine Codes</i>	<i>MMR codes</i>
65A1.00	18912
65A..00	18172
<i>MMR Vaccine Codes</i>	20845
65M1.00	3906
65MA.00	1033
<i>Measles refused</i>	38476
68NB.00	<i>Measles codes</i>
<i>Mumps</i>	12711
65F5.00	4189
<i>Rubella</i>	9089
65B..00	12005
<i>Measles refused</i>	15473
68NB.00	<i>Mumps Codes</i>
	25157
	4190
	11016
	<i>Rubella Codes</i>
	2244
	49697
	10348
	30506
	10335
	3468

Pertussis Vaccination

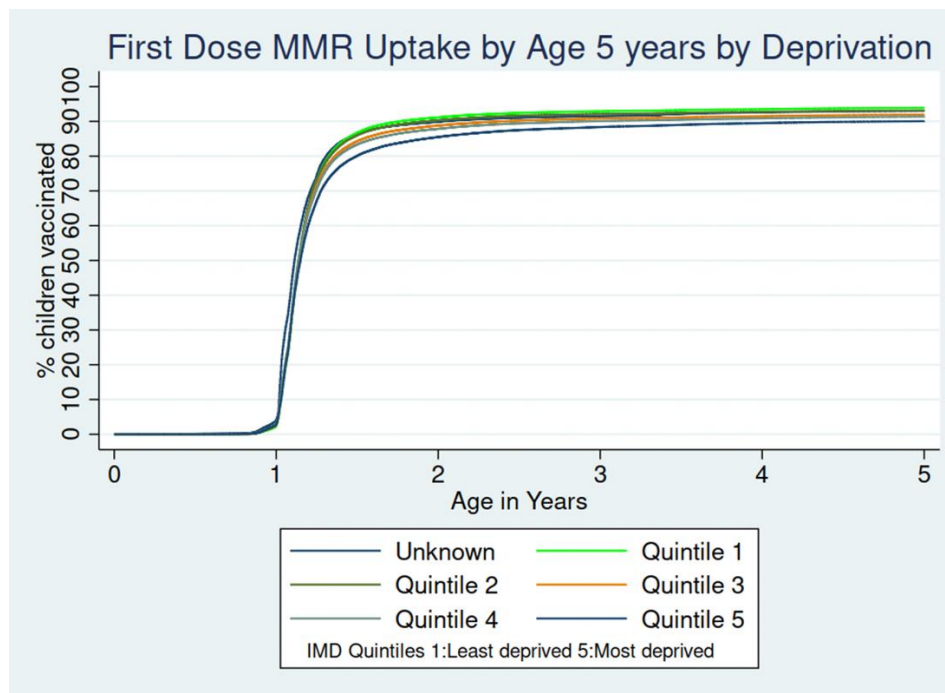
Read Code	
6556	Pertussis vaccination in pregnancy
6556000	Pertussis vaccination in pregnancy given by other healthcare provider
ZV03611	Whooping cough vaccination
655..11	Whooping cough vaccination
6553	Third pertussis vaccination
6551	First pertussis vaccination
6552	Second pertussis vaccination
ZV03600	[V]Pertussis vaccination
655..00	Pertussis vaccination

655Z.00	Pertussis vaccination NOS
9kv..00	Pertussis vaccination programme pregnant women enhanced service admin
6555	Pertussis vaccination given by other healthcare provider
6554	Pertussis booster vaccination
ZV06300	[V]Diphtheria-tetanus-pertussis + poliomyelitis vaccination
ZV06100	[V]Diphtheria-tetanus-pertussis, combined (DTP) vaccination
65I4.00	Booster diphtheria tetanus pertussis (DTaP) + polio vaccination
65H4.00	Booster diphtheria tetanus pertussis (DTaP) vaccination

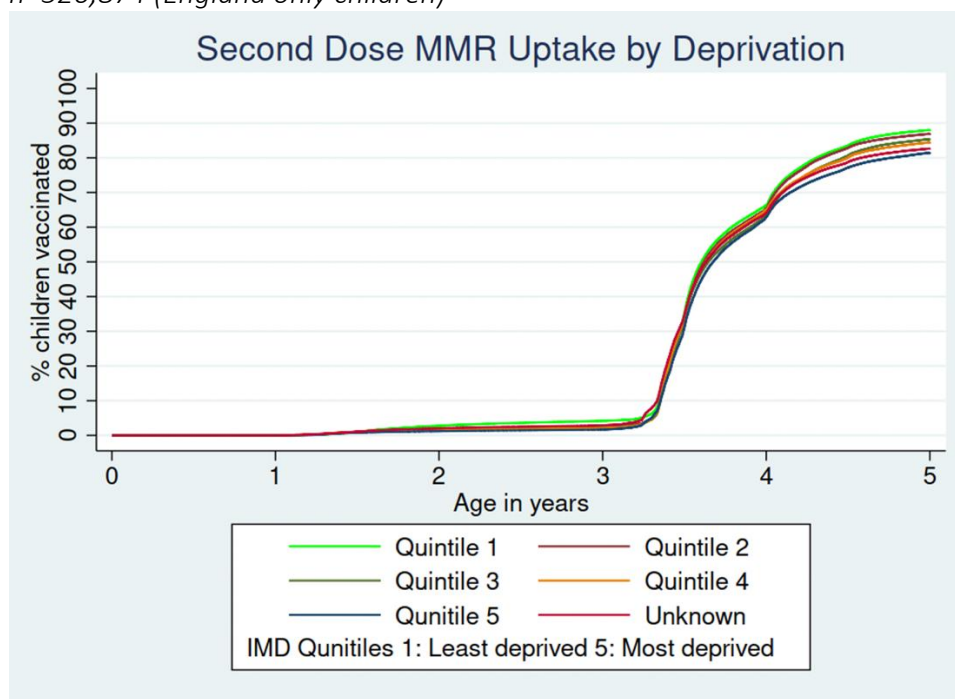
Appendix 3: Year of birth across the Cohort

Year of birth	n	%
2000-2001	60,657	7.63%
2002-2003	78,439	9.86%
2004-2005	93,362	11.74%
2006-2007	100,011	12.57%
2008-2009	103,307	12.99%
2010-2011	102,790	12.92%
2012-2013	92,512	11.63%
2014-2015	68,879	8.66%
2016-2017	53,185	6.69%
2018-2020	42,355	5.32%
Total	795,497	100.00%

Appendix 4: Uptake of MMR by Deprivation

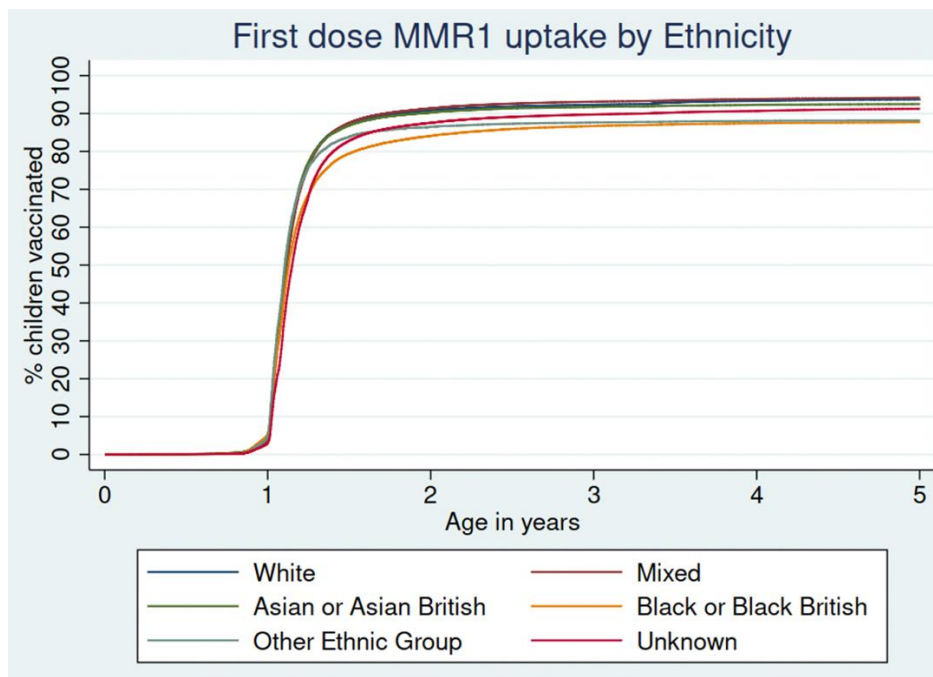


n=520,874 (England only children)

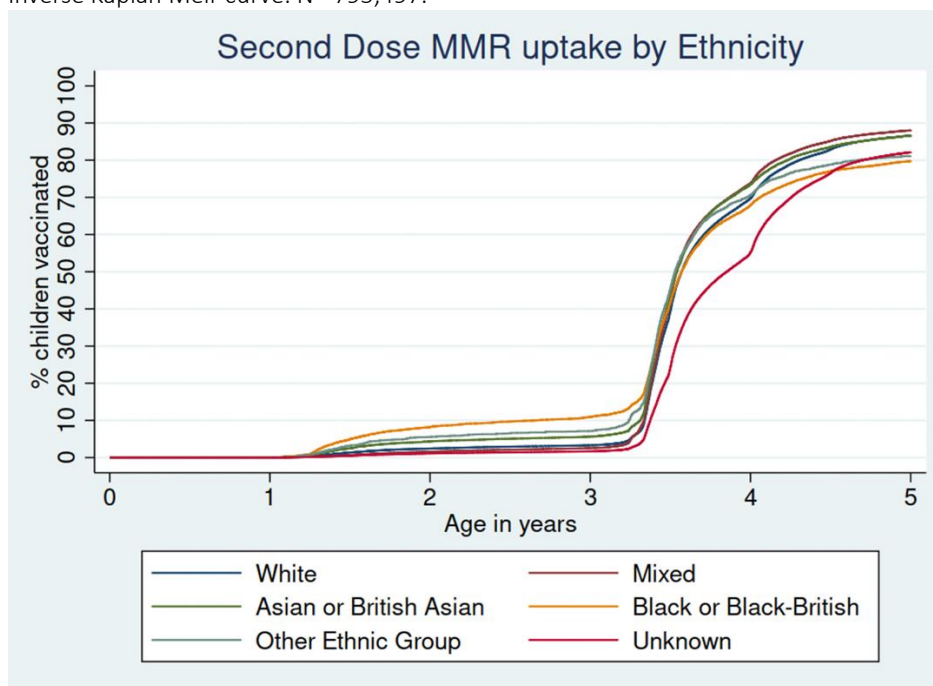


Inverse Kaplan Meir curve. n=297,179 (England only children still in cohort when second MMR due)

Appendix 5: Uptake of MMR by Ethnicity

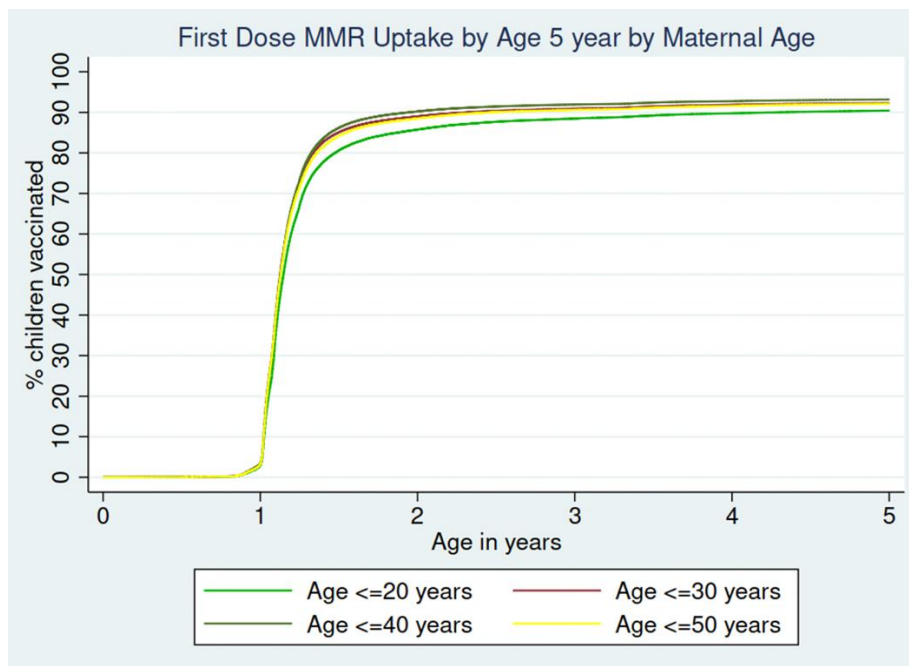


Inverse Kaplan Meir curve. N= 795,497.

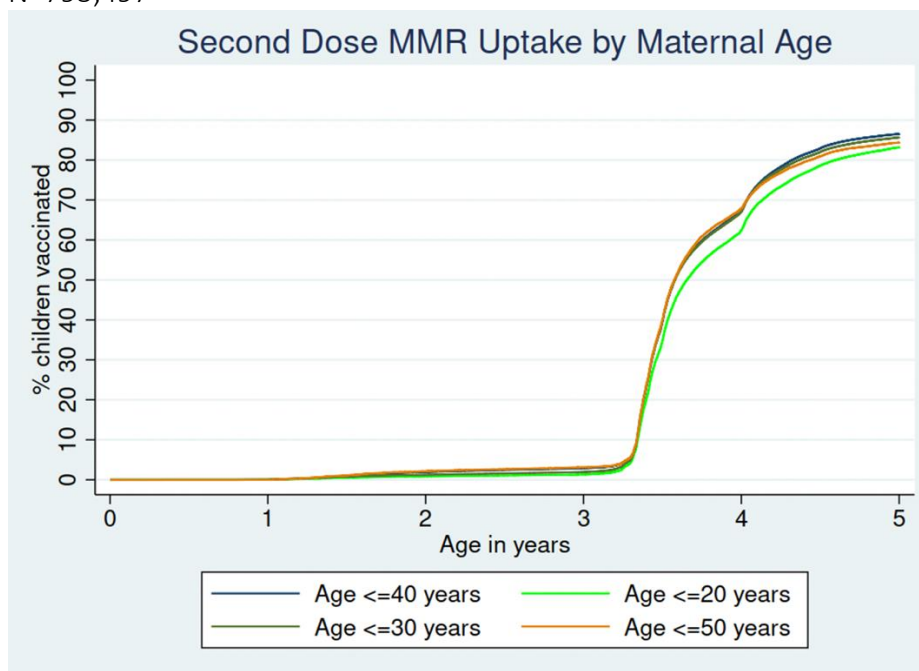


Inverse Kaplan Meir curve. N=557,050

Appendix 6: Uptake of MMR by Maternal Age

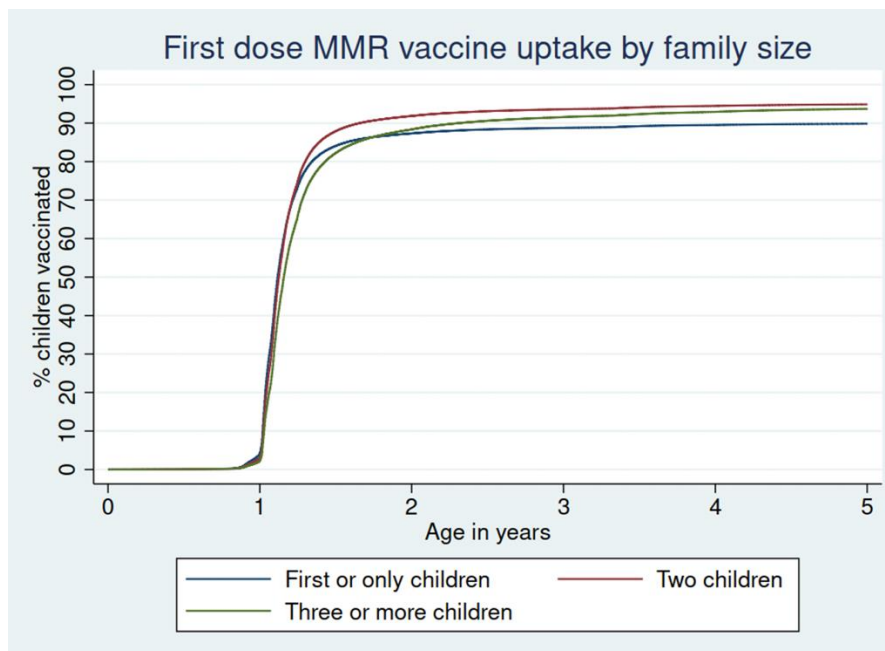


N=795,497



N=557,050

Appendix 7: Uptake of MMR by Family size/number of children

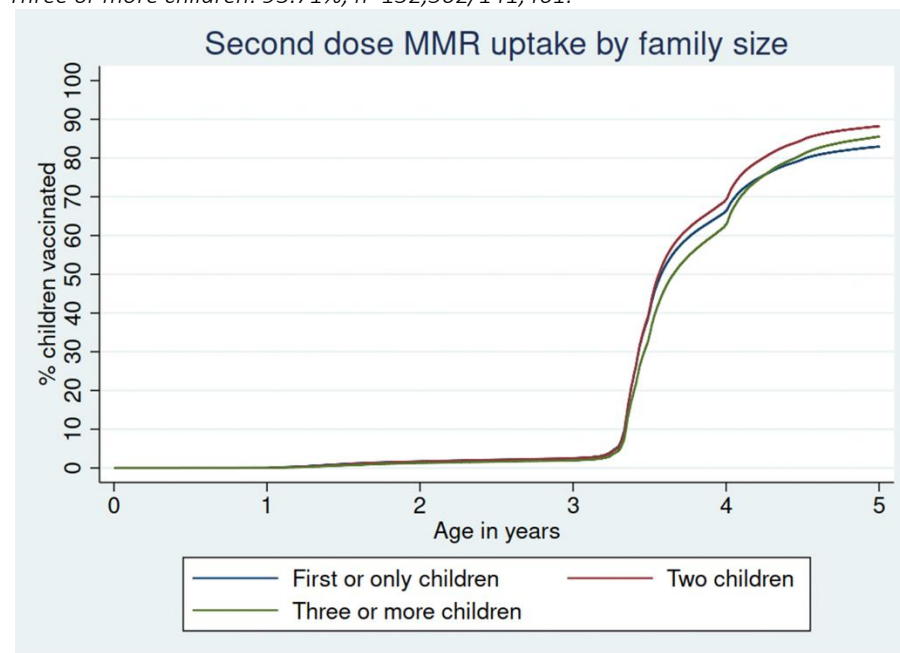


n=795,497

First or only children uptake: 89.85%, *n*=296,529/330,038.

Two children uptake: 94.88%, *n*=307,404/323,998.

Three or more children: 93.71%, *n*=132,562/141,461.



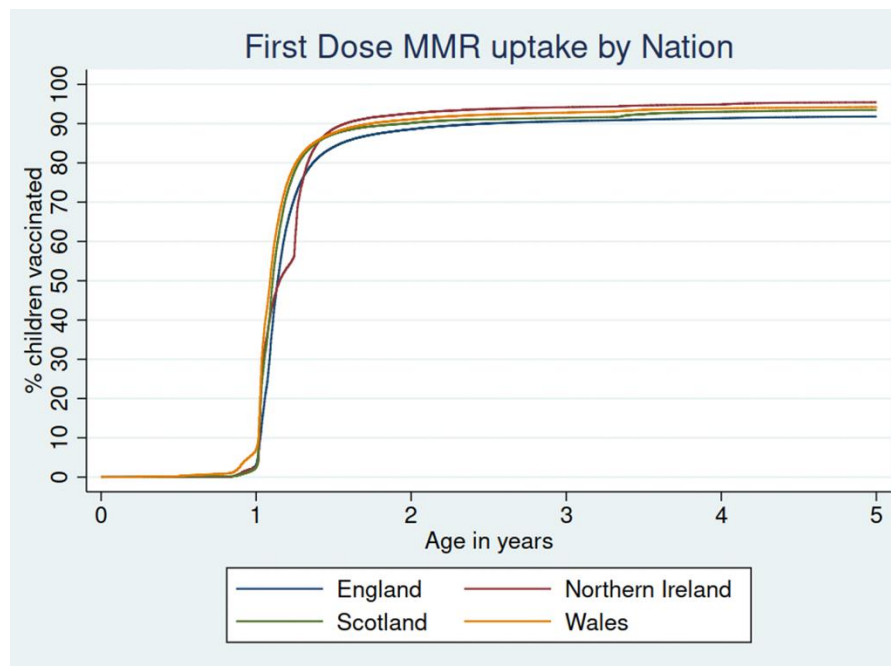
n=557,050

First or only children uptake: 82.97%, *n*=153,605/185,134.

Two children uptake: 88.22%, *n*=221,609/251,197.

Three or more children: 85.54%, *n*=103,266/120,719.

Appendix 8: Uptake of MMR by UK nation



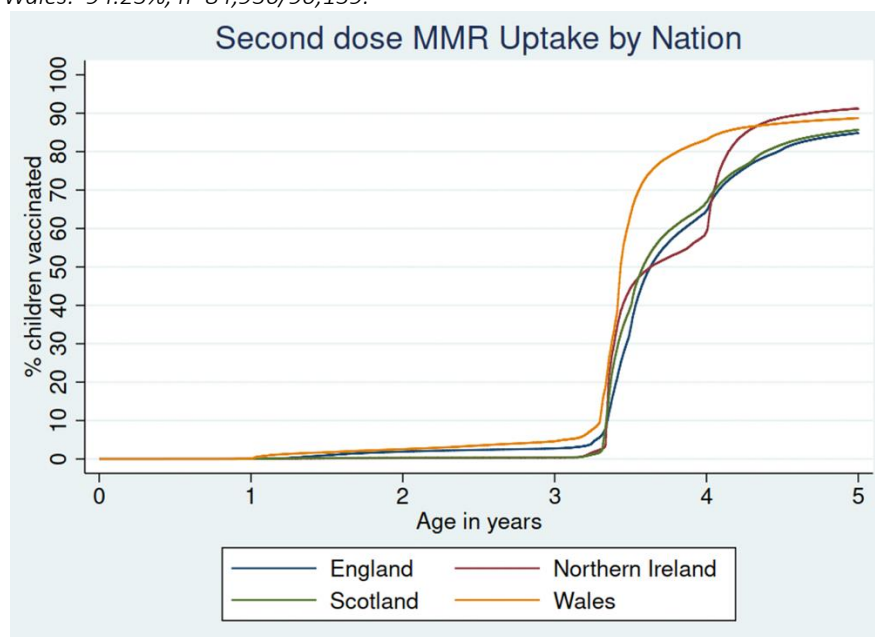
n=795,497

England: 91.81%, *n*=478,227/520,874.

Northern Ireland: 95.42%, *n*=43,137/45,207.

Scotland: 93.48%, *n*=130,195/139,277.

Wales: 94.23%, *n*=84,936/90,139.



n=557,050

England: 84.85%, *n*=297,179/350,241.

Northern Ireland: 91.21%, *n*=32,767/35,924.

Scotland: 85.70%, *n*=87,685/102,314.

Wales: 88.74%, *n*=60,849/68,571.

Appendix 9: Percentage of English Children in each ethnicity category by IMD Quintile

IMD Quintile	Ethnicity						Total
	White n (%)	Mixed n %	Asian or British Asian n %	Black or Black British n %	Other Ethnic Group n %	Unknown Ethnicity n %	
Quintile 1 (least deprived)	23,830 (16.4)	23,148 (20.2)	3,027 (12.6)	524 (4.2)	538 (10.8)	41,465 (18.9)	92,532
Quintile 2	22,271 (15.3)	18,783 (16.4)	3,190 (13.3)	797 (6.4)	545 (11.0)	34,650 (15.8)	80,236
Quintile 3	23,483 (16.1)	16,381 (14.3)	3,679 (15.3)	1603 (12.9)	831 (16.7)	32,842 (15.0)	78,819
Quintile 4	22,647 (15.6)	14,926 (13.0)	4,110 (17.1)	2720 (21.9)	1,018 (20.5)	29,542 (13.5)	74,963
Quintile 5 (most deprived)	21,543 (14.8)	14,455 (12.6)	4,757 (19.8)	3985 (32.0)	1,021 (20.5)	27,834 (12.7)	73,595
Unknown Deprivation	31,743 (21.8)	27,154 (23.6)	5,253 (21.9)	2817 (22.6)	1,024 (20.6)	52,738 (24.1)	120,729
Total	145,517	114,847	24,016	12,446	4,977	219,071	520,874*

*England only children.

Appendix 10: Percentage of English Children in each ethnicity category by Maternal age

IMD Quintile	Maternal age at birth of child (years)				Total
	≤20 n (%)	21–30 n (%)	31–40 n (%)	41+ n (%)	
Quintile 1 (least deprived)	1,528 (5.0)	28,800 (12.6)	58,226 (23.6)	3,978 (24.9)	92,532
Quintile 2	2,642 (8.6)	31,110 (13.7)	43,600 (17.7)	2,884 (18.0)	80,236
Quintile 3	3,948 (12.9)	35,339 (15.5)	37,128 (15.1)	2,344 (14.6)	78,819
Quintile 4	6,100 (20.0)	38,625 (17.0)	28,462 (11.5)	1,776 (11.1)	74,963
Quintile 5 (most deprived)	9,320 (30.5)	41,007 (18.0)	21,817 (8.9)	1,451 (9.1)	73,595
Unknown Deprivation	7,014 (23.0)	52,879 (23.2)	57,267 (23.2)	3,569 (22.3)	120,729
Total	30,552	227,820	246,500	16,002	520,874 *

*England only children.

Appendix 11: Sensitivity analyses examining how association between socio-demographic determinants and MMR uptake by age 5 years affected by missing data

Impact of missing deprivation

Uptake first dose MMR by age 5 years			Uptake second dose MMR by age 5 years	
Deprivation	HR Adjusted*	95% CI	HR Adjusted**	95% CI
Quintile 2	0.98	0.97-0.99	0.95	0.94-0.97
Quintile 3	0.94	0.93-0.95	0.90	0.89-0.91
Quintile 4	0.92	0.91-0.93	0.90	0.87-0.91
Quintile 5 (most deprived)	0.85	0.84-0.86	0.81	0.80-0.83
Ethnicity				
Mixed	1.03	1.02-1.04	1.09	1.08-1.11
Asian or British Asian	1.08	1.06-1.09	1.08	1.06-1.10
Black or Black British	0.86	0.84-0.87	0.92	0.89-0.95
Other Ethnic Group	0.97	0.94-1.01	0.99	0.95-1.04
Maternal age at birth of child (years)*				
<20	0.91	0.89-0.92	0.93	0.91-0.95
21-30	1.01	1.00-1.02	1.01	1.01-1.02
41+	0.95	0.93-0.96	0.94	0.92-0.97

Multivariable Cox regression analyses. Hazard Ratios are of first and second dose MMR uptake by age 5 years. Reference categories: Quintile 1 (least deprived), White Ethnicity, Mothers aged 31-40 years. *400,145 England only babies excluding those with missing deprivation. **301,803 England only babies excluding those with missing deprivation and still in the cohort when second MMR vaccine due.

Impact of missing ethnicity

Uptake first dose MMR by age 5 years			Uptake second dose MMR by age 5 years	
Deprivation	HR Adjusted*	95% CI	HR Adjusted**	95% CI
Quintile 2	0.96	0.95-0.98	0.95	0.93-0.96
Quintile 3	0.93	0.92-0.94	0.91	0.89-0.92
Quintile 4	0.91	0.90-0.92	0.90	0.88-0.91
Quintile 5 (most deprived)	0.86	0.85-0.87	0.81	0.80-0.83
Unknown	0.93	0.92-0.94	0.89	0.88-0.90
Ethnicity				
Mixed	1.03	1.02-1.04	1.08	1.07-1.09
Asian or British Asian	1.07	1.05-1.08	1.08	1.06-1.09
Black or Black British	0.87	0.86-0.89	0.94	0.92-0.97
Other Ethnic Group	0.98	0.95-1.01	0.99	0.95-1.03
Maternal age at birth of child (years)*				
<20	0.87	0.86-0.89	0.92	0.90-0.94
21-30	0.98	0.98-0.99	0.99	0.99-1.00
41+	0.95	0.93-0.97	0.94	0.92-0.97

Multivariable Cox regression analyses. Hazard Ratios are of first and second dose MMR uptake by age 5 years. Reference categories: Quintile 1 (least deprived), White Ethnicity, Mothers aged 31-40 years. *270,796 England only babies excluding those with missing ethnicity. **202,317 England only babies excluding those with missing ethnicity and still in the cohort when second MMR vaccine due.

Appendix 12: Multivariable analysis of 2013 Maternal Pertussis Cohort

	Adjusted Hazard Ratio for first MMR by Age 5 years*	95% Confidence Interval	Adjusted Hazard Ratio for second MMR by Age 5 years**	95% Confidence Interval
Mothers vaccinated with pertussis vaccine pregnancy	1.43	1.41-1.45	1.49	1.45-1.53
Deprivation				
Quintile 2	0.92	0.90-0.95	0.98	0.94-1.01
Quintile 3	0.91	0.88-0.93	0.90	0.86-0.93
Quintile 4	0.88	0.86-0.90	0.87	0.83-0.90
Quintile 5 (most deprived)	0.79	0.77-0.81	0.75	0.72-0.78
Unknown	0.93	0.91-0.95	0.86	0.83-0.89
Ethnicity*				
Mixed	1.06	1.04-1.08	1.03	1.00-1.06
Asian or British Asian	1.05	1.02-1.08	1.08	1.03-1.13
Black or Black British	0.93	0.89-0.96	0.90	0.84-0.96
Other Ethnic Group	0.97	0.92-1.02	0.90	0.82-0.98
Unknown	0.97	0.95-0.98	0.98	0.95-1.01
Maternal age at birth of child (years)				
≤20	0.92	0.89-0.95	0.85	0.79-0.91
21–30	0.96	0.95-0.98	0.96	0.94-0.98
41+	0.97	0.94-1.01	0.90	0.85-0.96

Reference categories: mothers unvaccinated against pertussis vaccine in pregnancy. Quintile 1 (least deprived), White Ethnicity, Mothers aged 31-40 years.

*Only English (96,865) children in 2013 cohort. **Only English children (n=35,433) still in 2013 cohort when eligible for second MMR.

Appendix 13: Study 2 Questionnaire

'Why did nobody ask us?!'

Understanding why parents and families think some children get vaccinated late or miss out on some of their routine recommended childhood vaccines.

Section 1: This section gives you some information about the questionnaire

Principal Investigator: Dr Helen Skirrow. Collaborator: The Mosaic Community Trust.

Co-investigators: Prof Helen Bedford, Dr Ceire Costelloe, Dr Celine Lewis, Dr Liz Whittaker, and Prof Sonia Saxena.

You are being invited to take part in a study to investigate why parents and families think some children are not being vaccinated or get vaccinated late. The information you give answering this study questionnaire could help improve how childhood vaccines are delivered. This could help more children get vaccinated, and on time, to protect them against potentially dangerous infectious diseases.

The study is part of Dr Helen Skirrow's PhD researching missed and late childhood vaccination in the UK. This is funded by the National Institute of Health Research of the Department of Health and Social Care. Helen is collaborating with The Mosaic Community Trust, a women's community group in Westminster, London for this research. They have been involved in designing the questions.

You are eligible to participate in this questionnaire if you:

- live in the United Kingdom
- are aged 18 years or older
- are the parent or guardian of a child or children aged 10 years or younger

It is up to you to decide whether or not to take part.

If you do decide to take part by completing this questionnaire, you are still free to pull out at any time and without giving a reason.

The questionnaire will take around 10-15 minutes to complete.

You do not need to answer all the questions if you do not want to.

The Head of the Department of Primary Care and Public Health and the Research Governance and Integrity Team have approved this study.

- *At the end of the questionnaire you will be given the opportunity to give more information about your views on childhood vaccination by taking part in a focus group.*
- *The focus groups will be held online or if you live close enough, at a location in Westminster, North-West London depending on COVID-19 restrictions. Focus groups will be run by The Mosaic Community Trust and Dr Helen Skirrow.*
- *If you decide you would like to take part in a focus group you will be asked to provide your contact details for us to get in touch with you. In this case, the contact details you provide will not be linked to any of the questionnaire answers that you provide.*
- *For more information about this research please feel free to contact me (Dr Helen Skirrow) at any time and I will be happy to answer your questions. You can email me: h.skirrow@imperial.ac.uk*

Thank you for taking part in research if you do decide to complete the questionnaire.

In this research study we will use the information you give. We will only use information that we need for the research study. Everyone involved in this study will keep your data safe and secure. We will also follow all privacy rules. At the end of the study we will save some of the data in case we need to check it. We will make sure no-one can work out who you are from the reports we write.

I AGREE I AM ELIGIBLE AND AGREE TO TAKE PART IN THIS RESEARCH.

Please tick.

☐ YES

☐ NO - Thank you for your time.

If YES:

Is someone else helping you to complete this questionnaire?

☐ YES _____

☐ NO

Is someone translating this questionnaire for you?

If yes please state which language.

☐ YES LANGUAGE? _____

☐ NO

Section 2: These questions ask some background information about you

1. What sex were you assigned at birth?
☐ Male
☐ Female
☐ Prefer not to say
2. What is your age in years? _____ (leave blank if you prefer not to say)
3. What is your postcode? _____ (leave blank if you prefer not to say)
4. What is your country of birth? _____ (leave blank if you prefer not to say)
5. Which of the following best describes your ethnicity?
☐ White:- British / White:- Irish / White:- Other White background
☐ Mixed:- White and Black Caribbean / Mixed:- White and Black African / Mixed:- White and Asian / Mixed:- Other mixed background
☐ Black or Black British:- African / Black or Black British:- Caribbean / Black or Black British:-
☐ Any other Black background
☐ Asian or Asian British:- Indian / Asian or Asian British:- Pakistani / Asian or Asian British:-
Bangladeshi / Asian or Asian British:- Other Asian background
☐ Chinese
☐ Other ethnic group not represented by these options _____
☐ Prefer not to say
6. What religion are you?
☐ Christian
☐ Buddhist
☐ Hindu
☐ Muslim
☐ Sikh
☐ Jewish
☐ Other
☐ No religion
☐ Prefer not to say
7. What is the highest level of education you have completed?
☐ Primary school
☐ Secondary school up to 16 years
☐ Higher or secondary or further education (A-levels, BTEC, etc.)
☐ College or university
☐ Post-graduate degree
☐ Prefer not to say
8. Which of the following describes you best?
☐ I am raising my child(ren) with a partner
☐ I am a single parent
☐ Other
☐ Prefer not to say

9. Please tick all relatives that live with you in the same house:

- ☐ Spouse and/or cohabiting partner
- ☐ Son and/or daughter (incl. adopted, foster or step-child/children)
- ☐ Son-in-law/daughter-in-law
- ☐ Parent/guardian
- ☐ Parent-in-law
- ☐ Brother/sister (incl. adopted, step or foster siblings)
- ☐ Brother/sister-in-law
- ☐ Grand-child
- ☐ Grand-parent
- ☐ Other relative/living situation_____

10. How many children do you have or are the guardian of?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4 or more

11. How many children do you have or are the guardian of **aged under 5 years old**?

- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4 or more

Section 3: These questions ask about routine vaccines recommended to all children in the UK by NHS General Practitioners (GPs) and other NHS staff such as health visitors & practice nurses.

(The routine vaccines as recommended in The Red Book you are given when your baby is born)

Please answer how much you agree or disagree with the following statements by circling your response.

1. It is important for parents to get the recommended vaccines for their child/children.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not applicable _____

2. Most parents I know in my community have their child/children vaccinated with all the recommended vaccines

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not applicable _____

3. Some people choose not to get their child/children vaccinated because of religious and/or cultural reasons.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not applicable _____

4. Wider family members such as grandparents, influence whether parents decide to get their child vaccinated.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not applicable _____

5. Have you personally ever refused or delayed any vaccines your child/children was/were offered before age 5 years?

☐ No – my child/children have had all their vaccines when offered.

☐ Yes – my child/children have not had or been vaccinated later than offered.

If yes:

A) Which vaccines did your child/children not have or have later?

B) Which of the following is most true for you?

☐ Child/children went onto have their vaccine later

☐ I plan to have my child/children vaccinated later

- ☐ I am not sure whether I will have my child/children vaccinated later
- ☐ I have no plans to have my child/children vaccinated later
- ☐ I will refuse to have my child/children vaccinated later

6. Is there anything else you would like to add about your opinions on vaccines recommended for children in the UK?

Section 4: Information and access to your child/children's vaccines before they are aged 5 years

Please answer how much you agree or disagree with the following statements about information and booking your child/children's vaccine appointments before aged 5 years by circling your response.

1. I was given enough information by healthcare professionals (doctors, midwives, health visitors, nurses and others) before my child/children vaccine appointments.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable _____

2. I understood the information that I was given before my child/children's appointments by healthcare professionals (doctors, midwives, health visitors, nurses and others).

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable _____

3. I knew how to book my child/children's vaccine appointments.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable _____

4. I was given enough opportunity to ask questions before my child/children's vaccine appointments.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable _____

5. I would have preferred the information provided by healthcare professionals about vaccines to be interpreted by a family member or friend into my own language before my child/children's vaccine appointments.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable _____

6. Before my child/children's vaccine appointment I felt confident about getting my child/children vaccinated.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable _____

7. I found it easy to book my child/children's vaccine appointments at their GP surgery at a time that was convenient for me and my family.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable _____

8. I found it easy to travel to my GP surgery for my child/children's vaccine appointments.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable _____

9. I found it difficult to take my child/children to my GP surgery for their vaccine appointments due to work.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable _____

10. I found it difficult to take my child/children to my GP surgery for their vaccine appointments due to my caring responsibilities (other children, relatives etc).

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable _____

11. I found it difficult to take my child/children to my GP surgery for their vaccine appointments due to religious and cultural events such as Ramadan, weddings, funerals.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable _____

12. I found it difficult to take my child/children to my GP surgery for their vaccine appointments due to having been away visiting family overseas.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable _____

13. I felt comfortable taking my child/children for vaccine appointments at their GP surgery.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable _____

14. I felt welcome taking my child/children for vaccine appointments at their GP surgery.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable _____

15. Appointments at other locations such as children's centres, community centres, nurseries would make it easier for me to take my child/children to be vaccinated.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable _____

16. Drop-in clinics (no fixed appointments) would make it easier to take my child/children to be vaccinated.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable _____

17. More appointments after school hours would make it easier to take my child/children to be vaccinated.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable _____

18. I know that if I miss a vaccine appointment for my child/children I am able to rebook and get my child/children vaccinated later.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable _____

Section 5: Your child/children's vaccine appointments and COVID-19 disease

Please answer how much you agree or disagree with the following statements about vaccines routinely recommended to all children in the UK by circling your response.

(NOT COVID-19 vaccines for children)

1. The COVID-19 pandemic has made me think it is more important for children to have their routine vaccines recommended to all children in the UK.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable_____

2. The COVID-19 pandemic has made me question whether the vaccines routinely recommended to all children are safe.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable_____

3. The COVID-19 pandemic has made me more likely to refuse or delay vaccines routinely recommended by for my child/children in the UK.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable_____

4. I have delayed or refused a vaccine routinely recommended for my child/children since the start of the COVID-19 pandemic.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable_____

5. The COVID-19 pandemic has increased my knowledge about all vaccines including vaccines routinely recommended for children.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable_____

6. The COVID-19 pandemic means I have more questions about all vaccines including the routinely recommended vaccines for children.

Strongly agree | Agree | Somewhat agree | Neither agree nor disagree | Somewhat disagree | Disagree | Strongly disagree |

Not/applicable__

Section 6: Any other comments.

Are there any other comments you want to make about why you think some children may not be vaccinated or vaccinated late?

Section 7: Thank you

Thank you for completing this questionnaire about childhood vaccination.

For this research study we are planning to combine the results of this questionnaire with the findings from focus groups with parents of children aged under 10 years. Focus groups will be held online or if you live close enough in the Church Street area of Westminster, North-West London.

If you would like to help us further and would be willing to participate in an approximately 45-60min focus group discussing similar topics as covered in this questionnaire please tick yes.

☐ YES – Please complete section 8 on the next page

☐ NO - Thank you for your time.

Section 8: Focus group interest

Please provide, your email address or mobile phone details below. You will be provided with a £10 Tesco gift voucher to thank you for your participation in the focus groups.

Alternatively, you can contact me directly on: h.skirrow@imperial.ac.uk

- Email:
- Phone Number:

This research is part Dr Helen Skirrow's PhD into missed and late childhood vaccination in the UK which is funded by the National Institute of Health Research, doctoral research fellowship award number NIHR300907.

Appendix 14: Study 2 Focus Group Topic Guide

Focus Group Topic Guide Why did nobody ask us?!

Understanding why parents and families think some children get vaccinated late or miss out on some of their routine recommended childhood vaccines.

1. Can we start off by talking about how many children we have and how old they are?
2. Can you tell me about your thoughts on vaccinations?
 - a. What do you see as the benefits of vaccinations for children?
 - b. Do you have any concerns (if any) about vaccinations for children?
3. We know that some children miss getting their routine vaccines before the age of 5 years or are late being vaccinated?
 - a. Why do you think this could be?
 - i. Do you know of parents/families getting their children vaccinated abroad? Or do you think being abroad when their vaccines are due might be a reason vaccinations are missed?
 - ii. Do you know of parents/families paying to have their children vaccinated privately? Do you know why this might be?
 - iii. Do you think religious or cultural events such as Ramadan or family weddings might mean vaccinations are missed?
4. How confident were you in your decision to have your child/ren vaccinated?
 - a. Were you given enough information on vaccines recommended before age 5 years?
 - b. Are you given enough time and opportunity to ask questions about vaccines due before 5 years?
 - c. What did you think of the of the information provided by the NHS/GP surgery about vaccines? How could information be improved? Interpreted by a family member or friend? Information leaflets in different languages? Formats? When information was available?
 - d. Did you have any concerns about the pain of vaccination or needles?
 - e. Do you think your experience of getting vaccinated in pregnancy (if you did) influenced you?
5. What has been your experience of getting your children vaccinated at your GP surgery?
 - a. Did you get reminders from your GP about your child/ren's vaccine appointments?
 - b. Did your GP surgery offer appointments at convenient times?
 - c. How do you find the process of booking appointments?
6. Has COVID-19 changed your views on routine childhood vaccines?
 - a. Has it made you more or less trusting?
 - b. Do you have more or less questions?
7. How do you think we can improve vaccine services so more children can be vaccinated and also vaccinated on time?
 - a. Do you think vaccinations being offered at different locations such as nurseries or children centres or when you take your child to a different hospital appointment might help?
8. Any other comments you want to make?

Appendix 15: Number of freetext responses to questionnaire, study 2A

- *Eighteen paper respondents left freetext comments.*
- *There were over 300 freetext comments made by parents who completed the online questionnaire, 154 parents left a freetext comment to the question 'Is there anything else you would like to add about your opinions on vaccines recommended for children in the UK?' and 146 parents left a freetext comment to the question 'Are there any other comments you want to make about why you think some children may not be vaccinated or vaccinated late?'.*
- *Some parents left freetext comments after the discrete choice answer questions ranging from one or two comments to a maximum of 20 comments.*

.

Appendix 16: Questionnaire free-text responses and focus group quotes illustrating components of the COM-B mode: study 2A.

Com-B Model Component: CAPABILITY (Knowledge & skills)	
Theme	Example quotes
Normal for parents to have questions about routine childhood vaccines	'I tend to have a lot of questions about vaccines. I mean, yes, one is, what's the benefit of it? Secondly, what's it made out of?' (FG1 participant) 'I must admit that vaccines scare me. We just blindly accept them without really knowing what's on them or if they will cause any issues in our children. There's so little information or studies/information about secondary effects for example' (qu n79).
Prioritising different childhood vaccines.	'Because I think, even in so many countries, in our country as well, they have seen... I know my sisters used to volunteer to give the polio vaccine to baby. So, I used to be a carer before and the lady, she was in a wheelchair, so she has polio and then she also said that because I think, she didn't take the polio (vaccine), and she's got polio.' (FG1 participant) 'Didn't take up flu for 2 year olds or any year since, all others have been on time' (qu n368)
Choosing to space out or delay vaccines/concerns about too many vaccines at the same time.	'we've spaced it out a bit...asked for a couple of them.... to be spaced out a little bit, as opposed to all at once. But they've got all of them. We've just staggered them a little bit.' (FG2 participant) 'It is better for babies and children to have single dose vaccines spread further apart' (qu 114)
Parents worry that vaccines are associated with the development of autism.	'For example, autism. It's such a common thing lately but one thing I've realised... I'm not going to say it's due to the vaccines, but I feel like maybe that's a side effect to vaccines.' (FG1 participant) 'And so my older daughter was vaccinated, had all the vaccines done, but then was diagnosed with autism, and I know... There's a rational part of me that knows that there's no evidence link, and things. But my husband is absolutely convinced that it was the vaccine, and he's very much into looking at blogs, and online, and everything.' (FG3 participant)
Com-B Model Component: OPPORTUNITY (Physical: Access, convenience, availability of information)	
Theme	Example quotes
Key factor in childhood vaccine decisions being conversations (not leaflets) with trusted healthcare professionals (e.g. practice nurses/health visitor)	'have meetings with doctors and people who know exactly what's in the drug and then the risk. That could really help.' (FG1 participant) 'we were receiving text messages, letters. We had a lot going on at the time. So, actually I didn't book it after two letters. And we received a phone call from the GP surgery, actually just saying have you got any concerns. Do you want to ask me questions about it, just a very gentle coaxing us to make the appointment, which was really useful actually.... they rang up and actually had a chat.' (FG2 participant) '(health visitor) they said this is what you need for your child... I was given all the information, I had no problem because my doctor knows me. I will not do anything until I'm given the full you know. I asked him can you please explain to me what is the benefit? What is this? What's the side effects?.....It was explained to me in a way, this is what's going to be given to your child. This is the side effects. I was given all....went to appointment I was explained by the nurse. And also given the leaflet and given the package.....all the side effects, that the temperature went up. So, ... Now I just have like experience. And I felt like okay.....I'm happy with the service.' (FG4 participant) 'I'm not sure I feel like I was given any information about the vaccines before, which is why I decided to go privately, and delay them. the vaccines I have done with them (NHS), they didn't say anything. They were very abrupt. And it was more like, okay. You've got a ten-minute appointment. We need to do the vaccine and get you out....weren't very nice about it. And when I went back there after doing some of the other private vaccines, and they saw that I wasn't doing their schedule, they were very rude. And so that actually stopped me going back to the NHS. And then ones that I could have done with the NHS, I did privately, because I was just so upset after going to the NHS ones that I was like I'm not going to do it again. But luckily

	<i>I've moved. And the NHS GP I go to now are very nice....the nurse there, who did her last vaccine, was very nice. And took time to go through everything, and all of that stuff. And she made me feel very comfortable. And there was no judgement.'</i> (FG2 participant).
Parents have questions that they want answered BEFORE the vaccine appointment e.g. about side effects but also logistics of the vaccine appointment.	<i>'I mean, one thing that would be helpful, I guess, is even someone to have a conversation about the practicalities. So aside from you're having a vaccine, so you know what to dress your child in, you know where they're going to inject. Because I remember, I think, for one of them, my daughter was in dungarees or... I remember I was in such a fluster trying to... She had a buggy, she had a nappy bag, I had to take the shoe off, and then she was wearing tights because it was in... I think it was winter, so there were all these layers. But if someone had told me, actually, you need to expose the thigh. I think it was the very first vaccine, and I didn't know that they would be doing the thigh, I think I assumed, like for an adult, it would be the arm. But even if someone just spoke about those sort of things, or to say that... Like they did, I remember they said, you can use Calpol afterwards. But even the fact that, okay, ... There may be some bleeding. Because I remember I was very worried when I undressed her, there was a little bit of blood on her bodysuit, and things. And then I had to go to my mum's group to ask, is this normal? What do I do? Can I put an alcohol wipe on it? And I was just very anxious I think.'</i> (FG3 participant) <i>'The appointment is not the right time because the child is screaming. And when the child is screaming, your instinct is to protect the child and your brain shuts and you just want to be out of there'.</i> (FG1 participant) <i>'I think there should be more information for parents about how sick your child can get after vaccines. It can be hard to manage work and caring for a child with a fever who has to stay home from nursery' (qu n71)</i>
Pregnancy offers opportunity to provide more information/discuss childhood vaccines with midwives/ or immediately post birth with health visitors	<i>'I think during pregnancy and after pregnancy care, there's times where there's conversation should happen. Because when you've just had a baby and you suddenly get told, go to your ...immunisations, it can be very overwhelming. You've got a tiny little human being and suddenly you've to make a decision on whether you want to or not. And if you don't have support or the right advice or the right knowledge, it's a hard decision to make. So, I think it should be something you're spoken to more about during pregnancy and during that first initial 10 days of the health visitor coming, midwife coming visits. There should be more conversations, not, here's a pamphlet, in four weeks' time go and have your injections.'</i> (FG1 participant) <i>'there is no proper support or follow up from health visitors etc around this (vaccines), it turns more into a lecture which has no chance of getting through... Health Visitors need....training' (qu n140)</i>
Parents want information and/or conversations with trusted healthcare professionals in different languages	<i>'if they can put it in different languages so people understand and get the benefits of this. Understand what it is for the kids and get... How do you put it? Understand it's not about them it's about for the kids.'</i> (FG4 participant) <i>'information in different languages...I think the conversation is more... important.</i> (FG1 participant) <i>'It's good to explain to the mothers who just come from another country because the health visitor she's come from NHS. So, the new mothers they don't know nothing about a lot of things about vaccination...and the health service in general.....She didn't speak with me about vaccination. Just speak me about... baby.....But....If I'm come from another country it's help. Because as well, the new mothers come here ...scared about the health visitor. They thought something with social worker or something like. That is why if she speaks same language she feels... give her good information because she speaks the same language.'</i> (FG4 participant)
Relying on the red book to track vaccinations	<i>'I found the red book very helpful. I love my red book....perfect.'</i> (FG4 participant) <i>'So all I have is what's in the... red book that I was given when X was born.'</i> (FG3 participant) <i>'Without the red book you're non-existent. Because that gets frowned upon if you dare forget that.'</i> (FG1 participant)
Inconsistent receipt of reminders from GP surgeries about childhood vaccines	<i>'there were no reminders.</i> (FG1 participant) <i>'There are no reminders from surgery' (Qu n153)</i> <i>'on me to find out when vaccines are due and to book the appointments....the gp surgery gave conflicting information. I know they are overstretched but they are rubbish.'</i> (Qu n237)

	• 'son was late getting vaccines at 4 years old because I hadn't realized they were due. Reminders are useful.' (qu 191)
Difficulties in making vaccine appointments - Parents struggling to get through to doctors surgeries to make vaccine appointments for their children	• 'I think they just make it also easier to book because if you think about it, to book an appointment for vaccination with a nurse, you still need to go through, in our case, 20 minutes on the phone with a receptionist in the GP surgery. In a way they can be, to some extent automated, done on a different schedule completely because the nurse could be run, separately a clinic, the one who looks after the kids' vaccination. Because I often forget, sometimes it takes me a week to book an appointment because I know that I can only call them at certain times, when they will pick up, because otherwise they just don't pick up. Also, that can be done online, because why do I have to be on the phone for half an hour? I don't have time for that. So that could be good. It depends on each trust and each surgery, for us they only release appointments for a week in hand.' (FG1 participant) • 'So, it was quite hard to get appointments. I remember feeling a little bit stressed about not doing it quickly enough, and not doing it in line with the red book, because I couldn't get an appointment' (FG2 participant) • 'I can only call (the GP surgery) between 10 and 11 to book an appointment. The receptionists are hostile at best.' (qu 213) • 'It should be easier to book vaccines rather than having to call up local surgery where it is increasingly difficult to get through and to plan around full time work.' (qu n146)
Difficulties in attending vaccine appointments – if only available on one day for example and parents having to take time off work to attend	• 'We have only Thursdays, and then also the time, only the afternoon until four o'clock. As long as I'm at home, fine, but then it's really a struggle for me. I have, every time, to take half a day off.' (FG3 participant) • 'Access to appointments in my local surgery has been very hard. Often it's only one day a week (a day I work) and very small selection of times. It's really hard to prioritise vaccines above work' (qu n134) • 'You have a certain time for the GP, ... which is the day they vaccinate like for example, Tuesday and Wednesday that is the day they... do the vaccination the GPs are really full for them to be able to give you an appointment. So, ... after work need... able to take the child because there isn't available appointment for the child, so the child misses out on vaccination.' (FG1 participant) • 'vaccination clinics....held one morning a week (Friday).... And cancelled on the day due to no availability of nurse, despite taking the day off and keeping kids out of nursery (a day we paid for). Undermines confidence that appointments will happen, result in delayed vaccination. Lack of understanding by GP reception staff' (qu n55)
Negative or positive experiences of taking child for first vaccines impacting future decisions for later vaccines or younger children. Including them or their baby being upset by the pain.	• 'When I took my child to get vaccinated the nurse wasn't nice and kept telling me to hold my son tightly without compassion' (questionnaire n23) • 'When you do it first time ... It's not exactly gentle....If the GP surgery is done in a way that there is a place to breastfeed afterwards, would be great because they do calm down that way. In our place for example, you then go into the waiting room and I'm never going to breastfeed a kid in the waiting room.' (FG1 participant) • 'Some nurses are quite gentle about it, and then some of them are more like, all right, get it done. Let's move on. So, I think depending on how sensitive the staff is, it makes you either really hesitant about the next time you're going to go in.... it can be quite upsetting, especially the first time. And I think if you have a really challenging first time, it makes you dread every single one after that. That's my personal experience.' (FG3 participant) • 'the reason I didn't take my son for the extra MMR dose was because the nurse at his 12 month vaccinations was rough with him and left him traumatised for over a week. I looked at private options with paediatricians, but appointments were too expensive.' (qu n18) • 'our particular surgery the nurse has a very small room and that's where your vaccination happens and then afterwards, if you need to calm the baby down then you can only do it in the waiting room because she has the next patient straight after. So, you're pretty much taking the crying baby out and then so problem how you calm them down. And then because when they're very tiny, the easiest way to calm them down is to breastfeed them, I'm not comfortable doing that in a waiting room. So, maybe having a side room free'. (FG1 participant).

Offering vaccines in different locations - but wanting them to be given by trusted known healthcare staff to answer questions.	'I would like some healthcare people... Not just random person.' (FG1 participant) 'For me it was very easy because in this area we have.... (children's) Centre. they bring the nurse to the (children's) Centre to do the vaccination for the babies, new babies...it's easy' (FG4 participant) 'I think if they know enough information and can answer your questions then I think that's a good idea. But if they're limited... Not pharmacist, maybe a health centre' (FG1 participant)
Other reasons for missing vaccines: Being abroad or child being ill, being in hospital, caring responsibilities	'The timings in the UK differ slightly from abroad so there have been times we've played "catch up" in either country if vaccination schedule was missed due to travelling' (qu n262) 'My child was in intensive care when her vaccinations were due. It would have been helpful for the hospital to administer them but instead we had to fight our local GP surgery for a late appointment once we were discharged. (qu n129) 'If she's sick, I will just cancel the appointment and not go' (FG2 participant) 'I was looking after my sick mother and I couldn't face having to look after my mum and two kids with fevers after vaccines. I will get their jabs soon' (qu n59)
Theme	Com-B Model Component: MOTIVATION (Attitudes, values, emotions)
Impact of family/wider community perceptions and anecdotal stories from local community impact whether parents feel confident in getting child vaccinated.	'I would ask my sisters how it was with their kids and then go from there, and then decide if I should get it done or not.' (FG1 participant) 'I know a lady in particular, and she's very vocal in the local area, and she will tell everybody, do not get your child vaccinated because my son is autistic and it's all because of the vaccination.' (FG1 participant) 'And then I changed my mind about vaccination when I see the children and when I heard a lot of stories about the same things' (FG4 participant) 'You've got to remember there's stigma in certain cultures where, if a child has got a need, a difference about them, they don't like to admit that that could be genetic, or just the way the child has been born. And it's easy to blame that on... Vaccinations.' (FG1 participant)
Women keeping vaccine decisions from men	'I managed not to tell my family I'm going to go vaccination because my partner is against it' (FG4 participant) 'My 4 year old has asd. My husband and family believe mmr caused asd and so we have declined mmr for my 2nd child until she meets all milestones' (qu n42)
Mistrust of vaccines	'And so my trust levels are at rock bottom with the medical profession' (FG3 participant) 'Many people have realised how untrustworthy some medical professionals are. The lies, coercion and cruelty have been extraordinary in the past few years. People are waking up to the corruption in pharma and healthcare.' (Qu n76)
Trust in vaccines	'the vaccines were relatively well established. And I guess that gives a certain degree of confidence in them. (FG2 participant) 'It's good for kids. Healthy.' (FG4 participant)

KEY TO THEMES

- Deductive codes on a priori set objectives (including some from previous literature)
- Codes developed from questionnaire
- Inductive codes that emerged from the data

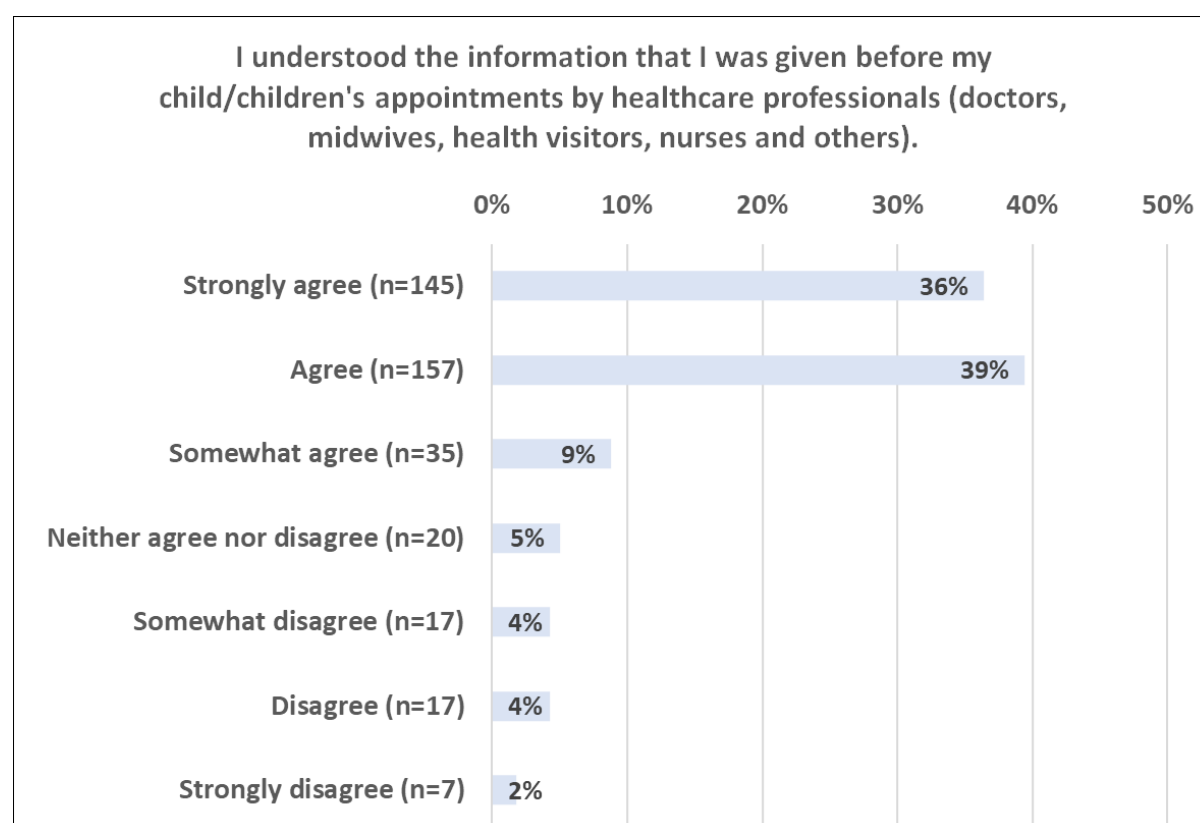
Appendix 17: Study 2A Question Responses by Ethnicity

Chi square analysis of parents' responses to questions by ethnicity.			
Have you personally ever refused or delayed any vaccines your child/children was/were offered before age 5 years?			
	Yes n (%)	No n (%)	p value
White ethnicity	41 (13)	268 (87)	0.0316
All other ethnic groups combined	29 (21)	107 (79)	
	Agreed n (%)	Disagreed n (%)	
I was given enough information by healthcare professionals (doctors, midwives, health visitors, nurses and others) before my child/children's vaccine appointments.			
White ethnicity	192 (68)	91 (32)	0.8417
All other ethnic groups combined	84 (69)	38 (31)	
I understood the information that I was given before my child/children's appointments by healthcare professionals (doctors, midwives, health visitors, nurses and others).			
White ethnicity	228 (86)	38 (14)	0.3604
All other ethnic groups combined	96 (82)	21 (18)	
I was given enough opportunity to ask questions before my child/children's vaccine appointments.			
White ethnicity	180 (64)	102 (36)	0.0179
All other ethnic groups combined	52 (51)	51 (49)	
I would have preferred the information provided by healthcare professionals about vaccines to be interpreted by a family member or friend into my own language before my child/children's vaccine appointments.			
White ethnicity	7 (10)	65 (90)	<0.0001
All other ethnic groups combined	29 (47)	33 (53)	
It is important for parents to get the recommended vaccines for their child/children.			
White ethnicity	301 (97)	8 (3)	0.0017
All other ethnic groups combined	119 (89)	15 (11)	
I knew how to book my child/children's vaccine appointments.			
White ethnicity	245 (87)	36 (13)	0.2869
All other ethnic groups combined	110 (90)	12 (10)	
I found it easy to book my child/children's vaccine appointments at their GP surgery at a time that was convenient for me and my family.			
White ethnicity	201 (75)	67 (25)	0.5899
All other ethnic groups combined	106 (83)	21 (17)	
I know that if I miss a vaccine appointment for my child/children I am able to rebook and get my child/children vaccinated later.			
White ethnicity	238 (87)	37 (13)	0.8190
All other ethnic groups combined	104 (87)	15 (13)	
I found it difficult to take my child/children to my GP surgery for their vaccine appointments due to work.			
White ethnicity	78 (32)	165 (68)	0.6898
All other ethnic groups combined	36 (34)	69 (66)	
I found it easy to travel to my GP surgery for my child/children's vaccine appointments.			
White ethnicity	263 (94)	18 (6)	0.5796
All other ethnic groups combined	104 (92)	9 (8)	
Drop-in clinics (no fixed appointments) would make it easier to take my child/children to be vaccinated.			
White ethnicity	184 (66)	94 (34)	0.1472
All other ethnic groups combined	84 (74)	30 (26)	

More appointments after school hours would make it easier to take my child/children to be vaccinated.			
White ethnicity	184 (71)	74 (29)	0.0853
All other ethnic groups combined	83 (81)	20 (19)	
I felt comfortable taking my child/children for vaccine appointments at their GP surgery.			
White ethnicity	253 (90)	27 (10)	0.8920
All other ethnic groups combined	107 (90)	12 (10)	
Appointments at other locations such as children's centres, community centres, nurseries would make it easier for me to take my child/children to be vaccinated.			
White ethnicity	157 (57)	119 (43)	0.9636
All other ethnic groups combined	60 (57)	45 (43)	
I found it difficult to take my child/children to my GP surgery for their vaccine appointments due to my caring responsibilities (other children, relatives etc).			
White ethnicity	32 (17)	153 (83)	0.05642
All other ethnic groups combined	24 (27)	64 (73)	
I found it difficult to take my child/children to my GP surgery for their vaccine appointments due to religious and cultural events such as Ramadan, weddings, funerals.			
White ethnicity	4 (2)	168 (98)	Chi sq not appropriate
All other ethnic groups combined	8 (9)	86 (91)	
I found it difficult to take my child/children to my GP surgery for their vaccine appointments due to having been away visiting family overseas.			
White ethnicity	27 (15)	148 (85)	0.05346
All other ethnic groups combined	6 (7)	80 (93)	
Most parents I know in my community have their child/children vaccinated with all the recommended vaccines			
White ethnicity	290 (95)	16 (5)	0.0518
All other ethnic groups combined	112 (90)	13 (10)	
Wider family members such as grandparents, influence whether parents decide to get their child/children vaccinated.			
White ethnicity	197 (64)	109 (36)	0.1584
All other ethnic groups combined	72 (57)	54 (43)	

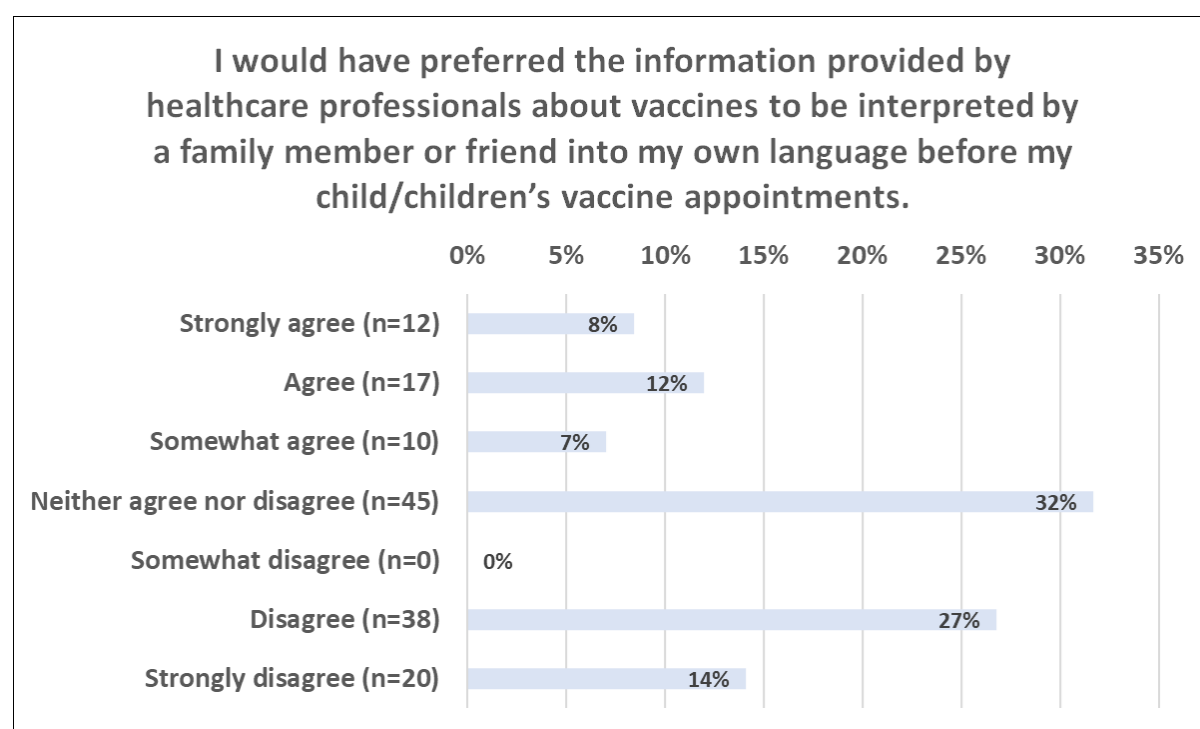
- Respondents were first dichotomised into those that answered the question: Which of the following best describes your ethnicity? As either **White ethnicity**: 'White, White Irish or Other White background' or '**All other ethnic groups combined**' if they answered any of 'Any Mixed background, Black or Black British or any Black background, Asian or British Asian or any Asian background, Chinese or other or unknown ethnicity group'.
- Likert responses to the questions were then also dichotomised into *Agreed (Strongly agree, Agree or Somewhat Agree) and **Disagreed (Neither agree or disagree, somewhat disagree, Disagreed or Strongly Disagree).
- P values reported are from Chi Square test results.
- **Note: Different numbers of parents answered each question**

Appendix 18: Understanding information before vaccinations



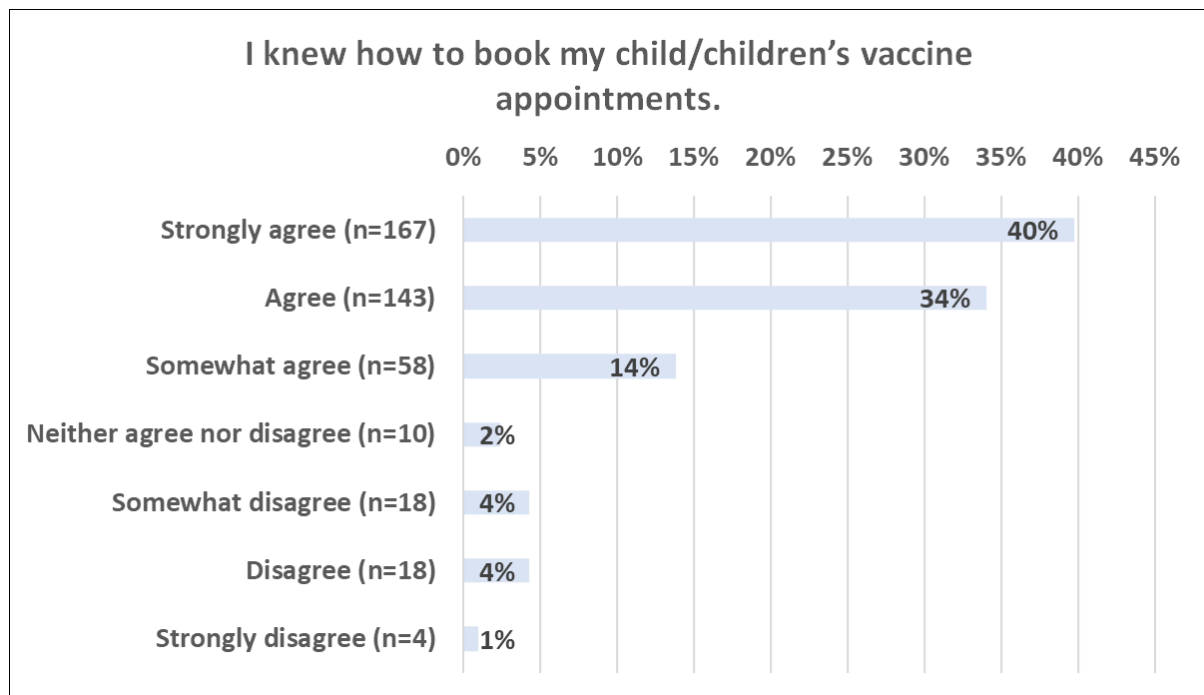
Total respondents answering question n=398.

Appendix 19: Translation of vaccine information



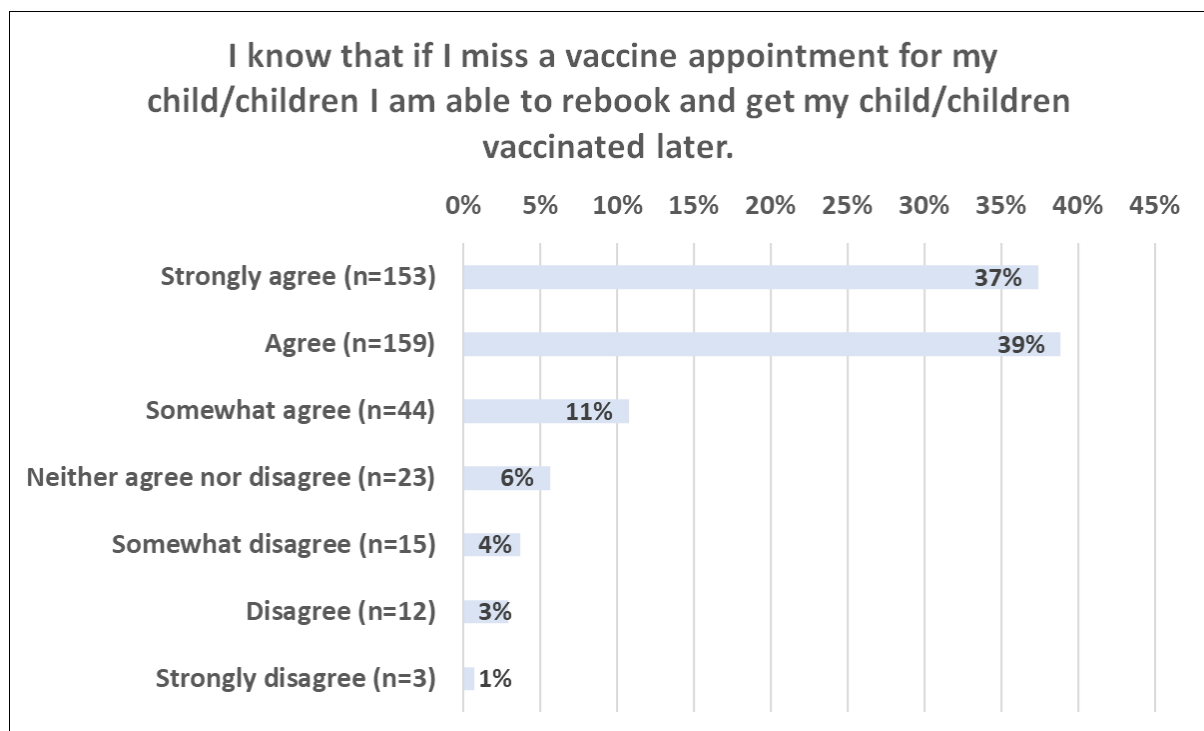
Total respondents answering question n=142

Appendix 20: Booking vaccine appointments



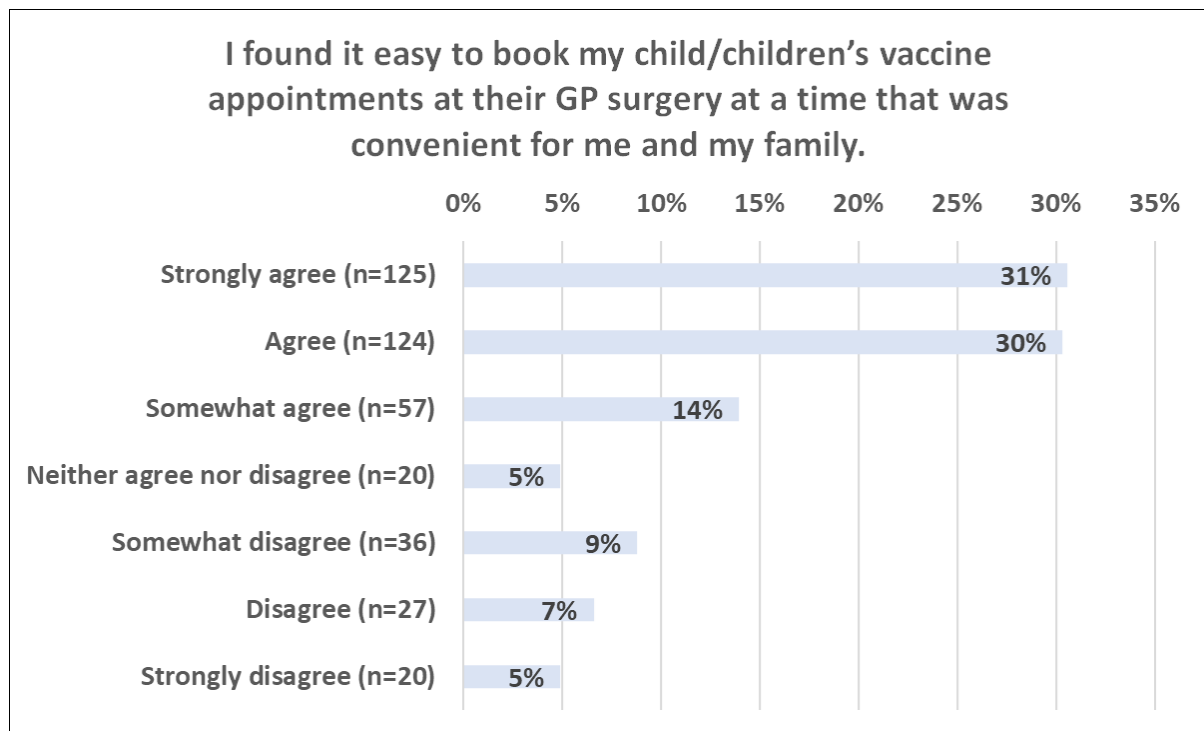
Total respondents answering question n=420.

Appendix 21: Rebooking vaccine appointments



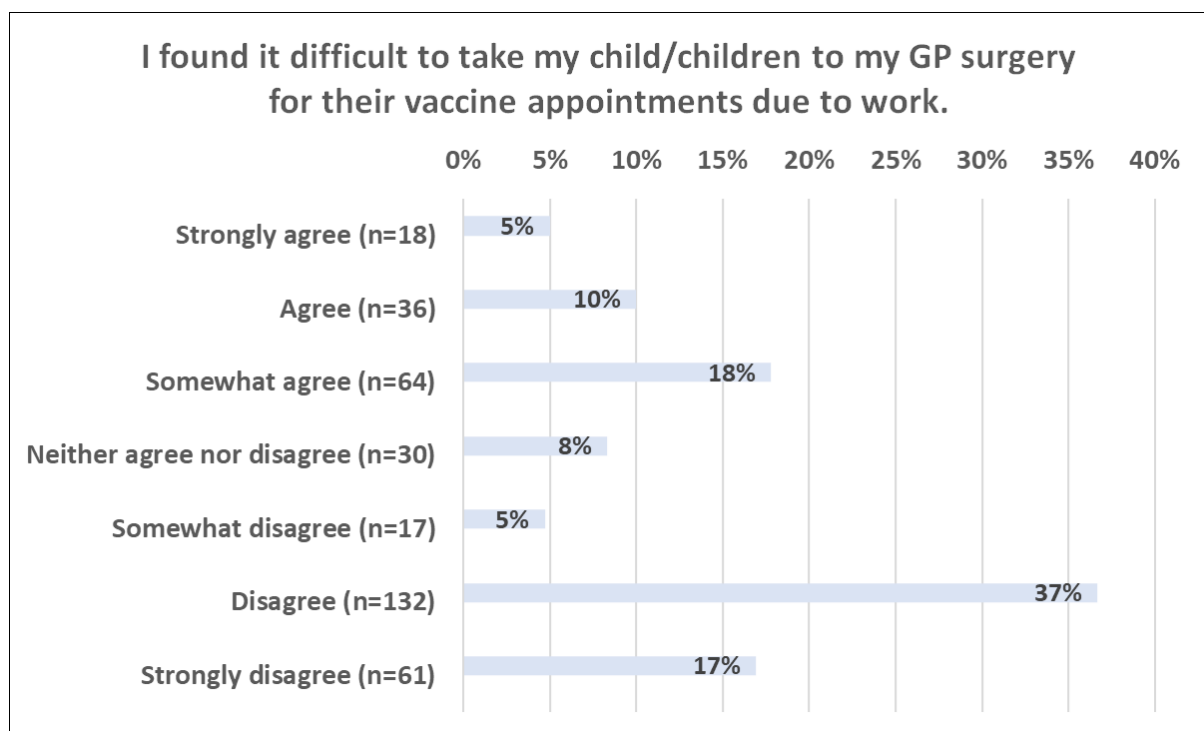
Total respondents answering question n=409.

Appendix 22: Vaccine appointment convenience



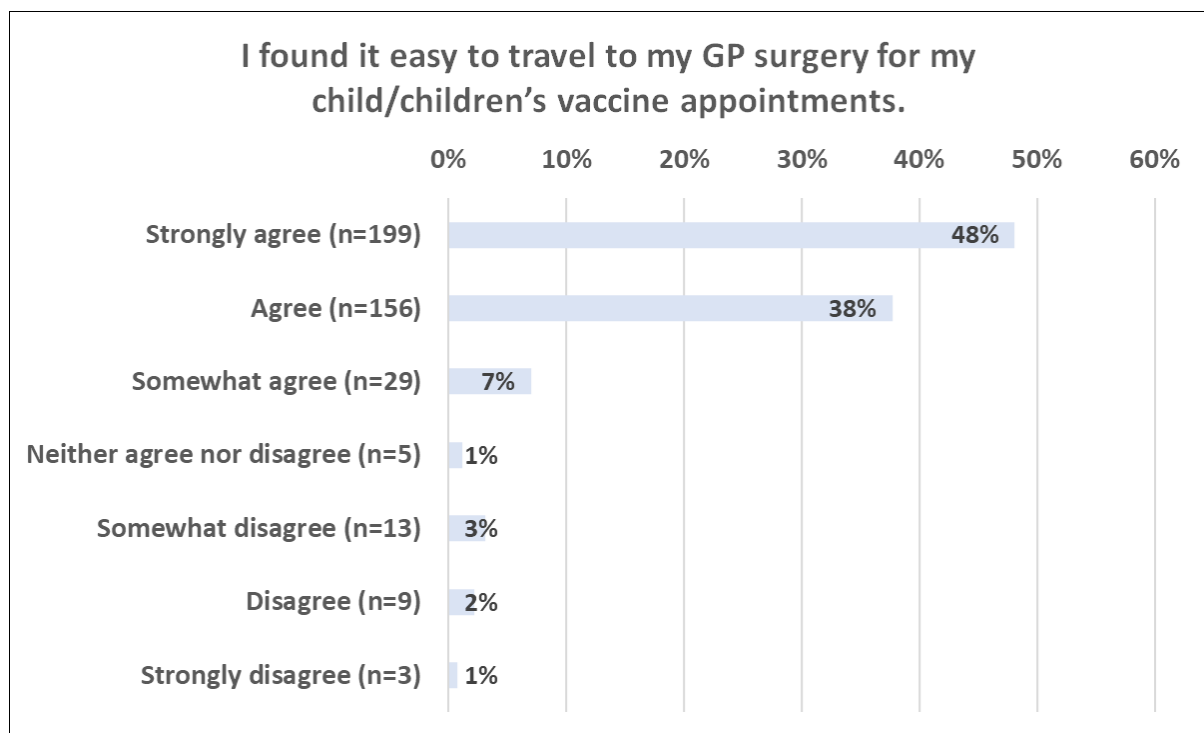
Total respondents answering question n=409.

Appendix 23: Attending vaccine appointments due to work



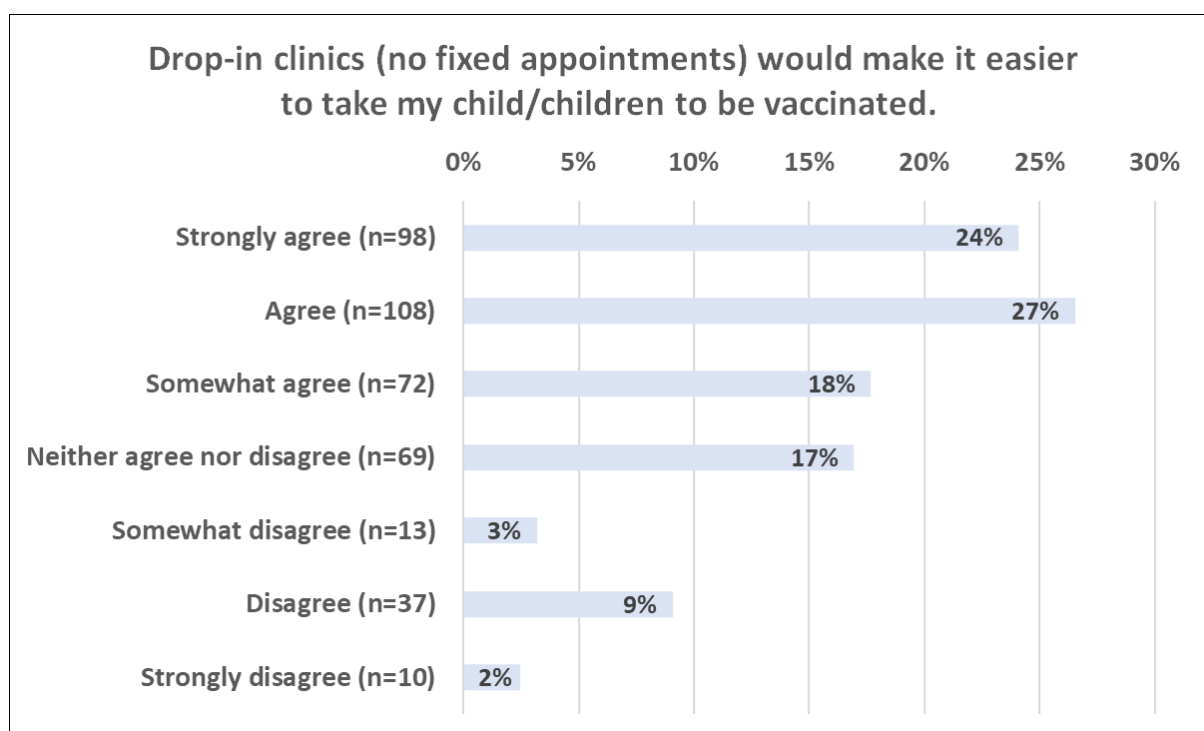
Total respondents answering question n=360

Appendix 24: Travel to vaccine appointments



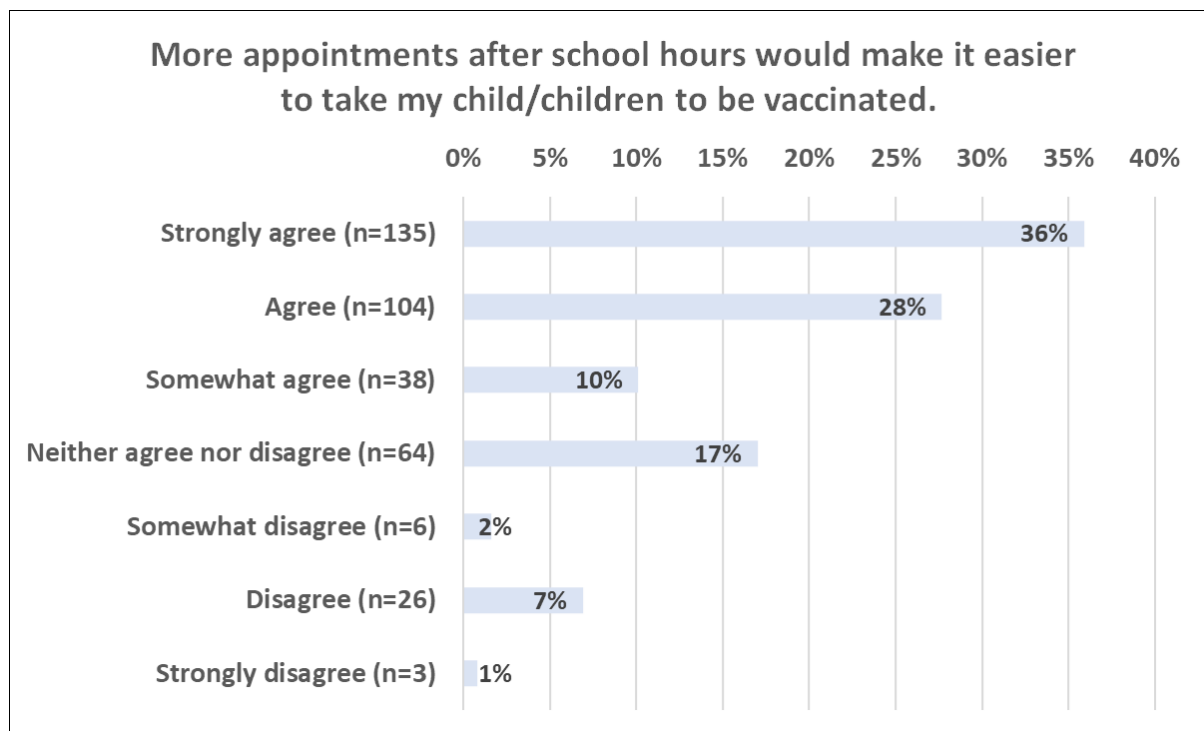
Total respondents answering question n=414

Appendix 25: Drop in vaccination clinics



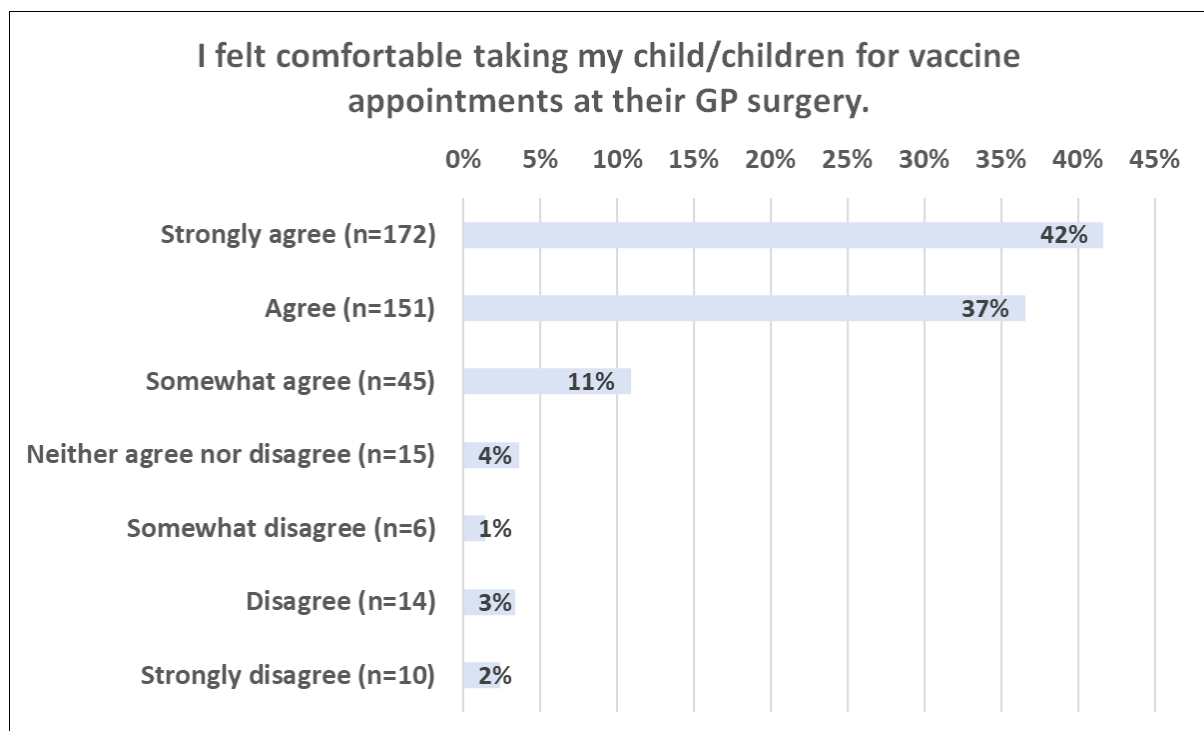
Total respondents answering question n=407

Appendix 26: After school hours vaccine appointments



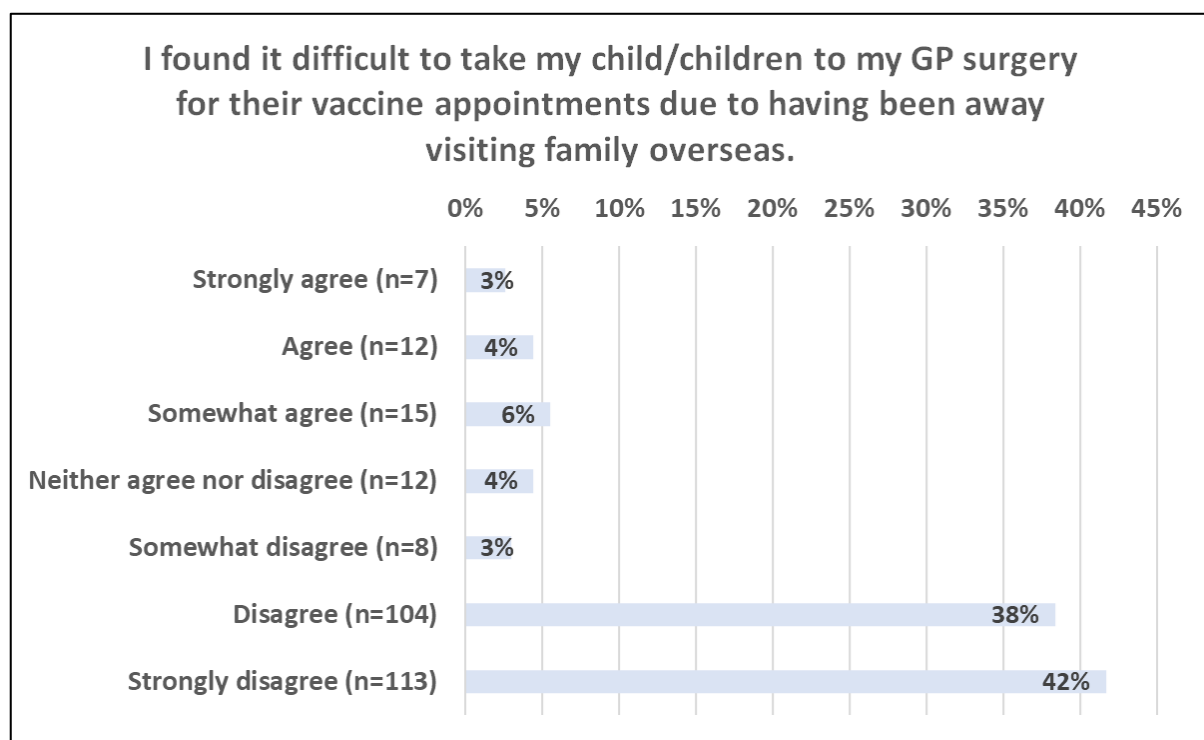
Total respondents answering question n=376

Appendix 27: Feeling comfortable at GP surgery



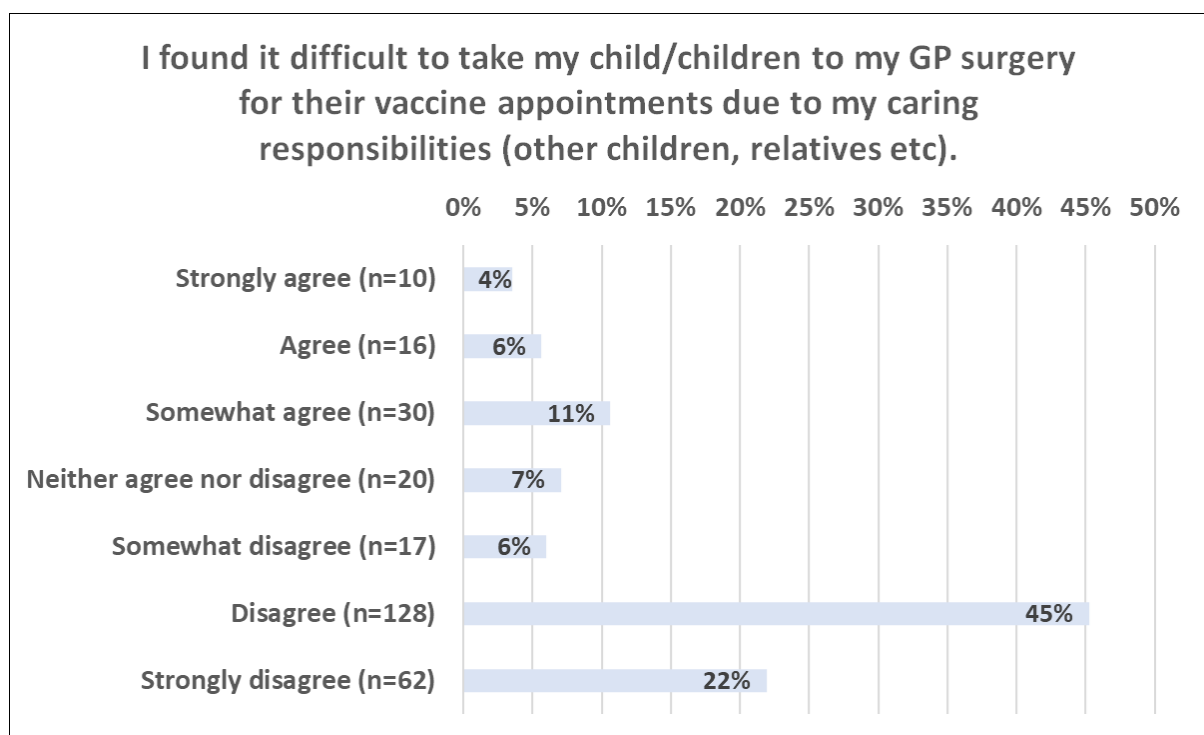
Total respondents answering question n=413

Appendix 28: Missing vaccines due to being overseas



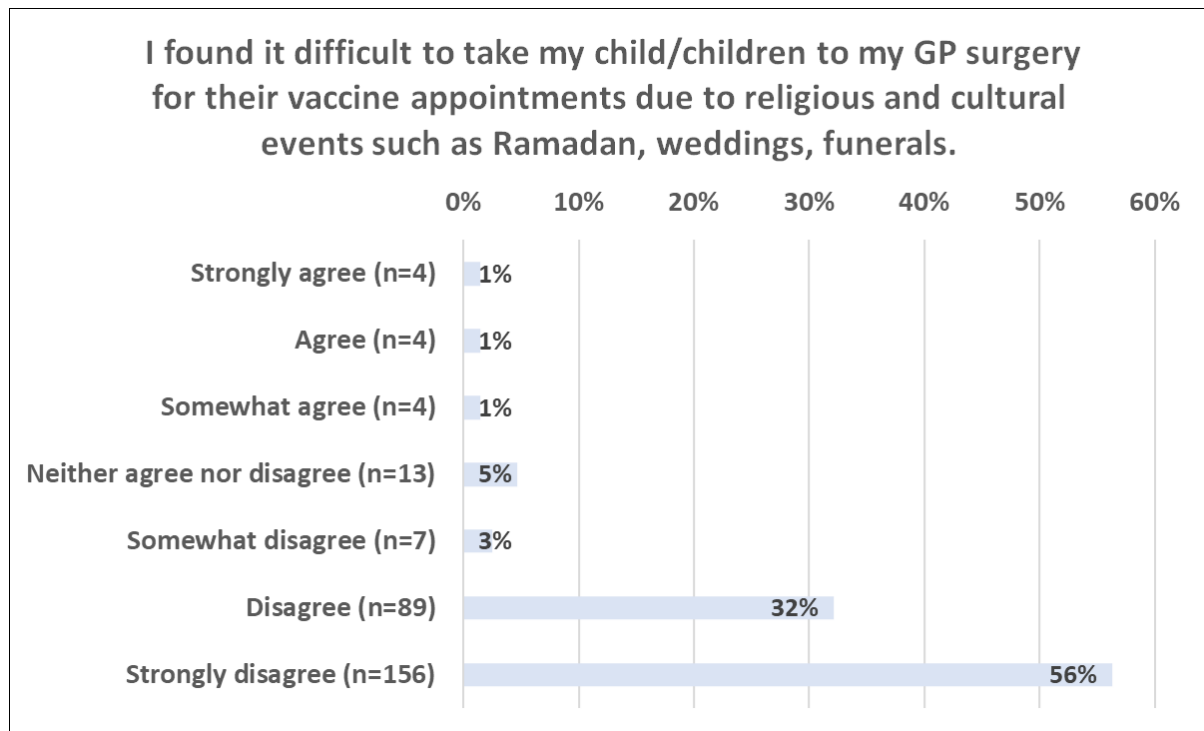
Total respondents answering question n=271

Appendix 29: Missing vaccines due to caring responsibilities



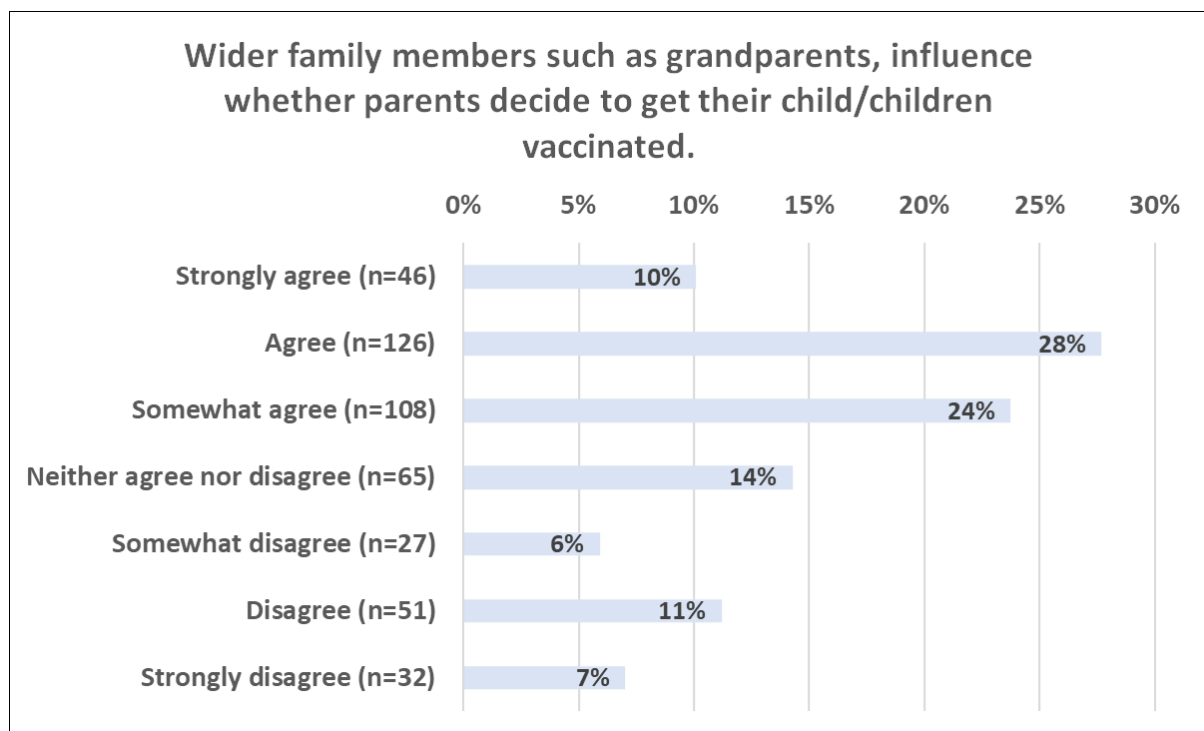
Total respondents answering question n=283

Appendix 30: Missing vaccines due to cultural events



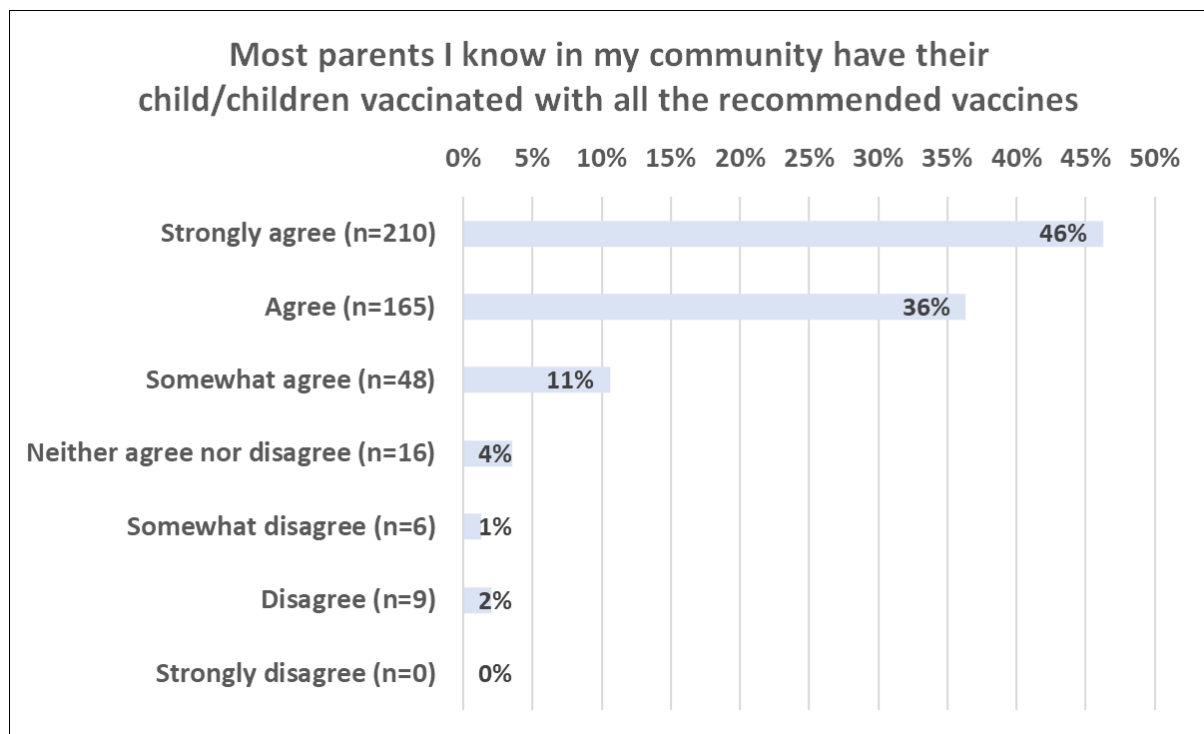
Total respondents answering question n=277

Appendix 31: Influence of wider family



Total respondents answering question n=455

Appendix 32: Parents' in community vaccination



Total respondents answering question n=454

Appendix 33: Number of freetext responses to COVID-19 questionnaire sections, study 2B

- *Paper respondents: 41/42 answered the section about COVID-19 and children's vaccinations.*
- *Online respondents to the COVID-19 questions varied between 353 and 374 responses depending on the question.*
- *Online respondents - 16 made free-text comments in the COVID-19 section and there were 52 online comments made in the other free-text sections of the questionnaire that directly referenced the COVID-19 pandemic and routine childhood vaccinations.*
- *Only one paper respondent left a comment referencing the pandemic and their children's routine vaccinations.*

Appendix 34: Questionnaire free-text responses and focus group quotes illustrating components of the COM-B model: study 2B

Com-B Model Component: CAPABILITY (Knowledge & skills)

Theme	Example quotes
Increased questions about vaccines	'Since covid, we know ... side-effect from the vaccines. So, when you're thinking like that, you don't know if kids aren't having... ... side effects to vaccines but we're not aware of it.' (FG1 participant) 'I feel that covid has created a lot of fear and confusion around standard jabs' (Questionnaire respondent n22) 'But it's (covid) definitely made me listen to the voices more. And then...navigate my own decision.' (FG2 participant) 'I am also questioning things as well.' (FG3 participant)
COVID-19 vaccine viewed similarly to flu vaccine	'I don't give them the flu jab or COVID jabs, haven't done them.' (FG1 participant) 'Refused to have the optional flu jab via nasal spray.' (Questionnaire respondent n98)
COVID-19 vaccination for children viewed differently	'I see the Covid vaccine as different to other vaccines as children aren't usually massively affected by Covid.' (Questionnaire respondent n31) 'I done vaccine for my children, flu. Just COVID, no vaccinated.' (FG4 participant) 'I have chosen not to vaccinate my 5 yr old re covid as the benefits appear to be aimed at protecting others rather than her' (Questionnaire respondent 119)
COVID-19 vaccination, pregnancy, and fertility	'So apparently, some people don't get pregnant, or it affects a woman's ovulation as well.' (FG4 participant) 'And it was a really big thing having the COVID vaccine or not when you were pregnant'. (FG3 participant)
COVID-19 didn't change perception of childhood vaccines.	'I'm not sure COVID changed my opinion on childhood vaccines. I think I question everything.' (FG2 participant) 'Held the same views pre-covid'. (Questionnaire respondent n10)

Com-B Model Component: OPPORTUNITY (Physical: Access, convenience, availability of information)

Theme	Example quotes
Reduced contact/conversations/face-to-face appointments with healthcare professionals during covid	'My child's first year of vaccines took place from March 2020 and this is why I sometimes felt... there was no time for questions - at the 16-week vaccination they didn't even fill in the red book due to wanting to get people in and out quickly'. (Questionnaire respondent 109) 'Reduced availability of face-to-face GP appointments due to the pandemic (i.e., in lockdown)' (Questionnaire respondent 118)
Difficulties in making/attending routine childhood vaccine appointments during covid	'And I remember the first one, I think the first few, it was quite hard to get appointments. And I don't know if that has to do with COVID, because my daughter's two'. (FG2 participant) 'Some of my children's vaccinations were delayed due to medical centre closures during the pandemic but I was proactive in ensuring they were up to date once normal operations resumed'. (Questionnaire respondent n15) 'Access to getting the vaccination is the hardest part. During COVID many GP surgeries were not offering routine vaccination appointments.' (Questionnaire respondent 151)
COVID-19 vaccinations & availability at different locations.	'Supposedly they were obviously offering them to children, there was a drive to encourage the younger years to get the vaccinations, the communication was almost non-existent. Booking was extremely hard. We had to drive for an hour to get it.' (FG2 participant) 'Need better availability of Covid 19 vaccine' (for children) (Questionnaire respondent 132)

Theme Com-B Model Component: MOTIVATION (Attitudes, values, emotions)

Increased belief and trust in vaccinations due to COVID-19	'I feel more aware now. And I don't know if that's because of COVID, just because of vaccine information being more widely available and discussed. But, if anything, it's probably encouraged me more down the vaccine front.' (FG2 participant) 'I think it's made me even keener to prevent any illnesses that my children could get. So, my kids have had COVID vaccines, and I vaccinate them against the flu. And that's offered and things like that. So, for me it's more like giving them the best possible odds, given that the future is uncertain.' (FG2 participant)
Increased vaccine misinformation	'I think there's a lot of misinformation out there, which has become a lot more of it in the last three years.' (FG2 participant) 'It confuses us because there's people who are for it and who are against it and they're very strong views. So, you're in the middle and it's so cloudy.' (FG1 participant)
Mistrust in COVID-19 vaccines (for adults)	'Because I not trust this vaccination. I no COVID vaccine and my husband no COVID vaccine.' (FG4 participant) 'Explain why and how the covid vaccine was approved quicker than normal (no red tape, years to find funding etc).'
Increased mistrust in vaccines now	'All of the nonsense with the COVID-19 vaccines came up, and the mandates, and firing people. And now have basically guaranteed I'll never get a vaccine again.' (Questionnaire respondent 177) 'Makes me wonder what other lies we've been told to safeguard people's opinions on vaccines, right. So, I do wonder if we've been told tales about the safety and efficacy of other medications, not just vaccines, to line people's pockets maybe.' (FG3 respondent)
KEY TO THEMES - Deductive codes on a priori set objectives (including some from previous literature) - Codes developed from questionnaire - Inductive codes that emerged from data	

Appendix 35: Study 2B Question Responses by Ethnicity

Chi square analysis of parents' responses to COVID-19 questions dichotomised into ethnicity groups.

The COVID-19 pandemic has increased my knowledge about all vaccines including vaccines routinely recommended for children.

	Agreed* n (%)	Disagreed** n (%)	p value
White British, White Irish, Other White background	137 (49)	141 (51)	0.163
Mixed, Black or Black British, Asian or Asian British, Chinese or other or unknown Ethnicity group	65 (57)	49 (43)	

The COVID-19 pandemic means I have more questions about all vaccines including the routinely recommended vaccines for children.

White British, White Irish, Other White background	84 (30)	197 (70)	<0.0001
Mixed, Black or Black British, Asian or Asian British, Chinese or other or unknown Ethnicity group	71 (59)	49 (41)	

The COVID-19 pandemic has made me think it is more important for children to have their routine vaccines recommended to all children in the UK.

White British, White Irish, Other White background	167 (62)	104 (38)	0.7900
Mixed, Black or Black British, Asian or Asian British, Chinese or other or unknown Ethnicity group	75 (63)	44 (37)	

The COVID-19 pandemic has made me more likely to refuse or delay vaccines routinely recommended by for my child/children in the UK.

White British, White Irish, Other White background	22 (8)	258 (92)	<0.0001
Mixed, Black or Black British, Asian or Asian British, Chinese or other or unknown Ethnicity group	30 (25)	90 (75)	

I have delayed or refused a vaccine routinely recommended for my child/children since the start of the COVID-19 pandemic.

White British, White Irish, Other White background	29 (11)	240 (89)	0.0031
Mixed, Black or Black British, Asian or Asian British, Chinese or other or unknown Ethnicity group	26 (22)	91 (78)	

It is important for parents to get the recommended vaccines for their child/children.

White British, White Irish, Other White background	301 (97)	8 (3)	0.0017
Mixed, Black or Black British, Asian or Asian British, Chinese or other or unknown Ethnicity group	119 (89)	15 (11)	

The COVID-19 pandemic has made me question whether the vaccines routinely recommended to all children are safe.

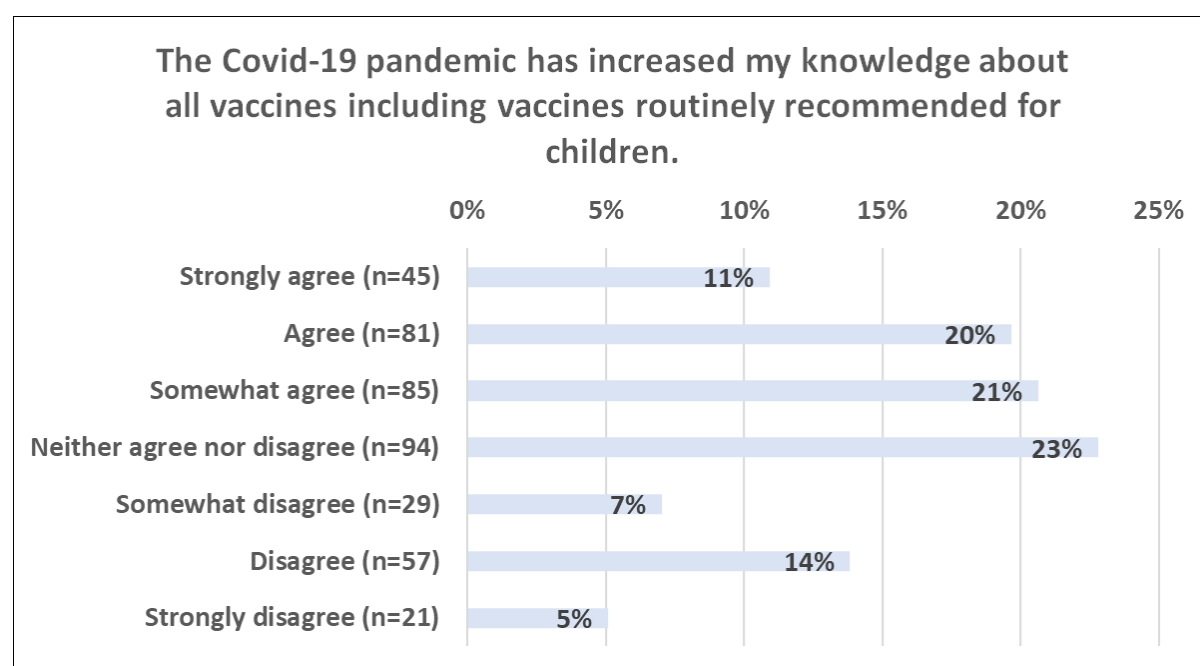
White British, White Irish, Other White background	50 (18)	230 (82)	<0.0001
Mixed, Black or Black British, Asian or Asian British, Chinese or other or unknown Ethnicity group	61 (51)	59 (49)	

Respondents were first dichotomised into those that answered the question: Which of the following best describes your ethnicity? as 'White, White Irish or Other White background' or those that answered any of 'Any Mixed background, Black or Black British or any Black background, Asian or British Asian or any Asian background, Chinese or other or unknown ethnicity group'.

Likert responses to the questions on how their attitudes to routine childhood vaccines had been impacted by the COVID-19 pandemic were then also dichotomised into *Agreed (Strongly agree, Agree or Somewhat Agree) and **Disagreed (Neither agree or disagree, somewhat disagree, Disagreed or Strongly Disagree).

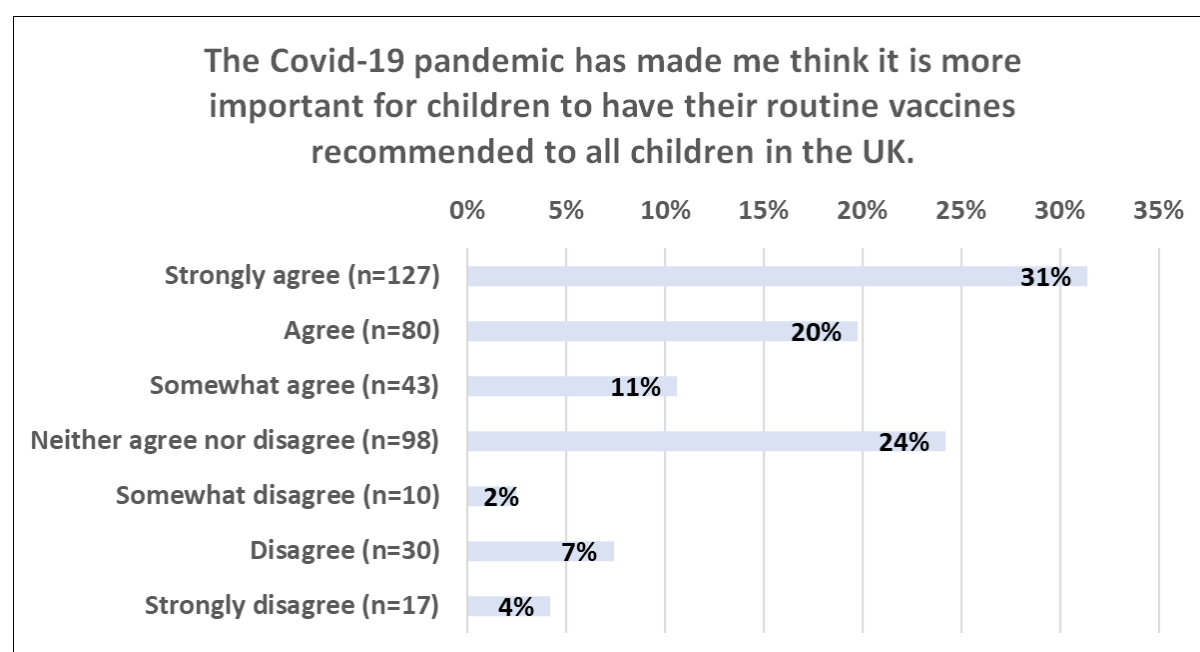
P values reported are from Chi Square test results.

Appendix 36: COVID-19 and knowledge of routine childhood vaccinations



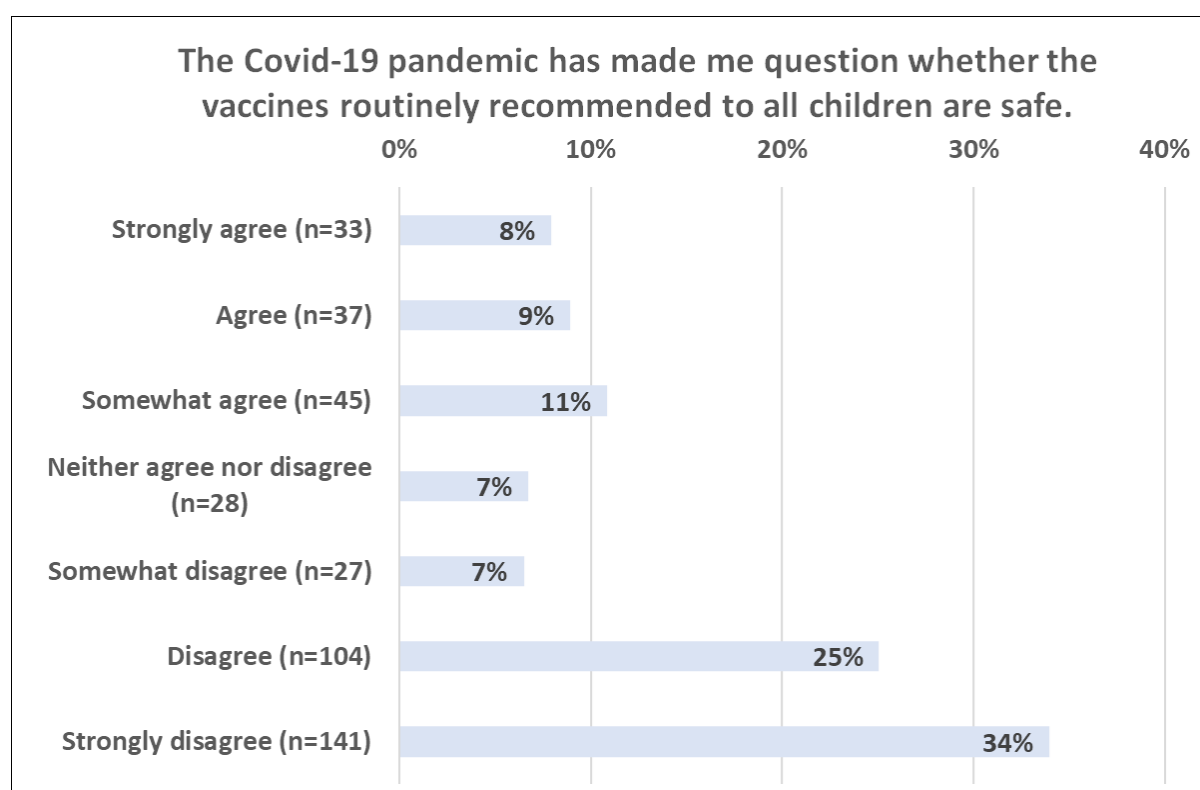
Total respondents answering question n=412

Appendix 37: COVID-19 pandemic and the importance of routine vaccines



Total respondents answering question n=405.

Appendix 38: COVID-19 pandemic and safety of routine vaccines



Total respondents answering question n=415.

Appendix 39: Paper 1: Skirrow H, Foley K, Bedford H, Lewis C, Whittaker E, Costelloe C, Saxena S. Impact of pregnancy vaccine uptake and socio-demographic determinants on subsequent childhood Measles, Mumps and Rubella vaccine uptake: a UK birth cohort study.

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Impact of pregnancy vaccine uptake and socio-demographic determinants on subsequent childhood Measles, Mumps and Rubella vaccine uptake: A UK birth cohort study

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Keywords:
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Socio-demographic determinants
Pregnancy vaccines

ABSTRACT

Background: We examined the association between socio-demographic determinants and uptake of childhood Measles, Mumps & Rubella (MMR) vaccines and the association between pregnant women's pertussis vaccine uptake and their children's MMR vaccine uptake.

Methods: We used nationally-representative linked mother-baby electronic records from the United Kingdom's Clinical-Practice-Research-Datalink. We created a birth cohort of children born between 01.01.2000 and 12.12.2020. We estimated the proportion vaccinated with first MMR vaccine by age 2 years and first and second MMR vaccines by age 5 years. We used survival-analysis and Cox proportional hazard models to examine the association between deprivation, ethnicity and maternal age and pertussis vaccination in pregnancy and children's MMR uptake.

Results: Overall, 89.4 % (710,797/795,497) of children had first MMR by age 2 years and 92.6 % (736,495/795,497) by age 5 years. Among children still in the cohort when second MMR was due, 85.9 % (478,480/557,050) had two MMRs by age 5 years. Children from the most-deprived areas, children of Black ethnicity and children of mothers aged < 20 years had increased risk of being unvaccinated compared with children from the least-deprived areas, White children and children of mothers aged 31–40 years: first MMR by 5 years, adjusted Hazard Ratios (HR):0.86 (CI:0.85–0.87), HR:0.87 (CI:0.85–0.88) & HR:0.89 (CI:0.88–0.90) respectively. Deprivation was the determinant associated with the greatest risk of missed second MMR: adjusted HR:0.82 (CI:0.81–0.83). Children of mothers vaccinated in pregnancy were more likely than children of unvaccinated mothers to have MMR vaccines after adjusting for ethnicity, deprivation, and maternal age (First and Second MMRs adjusted HRs:1.43 (CI:1.41–1.45), 1.49 (CI:1.45–1.53).

Conclusion: Children from most-deprived areas are less likely to have MMR vaccines compared with children from least-deprived areas. Mothers who take up pregnancy vaccines are more likely to have their children vaccinated with MMR. Healthcare services should promote and facilitate access to both maternal and childhood vaccines during pregnancy.

1. Introduction

In the United Kingdom (UK), since the two dose MMR schedule was introduced in 1996 all children are recommended to receive their first MMR vaccine at age 1 year, and then a second dose usually at age 3 years 4 months [1,2], though some areas offer a second dose earlier [3].

However, despite universal health coverage the UK has consistently not met the national target of 95 % children having two doses of MMR vaccine by five years of age – in line with the World Health Organization's (WHO) recommendation [4]. For example, data for the first quarter of 2023 show only 85.6 % of UK children were vaccinated with two doses of MMR by age 5 years [4]. Sub-optimal childhood vaccine

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uptake leaves individuals and populations vulnerable to infections, and increases the risk of infectious disease outbreaks [5]. This is of particular concern currently as the Covid-19 pandemic resulted in decreased childhood vaccine uptake [6], and a rise in measles cases has been reported in 2023 in the UK [5].

The now discredited publication and subsequent scandal [7] at the turn of the century that led to parents' concerns about the safety of MMR vaccine [8] negatively impacted uptake. However, many other socio-demographic determinants also affect MMR uptake. In the UK, children living in more deprived areas are at higher risk of being unvaccinated [9,10] or vaccinated late [11–13], as are children belonging to ethnic minorities, compared with White-British ethnicity children [9,10,13,14,15]. Uptake is affected by the ease of accessing vaccination for individuals or parents [16], as well as the degree of an individual's or a population's vaccine hesitancy - described as 'indecisiveness regarding a vaccination decision' [17].

Maternal factors such as age, smoking [18], education levels [18,19] and mental ill health [20] have also been found to be associated with childhood vaccine uptake. Maternal vaccination is a developing area – in the UK pregnant women are currently recommended to receive pertussis vaccine, seasonal influenza vaccine and the Covid-19 vaccine, and more maternal vaccines are likely to be introduced in the future [21]. Seasonal influenza vaccine has been offered to pregnant women since 2010 [22] following the H1N1 influenza outbreak and Covid-19 vaccines recommended for pregnant women since April 2021 [23], due to pregnant women being at increased risk from both influenza and Covid-19. Pertussis vaccine was introduced in Autumn 2012, following an outbreak of infections and deaths from whooping cough among infants under 3 months of age [22,24]. The vaccine is given during pregnancy to prevent infection in new-borns. Previous research in Australia for example has found that vaccine hesitancy in pregnancy is correlated with lower infant vaccine uptake post-delivery [25]. However, UK research to date has not examined the association between pregnancy vaccine uptake and subsequent childhood vaccine uptake.

This study aimed to describe MMR vaccine uptake and examine the association between socio-demographic determinants such as deprivation, maternal age, and ethnicity in a large, UK birth cohort over a 20-year period from 2000 onwards. This study also aimed to examine if children of mothers vaccinated in pregnancy are more likely to receive MMR vaccines.

2. Methods

2.1. Study design and data sources

We undertook a retrospective birth cohort study using data from the UK Clinical Practice Research Datalink (CPRD) Gold database, a large, nationally representative primary care research database with a total of 984 current and historic contributing UK general practices [26,27]. All primary care contacts are recorded in a patient's electronic medical records using codes to record diagnoses, prescriptions and procedures, including vaccinations; CPRD has been used previously to study vaccine uptake in the UK [20,28].

2.2. Cohort construction

To create the birth cohort, we identified children born between January 1, 2000, and December 31, 2020 (Fig. 1). We took the child's date of birth from the estimated date of delivery provided in the CPRD mother-baby link [29]. The mother-baby link estimates date of delivery through a validated process that identifies all maternal deliveries, identifies children born and then links births to deliveries by unique practice and family identifiers within specified time periods [29]. The estimated age that children received their MMR vaccines could then be calculated. Only children registered at an 'up to standard' CPRD-participating practice at birth and registered within 6 months of their birth were included. Up to standard indicates that a GP practice's data is deemed to be of research quality [27]. Children with less than one year of follow up were excluded as they were not eligible for their first MMR vaccine until one year of age. Children were followed up from birth until the end of the study period (December 31, 2020), or to the date they left the practice (deregistered), or died or the practice stopped collecting data, whichever came first. We created a sub-cohort of children who were still in the cohort when they became eligible for their second MMR vaccine, and another sub-cohort of children who were born after 2013 for the analysis of maternal pertussis vaccine uptake. Children were then also linked to the Indices of Multiple Deprivation (IMD) [30] based on their postcode. However, data on IMD was only available for children in England so multivariable analysis including deprivation was conducted including England only children.

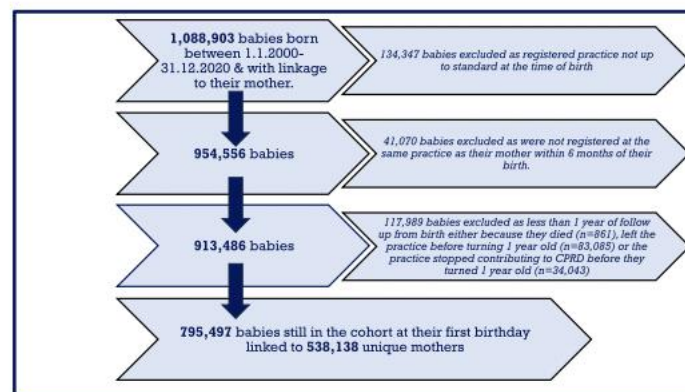


Fig. 1. Cohort construction of children born between January 2000 and December 2020 with a link to their mother and registered at CPRD Gold participating practices. Children leave the cohort at the end of the study period (31/12/2020). Consequently, children leave the cohort at varying ages. Children may also leave the cohort before the end of the study period if the last practice data collection date was prior to the end of the study period or if they leave their registered practice.

2.3. Outcomes

The main outcomes for the study were the proportions of children receiving first MMR vaccine by age 2 years, and both first and second MMR vaccines by age 5 years, in line with reported national childhood vaccine coverage statistics of MMR uptake [4]. The two dose schedule is to ensure that those individuals not fully protected by the first dose are protected by the second therefore reducing susceptibility in the population [2]. We determined from children's primary care records whether a child had received their MMR vaccines using Read codes (Supplementary 1), and the dates of their first and second MMR vaccinations.

2.4. Covariates

We examined the relationship between several covariates identified as being associated with childhood vaccine uptake from previous studies including ethnicity, deprivation, birth order and maternal age [9,14,19]. We assigned each child in England to one of five deprivation groups (quintiles) using English IMD based on the child's postcode [30]. Quintile 1 being the 20 % least deprived areas of England and Quintile 5 being the 20 % most deprived areas of England. We identified mothers who only had one child linked to their record as a proxy of being first or only children, and used maternal age at birth of the child to assign children to maternal age groups: <20 years, 21–30 years, 31–40 years, and 41 years or older. Children's ethnicity was determined using previously described code lists and a child assigned to one of the higher-level classification ethnicity groups: 'Asian', 'Black', 'Mixed', 'White', 'Other' and 'Unknown' [31]. If the child's record was missing any record of ethnicity then an ethnicity code from the mother's record was used. Maternal pertussis vaccine uptake was determined using the mother's GP record in the one year prior to the estimated delivery date in the mother-baby link (Supplementary 1). Influenza vaccination in pregnancy was not examined as accurately identifying the denominator of pregnant women eligible for influenza vaccine each year is challenging due to the seasonality of the vaccination programme. Pertussis vaccine in contrast is offered to all pregnant women. If a baby was missing data on deprivation or ethnicity they were allocated to an unknown category. We also used the region of CPRD practice to determine which UK nation a child lived in.

2.5. Statistical analysis

2.5.1. Calculating MMR vaccine uptake

We estimated MMR vaccine uptake in the cohort by calculating the number of children who had one MMR vaccine dose by ages 2 years and 5 years. We estimated second dose uptake from the number of children who were still in the cohort by age 3 years 4 months and therefore eligible for their second dose, and calculating the number who had two doses of MMR vaccines recorded. We then calculated first and second dose MMR uptake by different socio-demographic groups based on deprivation, ethnicity, maternal age, birth order or family size and nation by the same ages – age 2 and 5 years for first dose and by 5 years for second dose.

2.5.2. Examining socio-demographic determinants of MMR vaccine uptake

We plotted inverse Kaplan-Meier survival curves for each predictor variable (deprivation quintile, ethnicity, maternal age, birth order and nation of the UK where the baby lived) to compare uptake among different socio-demographic determinant groups. Children were censored before 5 years, if they died, left their practice or the practice stopped contributing to CPRD. We checked whether the predictors met the proportional hazard assumptions using Kaplan-Meier survival curves. We then used Cox proportional hazard models to estimate hazard ratios (HR) for MMR first dose vaccination by 2 and 5 years of age and second dose MMR vaccination by 5 years of age for predictors that met assumptions. We first carried out univariate analysis followed by

multivariable analyses adjusting for deprivation, maternal age, and ethnicity. Covariates were included in the adjusted multi-variable model if they were associated in the univariate analysis. We considered an association of $p < 0.05$ as statistically significant. We performed sensitivity analyses to understand how associations with socio-demographic determinants might be affected by missing data. We examined the association of socio-demographic determinants among children without known deprivation and then without recorded ethnicity. We used Stata version 17 (Stata Corp, College Station, Texas, USA) for the analyses.

3. Results

3.1. Cohort demographics

Our birth cohort consisted of 795,497 children born and registered with CPRD practices between January 2000 and December 2020. There were 557,050 children still in the cohort at age 3 years 4 months when their second MMR vaccine was due. By the age of 5 years there were 446,476 children still in the cohort. The largest ethnic group children were children of unknown ethnicity (329,215/705,497, 41.4 %) and second largest was White ethnicity (279,574/795,497, 35.1 %). Six per cent (47,993/795,497) of all children were born to mothers aged 20 years or younger (Table 1). The cohort included more children born in or before 2009 (435,776/795,497, 54.8 %) and 88 % (699,957/795,497) were born before 2015 (supplementary file 2).

Our cohort was broadly representative of the UK though among English children ($n = 520,874$) more lived in the least deprived areas (18 %: 92,532/520,874), compared to only 14 % of children (73,595/520,874) who lived in the most deprived areas. Deprivation information was unknown for 23 % (120,729/520,874) of English children.

Table 1
Socio-demographic determinants in the birth cohort.

Characteristic	Number (%)
Children	795,497^a
Boys	407,840 (51.3)
Deprivation^b	
Quintile 1 (least deprived)	92,532 (17.8)
Quintile 2	80,236 (15.4)
Quintile 3	78,819 (15.1)
Quintile 4	74,936 (14.4)
Quintile 5 (most deprived)	73,595 (14.1)
Unknown	120,729 (23.2)
Ethnicity	
White	279,574 (35.2)
Mixed	138,269 (17.4)
Asian or British Asian	27,985 (3.5)
Black or Black British	13,816 (1.7)
Other Ethnic Group	6,538 (0.8)
Unknown	329,215 (41.4)
Maternal age at birth of child (years)	
<20	47,993 (6.0)
21–30	355,663 (44.7)
31–40	368,438 (46.3)
41+	23,403 (2.9)
Family size/number children matched to mother	
First or only children	330,038 (41.5)
Two children	323,998 (40.7)
Three or more children	141,461 (17.8)
Country	
England	520,874 (65.5)
Scotland	139,277 (17.5)
Wales	90,139 (11.3)
Northern Ireland	45,207 (5.7)

^a Born between 01/01/2000 and 31/12/2020 registered to UK Clinical Practice Research Datalink practices.

^b IMD data only available for English children ($n = 520,874$). IMD: Index of multiple deprivation quintiles (5 the most deprived, 1 least deprived).

3.2. MMR vaccine uptake

Uptake of the first MMR vaccine in the cohort was 89.4 % ($n = 710,797/795,497$) by age 2 years and 92.6 % ($n = 736,495/795,497$) by age 5 years (Fig. 2). The median age of first dose MMR vaccine uptake was 13.3 months (1 year, 1 month). Second dose MMR uptake was 85.9 % ($n = 478,480/557,050$) among those children who were still in the cohort at age 3 years 4 months when they became eligible for it (Fig. 2) and the median age of second dose MMR vaccine was 42.2 months (3 years, 6 months).

3.3. MMR vaccine uptake by deprivation

Uptake of first dose MMR at 2 years was lowest at 85.5 % in the most deprived areas of England compared with 91.1 % uptake in the least deprived areas. Similarly, at 5 years of age, lowest uptake was also seen for first dose (90.1 %) and second dose (81.5 %) of MMR vaccine in the most deprived areas, compared to 93.9 % (first dose) and 88.0 % (second dose) in the least deprived areas (Tables 2 and 3 and supplementary 3). After the most deprived areas the children with lowest uptake were those with unknown deprivation who had first dose MMR uptake at 2 years and 5 years of 87.6 % and 90.6 % compared to 91.1 % and 93.9 % in the least deprived areas. For second dose MMR vaccine children with unknown deprivation had uptake of 82.7 % by age 5 years compared to 88.0 % in the least deprived areas (Tables 2 and 3 & supplementary 3).

3.4. MMR vaccine uptake by ethnicity

Children who were of Black or Black-British ethnicity had lowest MMR vaccine uptake for their first dose of MMR vaccine by 2 and 5 years and their second dose by 5 years (84.1 % vaccinated with first dose by age 2 years, 87.7 % vaccinated by age 5 years & 79.7 % vaccinated with two doses by age 5 years compared to 90.7 %, 93.7 % and 87.5 % uptake among white ethnicity children at 2 years, 5 years (first dose) and 5 years (second dose) respectively, (Tables 2 and 3 & supplementary 4). Children recorded as 'Other ethnicity group' had the second lowest uptake with 86.5 % having their first dose by age 2 years and 88.2 % by 5 years compared to 90.7 % and 93.7 % among children of white children. Only 81.6 % children in the 'Other ethnicity group' had two doses of MMR by age 5 years compared to 87.5 % of white ethnicity children.

3.5. MMR vaccine uptake by maternal age

Children born to mothers aged 20 years or younger had a lower uptake of the first dose of MMR vaccine uptake at 2 and 5 years, compared with mothers aged 31–40 years (85.8 % by 2 years & 90.4 % by 5 years compared with 90.2 % by 2 years and 93.2 % by 5 years respectively) (Tables 2 and 3 & supplementary 5). Uptake of the second dose of MMR vaccine at 5 years among children of mothers aged 20 years or younger was 83.2 %, compared with 86.5 % uptake for children of mothers aged 31–40 years.

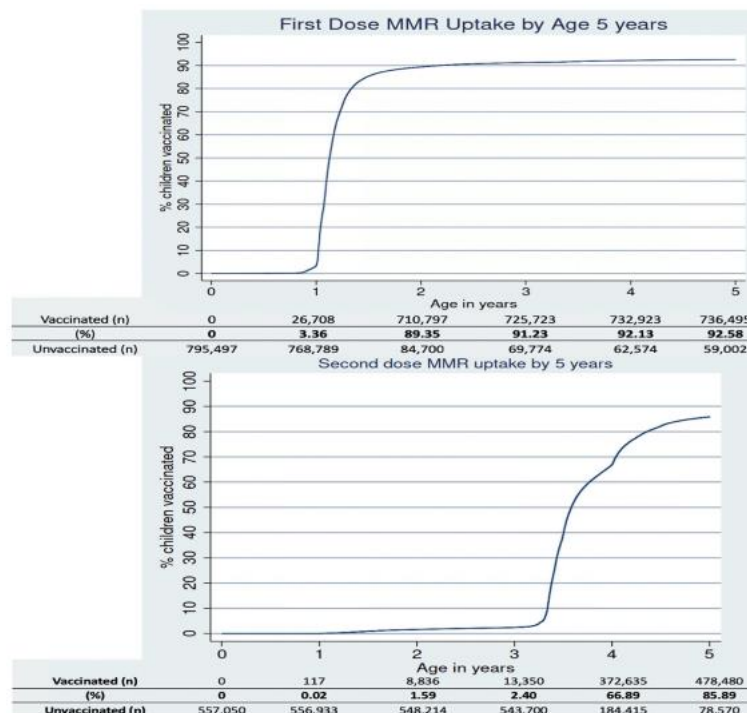


Fig. 2. First and second dose MMR Vaccine Uptake by 5 years of age in the birth cohort

i. First Dose MMR Vaccine uptake over the cohort shown by inverse Kaplan–Meier curve. ($n = 795,497$). ii. Second Dose MMR Vaccine uptake over the cohort shown by inverse Kaplan–Meier curve. ($n = 557,050$).

Table 2
Association of socio-demographic determinants on uptake of first dose of MMR vaccine by age 2 and 5 years.

	Uptake first dose MMR by age 2 years					Uptake first dose MMR by age 5 years				
	n (%)	HR	95 % CI	HR Adjusted*	95 % CI	n (%)	HR	95 % CI	HR Adjusted*	95 % CI
All Children*	710,797 (89.4)					736,495 (92.6)				
Deprivation**										
Quintile 1	84,324 (91.1)					86,895 (93.9)				
Quintile 2	72,452 (90.3)	0.99	0.98–1.00	0.99	0.98–1.00	74,731 (93.1)	0.99	0.98–0.99	0.98	0.98–0.99
Quintile 3	69,980 (88.8)	0.95	0.94–0.96	0.94	0.93–0.95	72,466 (91.9)	0.95	0.94–0.95	0.94	0.93–0.95
Quintile 4	65,835 (87.8)	0.93	0.92–0.94	0.93	0.92–0.94	68,481 (91.4)	0.93	0.92–0.94	0.93	0.92–0.94
Quintile 5 (most deprived)	62,908 (85.5)	0.85	0.84–0.86	0.85	0.84–0.86	66,269 (90.1)	0.86	0.85–0.87	0.86	0.85–0.87
Unknown	105,752 (87.6)	0.95	0.94–0.96	0.95	0.94–0.96	109,385 (90.6)	0.94	0.94–0.95	0.94	0.93–0.95
Ethnicity*										
White	253,656 (90.7)					262,051 (93.7)				
Mixed	126,346 (91.4)	0.99	0.98–0.99	1.03	1.02–1.03	130,223 (94.2)	0.99	0.98–0.99	1.03	1.02–1.04
Asian or British Asian	16,062 (90.3)	1.01	0.99–1.02	1.08	1.06–1.09	25,880 (92.5)	0.99	0.98–1.00	1.07	1.05–1.08
Black or Black British	11,615 (84.1)	0.80	0.79–0.82	0.87	0.85–0.89	12,117 (87.7)	0.79	0.78–0.81	0.87	0.85–0.88
Other Ethnic Group	5,742 (86.5)	0.95	0.92–0.97	1.01	0.98–1.04	5,854 (88.2)	0.92	0.89–0.94	0.98	0.95–1.01
Unknown	288,182 (87.5)					300,375 (91.2)				
Maternal age at birth of child (years)*										
≤20	41,115 (85.8)	0.84	0.83–0.85	0.88	0.87–0.89	43,400 (90.4)	0.85	0.85–0.86	0.89	0.88–0.90
21–30	316,537 (88.9)	0.98	0.98–0.99	1.00	0.99–1.00	328,260 (92.2)	0.98	0.98–0.99	0.99	0.99–1.00
31–40	332,387 (90.2)	–	–	–	–	343,280 (93.2)	–	–	–	–
41+	20,718 (88.5)	0.95	0.94–0.97	0.94	0.92–0.96	21,555 (92.1)	0.96	0.94–0.97	0.94	0.93–0.96

Proportion of children vaccinated by socio-demographic determinant and univariate and multivariable Cox regression analyses. Hazard Ratios are of first dose MMR uptake by age 2 and 5 years. *795,497**Only English children n = 520,874. Reference categories: Quintile 1 (least deprived), White Ethnicity, Mothers aged 31–40 years.

3.6. MMR vaccine uptake by family size

Children born to mothers with only one child linked to them in the birth cohort had lower first MMR vaccine uptake by 5 years (89.6 %), compared with children born to mothers with either two (94.9 %) or three or more children (93.7 %) (supplementary 6). For second dose of MMR vaccine uptake by age 5 years, children who were born to mothers with only one child linked to them had uptake of 82.9 % compared to 88.2 % uptake among those with two or more children or 85.5 % uptake among those with three or more children (supplementary 6).

3.7. MMR vaccine uptake by UK nation

Uptake in England was lower than in other nations of the United Kingdom with first dose MMR uptake by 5 years 91.8 %, compared with 95.4 % in Northern Ireland (supplementary material 9). For second dose MMR uptake in England was 84.6 %, compared again to the highest uptake in Northern Ireland of 91.2 % (supplementary 7).

3.8. Univariate and multivariable effects of deprivation, ethnicity, and maternal age on MMR vaccine uptake

Children living in the most deprived areas of England were less likely to have their MMR vaccines compared to children living in the least deprived areas in both the univariate and multivariable adjusted models. In the adjusted Cox proportional hazard model, English children born in the most deprived areas were less likely to have their first MMR vaccine by age 2 years and 5 years (adjusting for ethnicity and maternal age): first dose MMR uptake by 2 years adjusted hazard ratio (HR) 0.85, (95 % CI: 0.84–0.87) & first dose MMR uptake by 5 years adjusted hazard ratio (HR) 0.86 (95 % CI: 0.85–0.87). This association was strongest for second MMR vaccine dose by age 5 years with children born in the most deprived areas least likely to be vaccinated (adjusted HR 0.82 (95 % CI:

0.81–0.83) compared with children born in the least deprived areas (Table 3, Fig. 3).

In the Cox proportional hazard model English children of Black or Black-British ethnicity were less likely to be vaccinated with MMR vaccines compared with children of white ethnicity, though the strength of this association was reduced after adjusting for deprivation and maternal age. First dose of MMR vaccine by 2 years of age adjusted hazard ratio (HR) 0.87, 95 % CI: 0.85–0.89 and adjusted hazard ratios of first and second dose MMR by age 5 years: HR 0.87, 95 % CI: 0.85–0.88 & 0.93, 95 % CI: 0.90–0.95. There were also a higher percentage of children of Black or Black British ethnicity living in the most deprived regions of England (3,985, 32.0 %) compared to the percentage of White ethnicity children living in the most deprived areas of England (21,543, 14.8 %) (supplementary 8). Hazard ratios of the unknown ethnicity group from the Cox proportional hazard model are not reported as the unknown ethnicity group did not have a proportional relationship with other ethnicity groups (supplementary 4).

Children of mothers aged 20 years or younger were also less likely to have MMR vaccines compared to children of mothers aged 31–40 years, first dose MMR adjusted HR by 2 years 0.88, 95 % CI: 0.87–0.89 and 5 years 0.89, 95 % CI: 0.88–0.90 and second dose MMR adjusted HR by 5 years, 0.94 95 % CI: 0.92–0.96. There was also a higher percentage of children born to mothers aged under 20 years living in the most deprived areas of England (9,320, 30.5 %) compared to the percentage of mothers aged 31–40 years living in the most deprived areas of England (21,817, 8.9 %) (supplementary 9). Family size and nation were not included in the Cox models as assumptions were not met. Directions of associations and conclusions of the relationship between first and second dose MMR vaccine uptake and socio-demographic determinants were robust to sensitivity analyses excluding missing data (supplementary 10).

Table 3
Association of socio-demographic determinants on uptake of second dose of MMR vaccine by age 5 years.

	Uptake second dose MMR by age 5 years				
	n (%)	HR	95 % CI	HR Adjusted*	95 % CI
All Children*	478,480 (85.9)*				
Deprivation**					
Quintile 1	58,947 (88.0)				
Quintile 2	48,146 (86.9)	0.96	0.95–0.97	0.96	0.94–0.97
Quintile 3	44,965 (85.4)	0.91	0.90–0.92	0.90	0.89–0.92
Quintile 4	41,098 (84.4)	0.91	0.90–0.93	0.90	0.89–0.91
Quintile 5 (most deprived)	38,345 (81.5)	0.84	0.82–0.85	0.82	0.81–0.83
Unknown	65,678 (82.7)				
Ethnicity*					
White	173,816 (87.5)				
Mixed	86,520 (88.7)	1.08	1.07–1.08	1.09	1.08–1.10
Asian or British	15,134 (86.1)	0.99	0.98–1.01	1.08	1.06–1.10
Black or Black	6,400 (79.7)	0.84	0.82–0.86	0.93	0.90–0.95
British	3,066 (81.6)	0.91	0.88–0.95	0.98	0.94–1.02
Other Ethnic Group	193,544 (83.7)				
Maternal age at birth of child (years)*					
≤20	27,043 (83.2)	0.88	0.86–0.89	0.92	0.90–0.93
21–30	209,072 (85.7)	0.98	0.98–0.99	1.00	0.99–1.01
31–40	228,123 (86.5)				
41+	14,242 (84.3)	0.97	0.95–0.99	0.94	0.92–0.96

*n = 557,050. Univariate and multivariable Cox regression analyses for Hazard Ratios of second dose MMR uptake by age 5 years.

**Only English children n = 350,241. Reference categories: Quintile 1 (least deprived), White Ethnicity, Mothers aged 31–40 years.

3.9. Maternal pertussis and MMR uptake

Overall uptake of pertussis vaccine among pregnant women was 61.1 % (126,846 mothers of 207,531 children born from 2013 onwards were vaccinated against pertussis in their pregnancies). Among the children born to mothers who were vaccinated in pregnancy 94.8 % (n = 120,200) had one dose of MMR vaccine by age 5 years. Uptake was lower among children born to the 80,685 mothers unvaccinated in pregnancy: 87.9 % (n = 70,961) children had one dose of MMR vaccine by 5 years (Fig. 4). Of the mothers of children in the 2013 cohort when eligible for their second MMR vaccine (n = 98,838), 65.9 % (n = 65,109) were vaccinated against pertussis. Of children born to mothers vaccinated against pertussis in pregnancy 89.5 % had two MMR vaccines by age 5 years (n = 58,292). This compares with uptake among children of unvaccinated mothers 79.4 % (n = 26,777) for two doses of MMR vaccines by 5 years (Fig. 4).

In the Cox proportional hazard model of the 2013 cohort, children born in the most deprived areas of England were least likely to be vaccinated with their MMR vaccines by age 5 years (supplementary 11). Children in England who were born to mothers vaccinated in pregnancy were more likely to have their first and second dose MMR vaccines by the age of 5 years, HRs: 1.43, 95 % CI:1.41–1.45, 1.49, 95 %

CI:1.45–1.53 after adjusting for Ethnicity, deprivation, and maternal age (Table 4).

4. Discussion

4.1. Main findings

We found in a large birth cohort study of children born since 2000 that MMR vaccine uptake did not meet national targets in line with reported national uptake estimates [4]. Consistent with previous smaller cohort or regional studies [9,11], we found that being born in a more deprived area is associated with lower MMR vaccine uptake, compared to children born in least deprived areas. We also found that even after adjusting for ethnicity, deprivation and maternal age, which are all associated with both maternal and childhood vaccine uptake [9,22], children born since 2013 to mothers vaccinated against pertussis in pregnancy were 40 % more likely to have their first and second dose MMR vaccines by age 5 years. To our knowledge, this is the first study to assess the association between pregnancy vaccine uptake and childhood vaccine uptake in a UK birth cohort.

The estimates from our cohort of first, and second dose MMR uptake broadly reflect the national picture of MMR vaccine uptake over the same time-period: MMR uptake is sub-optimal in the UK and is below the national 95 % target by 5 years of age. In our overall birth cohort of 795,497 children registered with UK primary care, there was 89.4 % uptake of first dose of MMR vaccine by 2 years of age. UKHSA reports similar coverage of first MMR dose: below 90 % between 2000 and 2010 and then increasing to slightly above 90 % between 2011 and 2020 [32]. Our finding of pertussis vaccine uptake of over 60 % of mothers vaccinated in pregnancy is also broadly in line with other estimates, though uptake varies geographically [22,24].

We found that first dose MMR uptake by 5 years of age was higher than at 2 years with 92.6 % children vaccinated, this is again in line with national coverage estimates which reported coverage between 2010 and 2020 ranged between 92.4 and 94.3 % [32]. In our cohort, uptake of second MMR vaccine was also lower, again in line with national reported coverage – with 85.9 % of children vaccinated with two MMR doses by age 5 years and national coverage of 86.0–86.6 % between 2010 and 2020 reaching a high of 88.6 % in 2014–15.

Uptake for second dose of MMR vaccination increased at age 4 years (Fig. 2). This could be due to either unvaccinated 4 year old children being invited for their second MMR, or parents taking children to be vaccinated when they are due to start school after receiving reminders to check their child's vaccination status [33].

4.2. Comparison with previous literature

Our finding that being born in one of the most deprived areas of England was most strongly associated with a lower chance of receiving MMR vaccines is consistent with previous findings that deprivation is associated with vaccine uptake [9,11]. In our study children born in the most deprived areas of England were 14 % less likely to have the first dose of MMR vaccine by age 5 years compared to children in the least deprived areas. The association in our cohort between deprivation and MMR vaccine uptake was even stronger for the second dose of MMR, with children in the most deprived areas 18 % less likely to have their second MMR by age 5 years, compared to children in the least deprived areas. We found that children of Black or Black-British ethnicity were less likely to be vaccinated with MMR vaccines at ages 2 and 5 years though the association was reduced after adjusting for deprivation and maternal age. This finding is consistent with previous work in childhood vaccine uptake which finds that children with Black or Black-British ethnicity are less likely to be vaccinated in the UK [10,14]. Similarly, children born to mothers aged under 20 years were less likely to be vaccinated than older mothers, as reported from previous studies [19]. However, again, the association was reduced after adjusting for

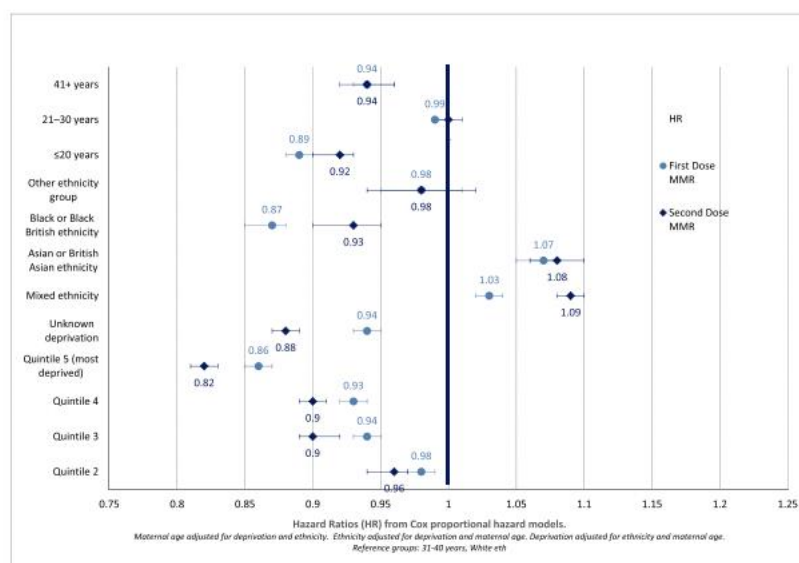


Fig. 3. Adjusted Hazard Ratios of likelihood of a child in England being vaccinated by age 5 years with one dose or two doses of MMR vaccines by maternal age, ethnicity group & deprivation quintile.

deprivation in the multivariable models.

Our finding that pregnancy vaccine uptake and childhood vaccine uptake in the UK are related is supported by previous studies from Australia [25] where antenatal interventions to improve both maternal and childhood vaccination are already being piloted [34]. In Australia a pilot intervention targeted three aspects of pregnant women's health-care encounters: changing 'practice' by having vaccine champions, improving 'providers' knowledge of vaccines and also giving 'parents' reminders and resources [34]. Given that sociodemographic determinants for both pregnancy and childhood vaccine uptake in the UK are similar [10] our finding is not surprising, however whether interventions such as included in the Australian pilot would be applicable and effective in a UK setting is unknown. However, there is increasing evidence that pregnancy vaccine intentions relate to subsequent childhood vaccine attitudes and uptake [35–37]. In previous work for example, Covid-19 vaccine acceptance among UK pregnant women was associated with likelihood of also accepting a Covid-19 vaccine for their children [23].

4.3. Limitations

The size of our cohort and representativeness of the CPRD database [26] reduces the possibility that our findings are due to chance and our analysis was highly powered. However, as with any observational cohort study, there are some important biases relating to medical coding accuracy, data completeness and loss to follow-up that need consideration. A main source of bias in our findings could arise from children being lost to follow-up, however by using survival analysis methods, and only analysing second MMR uptake among children still in the cohort when their second MMR was due, this was minimised. Children who deregistered from their practice before the age of 1 year were excluded, as they were never eligible for their first dose of MMR. However, moving during pregnancy and childhood has been found to be associated with lower vaccine uptake [38]. Our CPRD cohort may be biased and include families less likely to move and who stay registered with the same CPRD

practice and thus are more likely to be vaccinated. This bias may explain our finding that first born or only children had lower vaccine uptake compared to larger families, which is not consistent with previous studies in which larger family sizes have been found to be associated with increased chance of missing childhood vaccines [19,8]. The families in our cohort may have been more likely to have their children vaccinated anyway due to being less likely to have moved, or using their knowledge and experience of having older children vaccinated. For example, research during Covid-19 found that mothers often relied on knowledge from previous pregnancies when accessing childhood vaccinations [39].

Incompleteness of ethnicity and deprivation data is the main limitation of our study and likely arose as our cohort was historical, extending back to 2000, when medical coding and in particular ethnicity coding was less complete [26,40]. In the cohort 40 % were missing ethnicity coding. The numbers of children in the ethnic minority groups were small, for example, only (13,816, 1.7 %) of children in the cohort were Black or Black-British compared to 4 % of the population of England and Wales [41]. Though 17 % of our cohort were Scottish where only 1 % of the population are Black or Black-British [42]. As a result, we lacked power to identify associations between different smaller ethnicity groups which may have given more granular detail than the higher order ethnicity groupings used in our analysis. We did have deprivation data for the majority (77 %) of the England cohort though deprivation data for other UK nations is not available for CPRD data linkage. Another limitation is the historical nature of this cohort as fewer practices have contributed to CPRD Gold in more recent years. However the trends in MMR vaccine uptake are relevant for the UK today when due to the Covid-19 pandemic, MMR vaccine uptake has fallen further exacerbating existing inequalities, and leading to increasing outbreaks of measles [5,33].

Although almost all vaccinations occur in primary care our data sources would not capture vaccinations received in specialist settings such as hospitals, but this is likely to be the case for only a small minority of children. Some pregnant women may be vaccinated in hospital

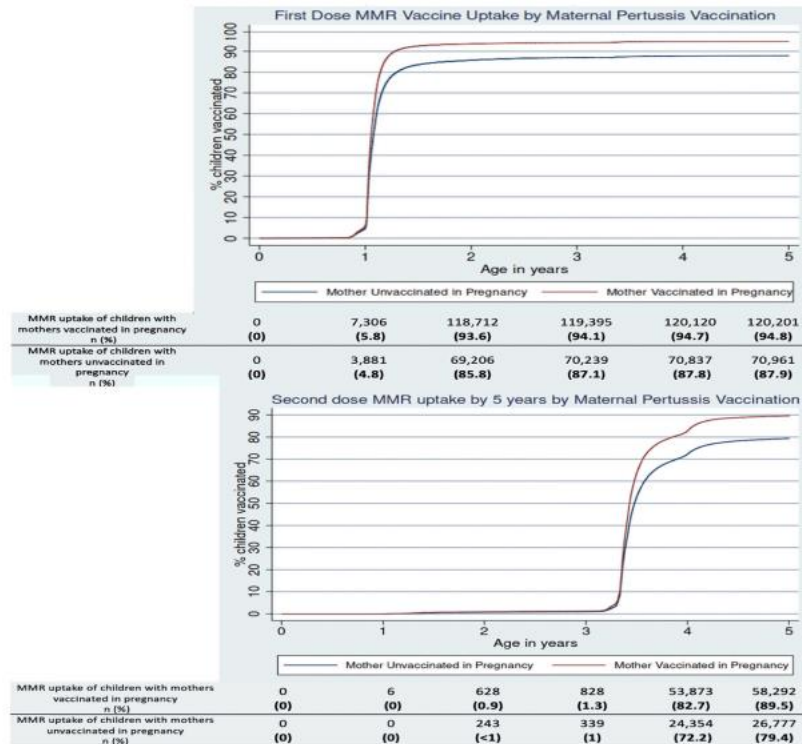


Fig. 4. First and second dose of MMR uptake by maternal pertussis vaccination
i. First Dose MMR Vaccine uptake over the 2013 cohort shown by inverse Kaplan–Meier curve. (n = 207,531). ii. Second Dose MMR Vaccine uptake over the 2013 cohort eligible for second MMR shown by inverse Kaplan–Meier curve. (n = 98,838).

Table 4

Univariate and multivariable Cox regression analyses for Hazard Ratios of first and second dose MMR uptake by age 5 years by maternal pertussis vaccination status.

Uptake first dose MMR by age 5 years						Uptake second dose MMR by age 5 years					
Children with mothers vaccinated in pregnancy n (%)	Children with mothers unvaccinated in pregnancy n (%)	HR	95 % CI	HR Adjusted *	95 % CI	Children with mothers vaccinated in pregnancy n (%)	Children with mothers unvaccinated in pregnancy n (%)	HR	95 % CI	HR Adjusted **	95 % CI
120,201 (94.8)	70,961 (87.9)	1.38	1.37–1.40	1.43	1.41–1.45	58,292 (89.5)	26,777 (79.4)	1.37	1.35–1.39	1.49	1.45–1.53

Reference category: mothers unvaccinated against pertussis in pregnancy.

*n = 96,865 children (only England children in 2013 cohort).

**n = 35,433 (only England children in 2013 cohort & still in cohort when eligible for second MMR).

maternity units and not be recorded in the GP records so we may have underestimated pregnancy vaccine uptake [24]. We were also not able to account for confounding factors that may have influenced both maternal and childhood uptake such as level of maternal education [19], as this information is not routinely recorded in the primary care record. We also did not examine influenza vaccine uptake among pregnant women in addition to the pertussis vaccine as an indicator of mothers who take up maternal vaccines due to the seasonality of the influenza vaccine programme making it difficult to identify eligible pregnancies.

Pertussis vaccine in contrast is offered to all pregnant women year round.

4.4. Implications for practice, policy, and research

In line with national estimates, we found sub-optimal MMR vaccine uptake [4] with being born in a more deprived area the most important determinant of not having childhood MMR vaccine. This is unsurprising but strongly supports targeting interventions and resource to increase

childhood MMR uptake towards the poorest areas. General practices since 2021 have been set new childhood vaccination targets and there has been subsequent concern that practices in more deprived areas are less likely to achieve these targets and thus be financially penalised [43]. There is evidence that interventions to increase vaccine uptake need to be multi-component [44], for example by improving availability of vaccination appointments as well as providing consistent reminders and recall and possibly opportunistic vaccination services [44–46]. Therefore GPs in more deprived areas may need to use greater resource to address low MMR vaccine uptake locally further leading to financial disparity. To reduce the MMR vaccine uptake inequalities that we report the current inequities in general practice resource allocation need addressing [47], particularly as inequalities have increased since the Covid-19 pandemic [6]. Vaccines being strongly recommended by healthcare providers as well as parents having the opportunity to ask healthcare providers any vaccine questions are also important drivers of vaccine uptake [16,44]. Healthcare professionals should opportunistically promote vaccination at any encounter with parents [16].

In a statement on the childhood immunisation schedule in the UK the Joint Committee on Vaccination and Immunisation (JCVI) advised that the NHS should offer the second dose of MMR vaccine at 18 months instead of at the current 3 years 4 months in order to improve coverage [48]. Second dose MMR uptake has been historically lower in the UK, as our study also found, so new considerations to increase uptake are needed. An ecological study of the impact of an accelerated, earlier second MMR dose in London on vaccine uptake found that it did increase uptake, but more research is needed to understand the impact on particular demographic groups [3]. Our findings support such a change to the schedule as the majority of children who get vaccinated with one MMR vaccine do so by age 2 years (89.4 %), with coverage only increasing slightly to 92.6 % by age 5 years. This suggests that families are more likely to engage with preventive vaccinations at earlier ages, which is also supported by the higher uptake of primary vaccines at 2, 3 and 4 months of age in the UK [4]. Our findings that pregnancy and childhood vaccine uptake are related suggest that interventions to increase uptake could start much earlier when parents are first expecting a baby. Pregnancy offers a unique opportunity to promote, inform and support new parents in accessing routine childhood vaccines [36], such as MMR.

More research is now needed into how maternal interventions, already being piloted in Australia [34], may be able to tackle the UK's long-standing childhood vaccine uptake inequalities. A life-course approach to reducing inequalities in maternal and childhood vaccine uptake is needed in the UK [49], particularly given that more maternal vaccines to protect new-borns are likely to be added to the schedule in coming years [21,50]. For example in summer 2023 the UK's JCVI advised that maternal Respiratory Syncytial Virus (RSV) vaccination was a candidate for a universal programme to protect neonates and infants against RSV [50].

5. Conclusion

Our study found sub-optimal MMR uptake in the UK with children born in the most deprived areas of England least likely to be vaccinated compared with children in the least deprived areas. We also found that whether a mother is vaccinated in pregnancy is an independent risk factor for childhood MMR vaccination: mothers vaccinated against whooping cough in pregnancy were over 40 % more likely to have their child vaccinated with MMR. Healthcare professionals and services should promote and facilitate access to both maternal and childhood vaccines during pregnancy, particularly to more deprived parents.

Ethics approval

We obtained ethical and scientific approval for the use of CPRD for our study from the Independent Scientific Advisory Committee Protocol number: 20_010.

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The views expressed are those of the author(s) and not necessarily those of the NIHR or the Department of Health and Social Care.

Availability of data and materials.

Additional unpublished data related to this study are not available. Access to CPRD data is only available to researchers with approved protocols via CPRD's Research Data Governance Process. Code lists are available in the supplementary files (see Method section) and are shared without investigator support.

This study is based in part on data from the Clinical Practice Research Datalink obtained under licence from the UK Medicines and Healthcare products Regulatory Agency. The data is provided by patients and collected by the NHS as part of their care and support. The interpretation and conclusions contained in this study are those of the author/s alone.

Declaration of competing interest

EW is local investigator for vaccine and treatment trials at Imperial College Healthcare NHS Trust funded by Sanofi, Pfizer and GSK, but does not receive any personal financial payment.

Data availability

The authors do not have permission to share data.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.vaccine.2023.11.063>.

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Appendix 40: Paper 2 Skirrow H, Lewis C, Haque H, Choudary-Salter L, Foley K, Whittaker E, Costelloe C, Bedford H, Saxena S. 'Why did nobody ask us?': A mixed-methods co-produced study in the UK exploring why some children are unvaccinated or unvaccinated.

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‘Why did nobody ask us?’: A mixed-methods co-produced study in the United Kingdom exploring why some children are unvaccinated or vaccinated late

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ABSTRACT

Objective: Childhood vaccine uptake in the United Kingdom (UK) is sub-optimal leading to outbreaks of preventable diseases. We aimed to explore UK parents’ perspectives on why some children are unvaccinated or vaccinated late.

Methods: We undertook a mixed-methods, co-production study involving a survey using a questionnaire followed by focus groups. We partnered with The Mosaic Community Trust (Mosaic) who are based in a more deprived, ethnically diverse, low vaccine uptake area of London. Targeted recruitment to complete the questionnaire (either on paper or online) was done through Mosaic, community networks and social media promotion. We collected demographic data alongside parents’ views on routine childhood vaccination, their vaccine decisions, and experiences of accessing childhood vaccine appointments. We report descriptive findings from the questionnaire and thematic analysis of free-text questionnaire answers and focus groups guided by the COM-B model of Capability, Opportunity, and Motivation.

Results: Between June–October 2022, 518 parents were surveyed of whom 25% (n = 130), were from ethnic minorities (13%, n = 68–unknown ethnicity). In 2023 we held four focus groups with 22 parents (10 from ethnic minorities). Only 15% (n = 78) parents had delayed or refused a vaccine for their child. A quarter of parents felt they had not been given enough information nor an opportunity to ask questions before their children’s vaccinations. Inconsistent reminders and difficulties booking or attending appointments impacted vaccine uptake with negative experiences influencing future vaccine decisions. Parents had mixed views on vaccinations being given in different locations and wanted trusted health professionals to vaccinate their children.

Conclusion: To reverse declining vaccine uptake and prevent future outbreaks it needs to be easier for UK parents to speak to health professionals to answer their childhood vaccine questions, alongside simplified booking systems and easier access to routine childhood vaccine appointments.

1. Introduction

In January 2024 a national incident was declared by the United Kingdom’s (UK) Health Security Agency (UKHSA) due to rising measles cases with outbreaks in London and the West Midlands [1]. This is the result of too few children receiving the recommended two doses of measles, mumps and rubella (MMR) vaccine by age 5 years [2–5]. Only 85.2% of children in England had two MMR doses by aged five years in 2022–23 [2] - below the national 95% target, based on the World Health Organization’s recommendation. There has been a continuing

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downward trend in uptake of all routine childhood vaccines in the UK starting before the Covid-19 pandemic [2–5], despite universal health-care through the National Health Service (NHS). There is an urgent need to ensure more children receive their routine childhood vaccines (particularly MMR) and are protected. Both nationally in the UK [1,6] and globally [7] it is a public health priority to increase childhood vaccine uptake to prevent infectious disease outbreaks.

In the United Kingdom, children living in more deprived areas or belonging to ethnic minorities are at higher risk of being unvaccinated or vaccinated late [8–12] and the Covid-19 pandemic exacerbated pre-existing inequalities [13,14]. London has historically also had lower uptake compared to national uptake [2] because of intersecting socioeconomic factors associated with the large, ethnically diverse and mobile population [8,15]. Vaccine uptake can be affected by both vaccine confidence [16] and access [17,18]. Vaccine confidence [16] has been described as *‘the belief that vaccination – and by extension the providers and range of private sector and political entities behind it – serves the best health interests of the public and its constituents.’* [19] Most parents have confidence in the national childhood vaccination programme with 90% getting their children vaccinated when offered [20] or ‘trust vaccines’. [21] However, some parents lack confidence in routine vaccines [22] with variation between different demographic groups [23,24]. Lack of vaccine confidence or vaccine hesitancy has been described by the WHO as one of the major threats to global health [25]. However, while a minority of parents may lack vaccine confidence, anti-vaccine sentiment may not be the predominant reason for declining vaccine uptake in England [26]. Other issues such as access and lack of knowledge have been suggested as important barriers to vaccination [26,27].

The National Health Service’s (NHS) vaccine strategy for England published in December 2023 emphasised the importance of vaccine services *‘being tailored to communities that are un- or under-vaccinated’* and the need to *‘build trust and confidence’* in vaccinations [28]. To date, surveys of parental attitudes and experiences of childhood vaccination have not been representative or explored the perspectives of parents whose children are less likely to be vaccinated – such as minority ethnic [17] or London families [21]. To understand these health inequalities, exacerbated by Covid-19 [13], more participatory health research has been called for to give a voice to those with lived experiences of an issue [29–31]. By involving public partners living in an area with historically low vaccine uptake and using a community based participatory [32] approach we aimed to explore perspectives on why some children are not vaccinated with parents who do not normally engage in research [30,33]. Our findings will help local vaccine services implement the NHS’s national vaccine strategy to increase childhood vaccine uptake and reduce inequalities [13].

2. Methods

Our public partners The Mosaic Community Trust [34] were involved from the study’s start, building on a pre-existing collaboration [35,36]. Mosaic is a community support group of ethnic minority, predominantly Muslim women, who provide health and wellbeing support and links into local healthcare services through regular community meetings [34]. Mosaic named this study *‘Why has nobody asked us?!’* to acknowledge that the views of ethnic minority parents living in an area of high deprivation with low childhood vaccine uptake had not been previously considered. A mixed-methods approach was agreed on comprising a survey using a questionnaire then focus groups.

2.1. Survey

2.1.1. Questionnaire design

We co-developed a questionnaire based on brainstorming sessions with Mosaic and previous surveys of parental vaccine attitudes and hesitancy [17,20,37,38]. The COM-B model [39], previously applied to vaccination behaviour [38,40,41], was also used to guide development.

The COM-B model suggests that *‘Capability’* (knowledge and skills), *‘Opportunity’* (physical access & convenience, availability of information) and *‘Motivation’* (Attitudes, values, emotions) are needed to perform a certain *‘Behaviour’* such as vaccination (B) [39]. Other community stakeholders in North-West London and the local public health department were also involved in informing question topics. Questions were developed, tested, and refined for acceptability and understanding among Mosaic members and other stakeholders. Some question topics were also considered to be better suited to be included in the focus groups to allow more in-depth exploration.

The questionnaire comprised the following four sections: demographics; routine vaccines for children; experiences of accessing information about routine vaccines for children and, routine vaccines for children and the Covid-19 pandemic (this section is reported elsewhere). Within each section of the questionnaire, parents were asked about their attitudes and experiences. For each question or statement respondents indicated their level of agreement on a 7-point Likert scale between *Strongly disagree* to *Strongly agree*. There was also a free-text response option for some sections. For full questionnaire see supplementary 1. Questionnaires were available online or on paper.

2.1.2. Survey recruitment

Participants were recruited to the study through either online promotion or by Mosaic who promoted the study in North-West London through local networks of parents and families. Mosaic promoted both online and paper questionnaire completion. Online promotion also involved emailing a link to the questionnaire to community organisations including Maternity Champions, Maternity Voices Partnership, Community Champions, and Connecting Care for Children who were invited to share and promote it through their networks by email and social media. By approaching a range of community groups embedded among local peer support networks, our recruitment strategy sought to recruit from underrepresented groups in particular. The questionnaire was also shared and distributed via the research team’s personal twitter accounts, including linking to other researchers and organisations interested in vaccine uptake. The questionnaire was live online and promoted from 7th June 2022 until 6th November 2022. The questionnaire was also advertised and promoted using Instagram paid for promotion which was geographically targeted to adults living in North-West London. The paid promotion feature was used from 12th August 2022 to 28th September 2022, reached 27,352 accounts and achieved 317 link click engagements.

Eligible participants were required to be aged 18 years or over, resident in the UK with children aged 10 years or younger at the time of completing the questionnaire. The questionnaire was prefaced by an information page explaining the study, and how the data were to be used. Participants were informed that by taking part they agreed for their responses to be used for research purposes. Participants were required to confirm, by tick-box, at the start that they met the eligibility criteria and that they consented to participate. Apart from the question confirming their eligibility, answers to questions were optional. At the end of the questionnaire, participants were invited to indicate their willingness to take part in a focus group by leaving their contact details.

2.2. Focus groups

2.2.1. Recruitment and data collection

Respondents who included their details at the end of the questionnaire were contacted later and invited to take part in focus groups with a choice of taking part either in-person or online. Written informed consent was obtained from each participant. Depending on the participant preference, the consent form was sent and returned completed via email or in person. For the final fourth focus group participants were recruited from local parents among Mosaic’s network, as data saturation had not been reached by recruiting from the questionnaire respondents alone after three focus groups. Of the four focus groups conducted, two were in

person at a community venue used by Mosaic for meetings in Westminster, London and two online via Zoom. The topic guide (supplementary 2) was informed by the questionnaire responses and included topics such as attitudes to vaccination, vaccine information and experiences of accessing childhood vaccinations. Participants received a £10 gift voucher in recognition of their time. Focus groups were conducted between the 15th March and 24th May 2023 and lasted between 60 and 90 min. All interviews were facilitated by both HS and HH with HB, CL and EW acting as co-facilitators at different focus groups.

2.3. Questionnaire analysis

Descriptive statistics of question responses are reported, apart from for the Covid-19 questions which are reported elsewhere. Given the longstanding disparity in childhood vaccine uptake between different ethnicity groups [8,13], chi-square analyses were conducted to test for significant associations between ethnicity and agreement/disagreement with statements. Respondents were split into two ethnicity groups as we were underpowered to analyse by different ethnicity subgroups. Parents who answered which of the following best describes your ethnicity? as 'White, White Irish or Other White background' were compared to those that answered any of 'Any Mixed background, Black or Black British or any Black background, Asian or British Asian or any Asian background, Chinese or other or prefer not to say'. Likert responses were then also dichotomised into 'Agreed' (Strongly Agree, Agree or Somewhat Agree) and 'Disagreed' (Neither Agree or Disagree, Somewhat Disagree, Disagree or Strongly Disagree). Parents who left the question about ethnicity blank were not included in the chi-square analysis.

2.4. Focus group analysis

Focus group recordings were transcribed verbatim by an external professional transcription service. Both the questionnaire free-text responses and the data from the focus groups were analysed using a codebook thematic analysis [42,43], following an inductive and deductive coding scheme. Deductive codes were based on the COM-B model [39] as well as the study objectives and previous literature, while inductive codes were developed from the data. To enhance the rigour of the analysis, coding approaches and data interpretations were discussed between HH, HB, CL, and EW, with CL double coding to check for agreement.

2.5. Ethical approval

Ethics approval was granted on 26th January 2022 by the Imperial College Research Ethics Committee (study reference: 22IC7458).

3. Results

3.1. Questionnaire sample

A total of 518 parents completed the questionnaire, 476 online and 42 on paper. The total number of parents answering each question differs. Characteristics of parents surveyed are shown in Table 1. Of the 72 respondents who gave a postcode outside London, 70 were from England and two from Scotland. Demographic characteristics between paper and online respondents differed. The average age of all respondents was 37 years (median and mean) and ranged between 19 and 57 years though paper respondents had a lower median age of 35 years. Among all respondents, 25% were from ethnic minority groups, though among paper respondents, the majority (83%, 35/42) were from ethnic minorities. The 14 paper respondents who described themselves as 'Other ethnicity group' gave their ethnicity as 'Arab'. Among paper respondents the majority were Muslim (88%, $n = 37/42$). Only 31% ($n = 13$) of paper respondents were university educated with the majority completing secondary school education to either 16 years (29%, $n = 12$) or 18 years

Table 1
Characteristics of Questionnaire respondents.

	Respondents (n)	%
Gender		
Female	456	88
Male	11	2
Not given	51	10
Geographical location		
North-West London	203	39
All London	330	64
Outside London	72	14
Not given	116	22
Country of birth		
United Kingdom (UK)	267	51
Non-UK	149	29
Not given	102	20
Ethnicity		
White or White British	320	62
Mixed	28	5
Black or Black British	21	4
Asian or Asian British	43	9
Other, ethnic group	38	7
Not given	68	13
Religion		
No religion	219	42
Christian	164	32
Muslim	71	14
Hindu	8	2
Jewish	8	2
Not given	48	9
Education		
Educated to primary school level, secondary school up to 16 years or 18 years	48	9
Educated beyond 18 years at college, university or to post-graduate level	415	80
Not given	55	11
Household structure		
Raising children with partner	428	83
Single parent or other	47	9
Not given	43	8
Number of children		
1	206	40
2	206	40
3 or more	48	9
Not given	58	11

Demographic characteristics of both paper ($n = 42$) and online ($n = 476$) questionnaire respondents (total $n = 518$).

(26%, $n = 11$). Paper respondents also differed from online respondents with respect to family size: over a third of the paper respondents who answered the question had 3 or more children (36%, $n = 15/42$) compared with only 7% ($n = 33$) of on-line respondents. Very few respondents answered that they were living with extended family members 7% ($n = 35$) - though among paper respondents this was higher (17%, $n = 7/42$).

3.2. Focus group sample

In total 19% ($n = 100$) of all parents surveyed provided their details to be contacted for a follow-up focus group and were contacted by email by HS, or by phone by HH, to participate. Twenty-two responded to the invitation, with 16 taking part in one of the first three focus groups. The remaining six parents opted out prior to the focus groups. Mosaic recruited a further six women to take part in the final focus group from among the local parents who use Mosaic services but who had not completed the questionnaire. The characteristics of focus groups' participants are outlined in Table 2, (100% were women) of whom 10 were from ethnic minority groups. The focus groups included parents who had chosen to delay or decline some childhood vaccinations (see Table 2).

Table 2
Characteristics of focus group participants.

No	Ethnicity	Online or in person focus group in North-West London	Vaccines ever delayed or refused for the child/ren (not including childhood Covid-19 vaccine)
1	White (other)	In person (FG1)	None
2	White (British)	In person (FG1)	Flu, whooping cough & additional polio booster
3	Asian or Asian British	In person (FG1)	None
4	Asian or Asian British	In person (FG1)	None
5	Other ethnic group (Arab)	In person (FG1)	MMR
6	White (British)	Online (FG2)	None
7	White (British)	Online (FG2)	Paid for some vaccines separately.
8	Mixed	Online (FG2)	None
9	White (Other)	Online (FG2)	None
10	White (Other)	Online (FG2)	Delayed MMR and paid privately for other vaccinations to be spaced out.
11	White (British)	Online (FG2)	None
12	White (British)	Online (FG2)	None
13	White (British)	Online (FG3)	None but chose to have 1 year old vaccines at separate appointments.
14	White (Other)	Online (FG3)	Preschool booster
15	Asian or Asian British	Online (FG3)	MMR - both 1 year and preschool booster declined.
16	White (British)	Online (FG3)	None
17	White (British)	In person (FG4)	None
18	Asian or Asian British	In person (FG4)	MMR vaccine
19	Asian or Asian British	In person (FG4)	None
20	Asian or Asian British	In person (FG4)	None
21	Other ethnic group (Arab)	In person (FG4)	MMR vaccine
22	Other ethnic group (Chinese)	In person (FG4)	None

3.3. COM-B Model

The following sections present data according to the COM-B model [39], which was used to guide analysis (see Table 3). The themes draw on a combination of questionnaire responses, free-text questionnaire answers and data from the focus groups (see supplementary 3 for number of free-text responses). Given the variation in the number of respondents per question, descriptive statistics and chi square analysis report on the percentages among those who chose to answer each question. Quotes from focus group participants and free-text responses are provided in Table 3 to illustrate key themes. Themes were developed from either deductive codes based on the a priori study objectives and some were inductive either developed from the questionnaire responses or from the focus group data.

3.3.1. Capability (Knowledge and skills)

3.3.1.1. Normal for parents to have questions or want more information about routine childhood vaccines. In both the questionnaire and the focus groups, parents talked about having questions about childhood vaccines that they wanted answering (Table 3). One parent said:

'I have a lot of questions and I feel like I don't know that many information' (FG1 participant) while another said 'I will not do anything until I'm given the full (information)...can you please explain to me what is the benefit? What is this? What's the side effects?' (FG4 participant).

A lot of the questions were linked with parents wanting more

information about ingredients and side-effects of routine childhood vaccines. One parent said:

'Information about risk and benefit needs to be more available'; (qu n41) while another said, 'share information on how the vaccines work, and that the ingredients are safe and have been tested.' (qu n142). While several parents mentioned wanting more information specifically about vaccines ingredients and side effects the desire for more information was probably linked to the other theme of parents wanting greater opportunity to discuss vaccines with healthcare providers.

3.3.1.2. Delaying or refusing some routine childhood vaccines. Only 15% of all parents ($n = 78/518$) said that they had ever refused or delayed a vaccine (though only 464 parents surveyed chose to answer that question, Fig. 1). Among those who had delayed or refused a vaccine, the majority answered that their child had the vaccine later or they planned to get them vaccinated later (63%, $n = 49/78$). Among parents who gave written details of which vaccines they had refused or delayed ($n = 45$), the most common was the MMR vaccine ($n = 10$) or the 1 year ($n = 6$) and preschool booster vaccines ($n = 5$), (which in the UK includes the first and second MMR doses). A very small minority of parents had refused all their children's vaccines ($n = 8$) and <5 parents specifically mentioned refusing the flu vaccine. A smaller percentage of parents who identified as white ethnicity said that they had refused or delayed vaccines (13%, $n = 41$) compared to parents who identified as an ethnic minority group (21%, $n = 29$, p value = 0.03, (supplementary 4)). The majority (>90%) of parents also answered that they thought it was important for their child to be vaccinated (supplementary 5), though this was higher among parents who identified as white ethnicity (97%, $n = 301$) compared to those who identified as ethnic minority (89%, $n = 119$, p value = 0.002, supplementary 4).

3.3.1.3. Prioritising different childhood vaccines. Parents discussed prioritising some vaccines over others (Table 3), with both the flu and polio booster vaccinations offered in London in 2023 [44] mentioned. One parent talked about having seen effects of polio first hand and prioritising the vaccine (see Table 3). While another parent chose to decline the additional booster polio vaccine:

'when there was a big, massive polio vaccination for all children...I refused to give my son the polio injection' (FG4 participant) while another said they 'chose not to get my son the flu vaccine' (qu n435).

3.3.1.4. Choosing to space out or delay vaccines due to concerns about too many vaccines being given at the same time. Linked with the decisions some parents made to prioritise certain vaccines over others, some parents talked about being concerned about too many vaccines being given at once (Table 3). One parent said:

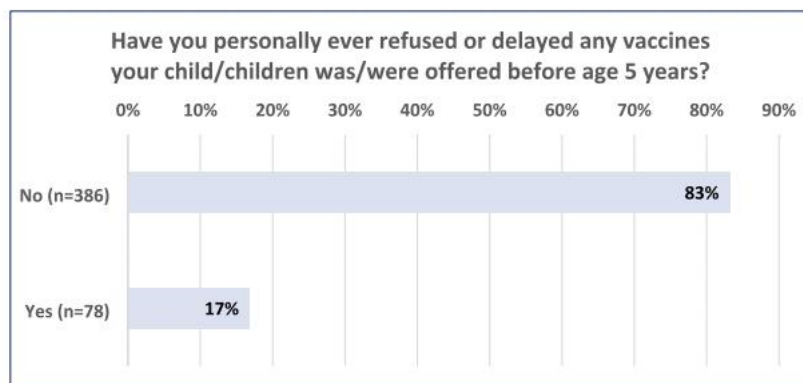
'The NHS vaccine programme is too much too young and I have chosen a more spaced out vaccine programme that I mostly do privately as the NHS don't offer single doses for most vaccines. I also chose not to have one vaccine and delay some of them' (qu. n479). However, the ability to choose to pay for single dose vaccines privately requires parents to have disposable income which lower income families may not be able to afford. Nonetheless this was still a concern among different parents as another parent said they thought that there were: 'Too many jabs in 1 go, especially 1yo vaccination - creates an overload' (qu. n417).

A few parents reported choosing to have their children's vaccines given at different spaced-out appointments, one parent said:

'so I think she did three, and then we went back for the other two' (FG3 participant).

Com-8 Model Component: CAPABILITY (Knowledge & skills)	
Theme	Example quote
Normal for parents to have questions about routine childhood vaccines	"I tend to have a lot of questions about vaccines, I mean, yes, one is, what's the benefit of it? Secondly, what's it made out of?" (P1, participant) "I just think that vaccine cause a lot of harm. My kids already got their without really knowing that they're not safe. So I think if they said any more to us children, there's no harm information or studies, I believe that that's necessary effects for them." "Because I think, even in so many countries, in our country as well, they have some... I know my female cousin to volunteer to give the polio vaccine to her kids. So, I tend to be a bit of a skeptic."

5



Total respondents answering question n=464.

Percentage of total parents who did the questionnaire n=78/518, 15%

Fig. 1. Parental refusal or delay of routine childhood vaccines under the age of 5 years.

3.3.1.5. *Parents worry that vaccines are associated with the development of autism.* Though the issue was not specifically raised and only mentioned by a few parents ($n \leq 10$) in the questionnaire, in every focus group parents brought up concerns about the link between vaccines, specifically MMR, and autism (see Table 3). One parent said:

'Personally I still question whether it is good for them to be vaccinated a number of diseases at the same time. Even though it's disproven I still question aluminium/autism' (qu. N210).

A couple of parents whose children had been diagnosed as autistic brought up that they now thought that this could have been caused by vaccination. A parent described how her son:

'was vaccinated on time. I had no problem with that, even though there was on the back of my mind, is it. He ended up having autism at a younger age. I thought could be from the vaccination?' (FG4 participant).

3.3.2. Opportunity

3.3.2.1. *Conversations with trusted healthcare professionals.* Parents discussed having conversations with healthcare professionals – including doctors, practice nurses and health visitors as key influences on getting their children vaccinated (Table 3). One said:

'I think that's a really important thing to be able to talk to people about ... (them) with the right information and the right support.' (FG1 participant).

Parents wanted these conversations to be with someone they trusted, who was informed and who would know the medical answers to their vaccine questions. One mother said:

'I prefer just speaking to someone, and I think for me, I like the information. And that's probably why I go to the GP and I'm comfortable to just ask them before they do anything, that's what I would prefer to do.' The same mother went on to describe 'I've had fairly good experiences...so they've built my trust'. (FG3 participant).

One parent described differing experiences at vaccine appointments. At one they felt they had not been given opportunity to have a conversation resulting in them choosing to delay some vaccines and go privately; at a different appointment they felt a practice nurse took the time to talk to them (Table 3). Another parent mentioned how their health visitor had spoken to them about vaccines first, followed by their doctor

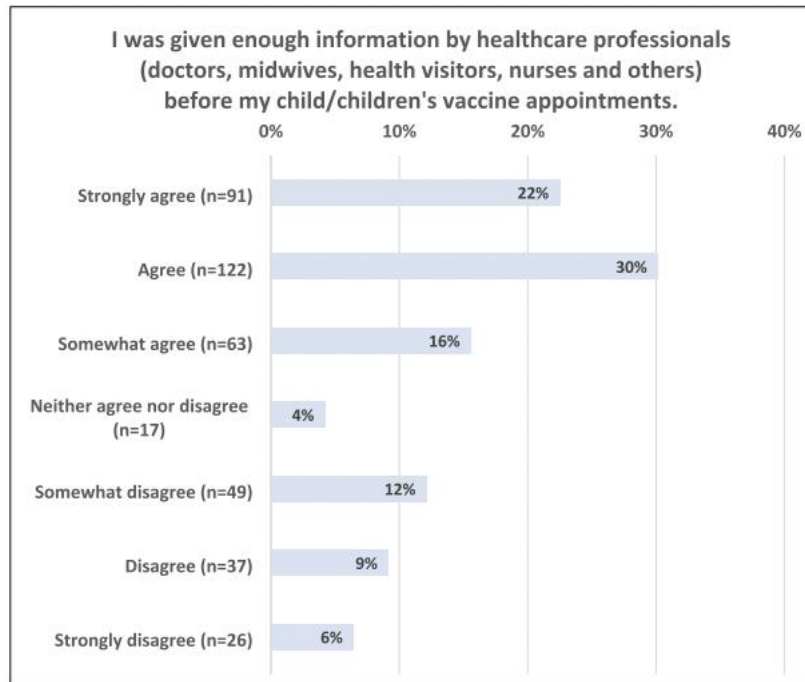
and nurse who knew them personally and so were able to give them the information they wanted about their child's vaccines clearly (Table 3).

3.3.2.2. *Parents have questions that they want answered before the vaccination appointment.* Parents wanted both vaccine information and information about vaccine appointment logistics before appointments (Table 3) delivered through a conversation with a trusted health professional. One parent said:

'want the information before....ideally, so I've got time to process it. And then also, because I might want to go away and then do some digging around, okay, well, they've mentioned this, let me research this by myself and come up with all the things that I need to ask. ... I don't think I'm really selective about who... So long as they were someone who was knowledgeable, so I think a nurse, even a health visitor, a GP, anyone' (FG3 participant).

Most parents (68%, $n = 276$) strongly agreed, agreed, or somewhat agreed that they had been given enough information by healthcare professionals beforehand (Fig. 2). However, over a quarter (28%, $n = 122$) did not agree they had been given enough information before their child's vaccine appointment (Fig. 2). Around two thirds of parents (63%, $n = 259$) agreed to differing degrees that they had had enough opportunity to ask questions before their vaccine appointments. However, over a quarter (27%, $n = 111$) did not agree with this statement (Fig. 3). More parents, (84%, $n = 337$) agreed to differing extents that they understood the information they were given before their child's vaccine appointment (supplementary 6a). However, although there was no difference between ethnic minority or white parents as to whether they had received enough information before their child's vaccine appointment or whether they understood the information (supplementary 4), slightly fewer parents who identified as belonging to an ethnic minority other than White agreed that they had had enough opportunity to ask questions before their child's vaccine appointments (64% ($n = 180$) white ethnicity parents versus 51% ($n = 51$, $p = 0.02$) ethnic minority parents (supplementary 4)).

3.3.2.3. *Pregnancy offers opportunity to provide more information/discuss childhood vaccines with midwives/ or immediately post birth with health visitors.* Parents discussed wanting more information about childhood vaccines during their pregnancy or immediately after their babies' birth from health visitors. One mother said:



Total respondents answering question n=405.

Fig. 2. Information from healthcare professionals before vaccine appointments.

'I don't think I received any information about childhood vaccines when I was pregnant.....And I probably would have liked it, because it would have been part of the thinking about having a baby, what that meant, and what I'm putting in my own body.' (FG2 participant).

Again, parents wanted the information to be given via a conversation with a healthcare professional and not just a pamphlet (Table 3). Parents mentioned the information in pregnancy about childhood vaccines could be provided in birth preparation courses:

'Maybe, more information could be given in preparation to birth courses. For example, explaining ...how the illnesses can impact children' (qu n89).

3.3.2.4. Parents want information and/or conversations with trusted healthcare professionals in different languages. Some parents felt that there should be better information about vaccines for parents who were from ethnic minority backgrounds or who spoke languages other than English. One parent said that there needed to be:

'Better information for parents of ethnic backgrounds. Translated ingredients list, up to date responses to all worries that they may hear by word of mouth or social channels. What the vaccine does and doesn't do in the language they understand. E.g. address issues some might fear' (qu n51).

One mother who was born outside the UK described how helpful she found a health visitor who spoke the same language as her (Arabic) when she gave birth in the UK and would have liked to have a conversation with her in Arabic about her child's vaccinations (Table 3). Again,

as with previous themes, it was felt the conversation in a different language was more important than a leaflet (Table 3).

Only 142 parents answered the question about wanting vaccine information provided in their own language (supplementary 6b). Of these the most common answer was to 'neither agree or disagree' (32%, n = 45) and only 27% (n = 39) agreed to different extents that they wanted information translated. A higher proportion of ethnic minority parents (47%, n = 29) who answered the question would have preferred the information translated compared to white parents (10%, n = 7, $p \leq 0.0001$) who answered (supplementary 4).

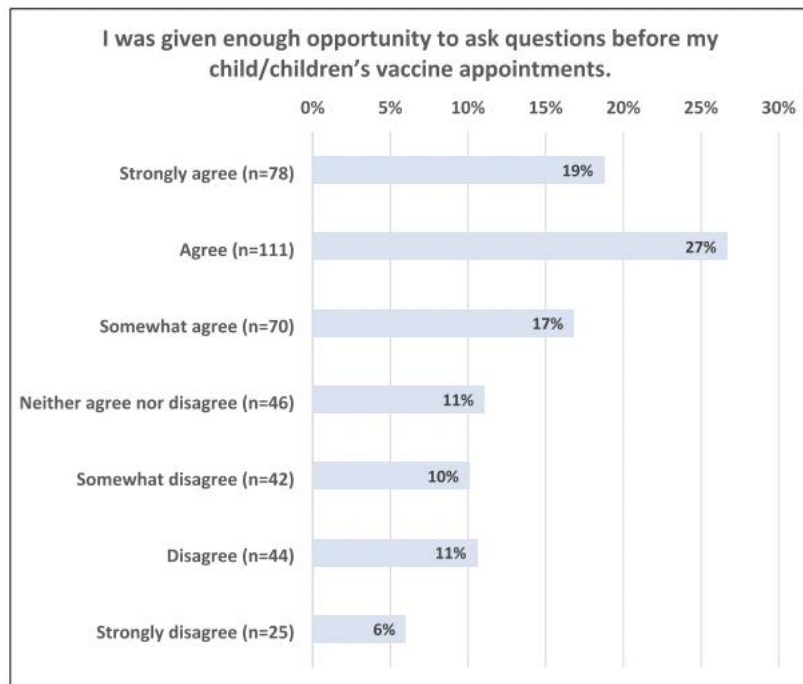
3.3.2.5. Relying on the red book to track vaccinations. Parents mentioned the importance of their child's red book (personal child health record) in keeping track of their vaccinations (Table 3) – one said:

'I relied on my red book to know when to book my child's vaccines.' (qu n267). Parents also described how they used the red book when they did not get reminders from their GP: *'I was expecting to get reminders for the vaccinations from our GP and that wasn't the case. So we had the one you do at 1 year old and around 3 years old delayed by months because I randomly remembered to check the red book'* (qu n157).

3.3.2.6. Inconsistent receipt of reminders from GP surgeries about childhood vaccines. Parents did not consistently receive reminders or notifications from their GP to book children's vaccinations meaning children were unvaccinated or vaccinated late (Table 3). One parent said:

'our surgery are not sending notifications automatically' (qu n111).

Variation between different GP surgeries (and even different



Total respondents answering question n=416

Fig. 3. Opportunity to ask questions before vaccine appointments.

siblings) about reminders was reported. One parent said:

'Reminders would be useful, but everyone seemed to get one but me.' (FG4 participant). While another said: *'I have 3 kids within 4 years & you.... invite one child and the others not... doesn't give me confidence.... I got a letter for ...vaccination for one child and not others'* (qu n123).

3.3.2.7. *Difficulties in making vaccine appointments -parents struggle to get through to doctors' surgeries to make vaccine appointments for their children.* A key theme was parents having difficulties in making vaccine appointments at GP surgeries. One parent said:

'arranging them with the GP is not easy. You often have to wait a long time to speak to a receptionist and if you call too early the appointments are not available to book and when you call again you have missed the chance to get an appointment when required. It should be easier to book' (qu n14).

Many mentioned difficulties in getting through to GP surgeries by telephone to book appointments and wanted an easier way to book appointments (Table 3). One parent implied that having to call to make an appointment was an extra barrier to being able to vaccinate your child conveniently:

'Having to book separate appointments at the GP for vaccinations is a bit of a faff - long phone queues' (qu n72).

The majority (88%, n = 368) of parents knew how to book their children's vaccine appointments (supplementary 7a), so the difficulties faced were booking appointments rather than a lack of understanding about how to book them; there was no difference in booking knowledge

by ethnicity (supplementary 4). The majority also understood they could rebook vaccine appointments if they missed them (87%, n = 356, supplementary 7b) with no difference by ethnicity (supplementary 4).

3.3.2.8. *Difficulties in attending vaccine appointments.* Many parents mentioned difficulties in attending their children's vaccine appointments for they were only available on one day or they had to take time off work (Table 3). One parent said:

'surgery...just need to provide more appointments than every-other Wednesday' (qu n186). Another parent described how her child was late being vaccinated as the nurse at their surgery was only able to offer vaccine appointments one day a week:

'the nurse that does the vaccinations is only there one day a week. And if you've missed your chance to get in then it's delayed a week and another week and another week.... Months.' (FG4 participant).

Parents talked about difficulties in taking time off work:

'With preschool children, it is a pain getting them to the surgery.... Finding an appointment slot when I could take time out of work, go and get her from nursery, get her vaccinated, take her back to nursery etc just proved impossible... especially when clinics were only 1-2x weekly' (qu n143).

Three quarters of parents agreed to different extents that they were able to book vaccine appointments at convenient times (75%, n = 306, supplementary 8a), with no differences by ethnicity (supplementary 4). Around a quarter (28%, n = 118, supplementary 8b) of parents also agreed to different extents that they found it difficult to take their children to vaccine appointments due to work, with no differences by ethnicity (supplementary 4). Parents did not report difficulties in travelling to vaccine appointments at the GP surgeries (supplementary 8c).

Over two thirds (69%, $n = 278$, supplementary 8d) of parents surveyed said that drop-in clinics would make it easier for their children to be vaccinated with no difference found between ethnic minority or white parents (supplementary 4). Similarly, 74% ($n = 277$) of parents agreed to different extents that more appointments after school hours would make it easier to get their children vaccinated (supplementary 8e) with no difference by ethnicity (supplementary 4).

3.3.2.9. Negative or positive experiences of taking child for first vaccines impact future decisions for later vaccines or younger children. Including them or their baby being upset by the pain. Parents described how their first experiences of taking their children to be vaccinated often influenced how comfortable they felt taking their children to future vaccine appointments (Table 3). Some parents also mentioned not liking needles and wanting more nasal vaccines like the flu vaccine. One parent said:

'My daughter had a terrible reaction to her very first vaccinations and that scared us.... That first experience has shaped my subsequent thoughts and certainly made me hesitate about vaccines. Fortunately, I have a partner who was willing to do the appointment. I wish more funding was put into how vaccines are administered and it would be great to see more alternatives to needles like the flu vaccine....' (qu n190).

Also mentioned by some focus group participants who were Muslim was that they wanted somewhere more private after vaccinations to breastfeed their children (Table 3). This went with the feeling that 'very often appointments can be rushed' (FG1 participant) when parents felt that they had to leave the nurse's room quickly but didn't feel comfortable about breastfeeding in the waiting room. However, 90% ($n = 368$) of parents surveyed agreed to some extent that they felt comfortable taking their children to their GP surgery to be vaccinated (supplementary 9), with no difference by ethnicity (supplementary 4).

3.3.2.10. Offering vaccines in different locations - but wanting them to be given by trusted known healthcare staff to answer questions. Parents discussed how comfortable they would feel about getting their children vaccinated at different locations including one mother describing how easy it had been to get her child vaccinated at her local children's centre (Table 3). Some parents wanted vaccines to be offered in more locations

one said:

'more appointments and options on where to receive the immunisations should be available.....Can't pharmacies administer them?' (qu n14).

However, in the focus groups while some parents said they would be happy to go to a health centre as opposed to their own GP, some mentioned that they would not want to go somewhere 'random' and that they would want someone they knew, trusted and who was knowledgeable to vaccinate their child (Table 3). One parent said:

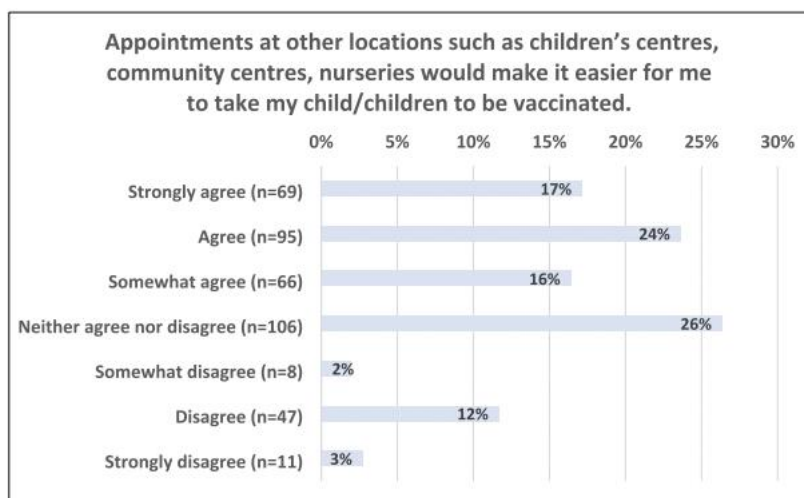
'I remember having my Covid vaccine in a leisure centre and, yes, I don't know that I would want to take X to a leisure centre.... if it's not somebody that I know that's vaccinating him either.' (FG3 participant).

Over half of parents surveyed (57%, $n = 230$, Fig. 4) agreed to different extents that appointments in different locations would make it easier to get their children vaccinated, with no difference by ethnicity (supplementary 4).

3.3.2.11. Other reasons for missing vaccines: being abroad or child being ill or in hospital. Parents discussed several other reasons for their children sometimes missing their routine vaccines such as children being ill, caring responsibilities or them being overseas visiting family (Table 3). A small minority of parents mentioned vaccinating their children abroad, one parent said:

'Sometimes... had them vaccinated abroad to be on track with their schedule' (qu n128).

However, <5% of parents surveyed agreed that visiting relatives overseas made it difficult to vaccinate their children (supplementary 10a). One fifth of parents surveyed agreed to different extents that caring responsibilities made it harder to get their children vaccinated (21%, $n = 46$) (supplementary 10b) with one parent commenting 'has to take all her children with (me)' (qu n21) to get one child vaccinated. Religious and cultural events were not given as a reason parents found it difficult to vaccinate their children (supplementary 10c).



Total respondents answering question $n=402$

Fig. 4. Vaccine appointments in other locations.

3.3.3. Motivation

3.3.3.1. Impact of family/wider community perceptions and anecdotal stories from local community impact whether parents feel confident in getting child vaccinated. Among parents surveyed 62% ($n = 280$) agreed to different extents that wider family members influenced their vaccine decisions (supplementary 11a), though there was no variation by ethnicity (supplementary 4). This was similarly reflected in the free text responses and the focus group discussions where mothers discussed their wider community influencing their vaccination choices sometimes more than medical establishment (Table 3). One parent said:

'it can be very scary to parents especially if, for example religion or grandparents do not approve of vaccines' (qu n142).

These conversations were particularly prominent in the in-person focus group discussions though among all parents surveyed, over 90% ($n = 423$) thought that parents in their local community had their children vaccinated (supplementary 11b), with no difference by ethnicity (supplementary 4).

3.3.3.2. Women keeping vaccine decisions from men. Some mothers discussed the role their husband's views had on vaccine decisions for their children. A mother who was against vaccination herself described how she reached a compromise with her 'pro-vaccine' husband:

'I have no plans to have my child vaccinated (if she chooses to catch up as a teenager or adult that's her choice), but I agreed a compromise with my pro-vaccine husband that he could take her for the 6-in-1 vaccine, however he hasn't done anything about it.' (qu n258).

Some mothers in the focus groups described keeping their own vaccine decisions from their partner and family for fear of being judged, one mother said:

'I didn't tell my family until I was vaccinated (referring to Covid-19 vaccine).' (FG4 participant).

3.3.3.3. Mistrust of vaccines. A minority of parents discussed their distrust of vaccination in the survey and the focus groups. One parent said in the questionnaire:

'Big pharma money making business not necessary and I no trust whatsoever in the system' (qu n164). The mistrust of vaccination was often mentioned as mistrust of the pharmaceutical industry in general as well as mistrust of medical professionals and research (Table 3). One parent said:

'Where there is obvious financial gain for a few I don't trust the research' (qu n159).

3.3.3.4. Trust in vaccines. Parents also talked about their belief and trust in vaccination overall. One parent said:

'I believe that all vaccines are appropriate and have willingly ensure my children are vaccinated' (qu n158).

Parents felt vaccines were important to protect their children and mentioned that the vaccines routinely offered to children in the UK as part of the schedule were established and therefore, they trusted them (Table 3).

4. Discussion

In this mixed-methods co-production study we found that most parents vaccinate their children – only 15% ($n = 78$) reported that they had ever refused or delayed a routine childhood vaccine, with the MMR vaccine the most commonly delayed or refused. Using the COM-B model [39,41], we found the main reasons for not vaccinating or vaccinating

children late related to 'Opportunity'. Parents reported inconsistent reminders about their children's vaccines, inadequate information, and physical difficulties in booking and attending their children's vaccine appointments. Over a quarter (27%) of parents felt they had not been given enough opportunity to ask questions, nor given enough information before their children's vaccine appointments. Parents wanted more information provided through conversations with trusted and knowledgeable health professionals, often 'before' appointments, which parents often felt were rushed and not the right opportunity to ask questions. We found that ethnic minority parents were slightly more likely to have refused a vaccine for their child compared to white ethnicity parents and nearly a half of parents (47%) from ethnic minorities would have preferred to have information about their children's vaccinations translated by someone they knew, before appointments. Some parents wanted more conversations about childhood vaccinations in pregnancy or with health visitors after they have given birth. Over half of parents (57%) thought that vaccinations offered in different locations might make it easier to vaccinate their children, however some parents were more reluctant about going anywhere other than their own general practice and wanted their children to be vaccinated by someone they knew and trusted. Though over two thirds of parents (69%) thought drop-in clinics would make vaccinating their children easier. Parents' experiences of getting their child vaccinated often influenced future vaccine decisions – if parents felt they were listened to or not rushed they remembered and valued that interaction. With regards to 'Capability' and parents' knowledge about vaccinating their children, we found that parents commonly have questions about routine childhood vaccines, including some parents believing that it was better to delay or space out vaccines as well as a very small minority worrying that vaccines were associated with autism. Parents were 'Motivated' to get their children vaccinated by the attitudes among their local communities, though some mothers reported vaccine beliefs that differed from those of family members. Most parents trusted vaccines (>90%) and thought it was important to get their children vaccinated, though among ethnic minority parents this was slightly lower (89%). A very small minority mistrusted vaccinations.

4.1. Comparison to previous research

Our findings that access and practical barriers impact childhood vaccine uptake is consistent with previous research. Prior to the pandemic, in 2019, the Royal Society of Public Health surveyed UK parents and found that access to appointments was a primary factor in children missing vaccinations and similarly found that over 90% of parents thought vaccinating children was important. However, their survey included 95% respondents from white ethnicity backgrounds compared to our survey of 25% parents from ethnic minority backgrounds. Our findings are also consistent with attitudinal surveys of parents by national public health bodies both pre and post pandemic [20]. The UKHSA 2022 parental attitudes survey found that over 90% of parents trust vaccines, think they are safe, and that they work to protect children [21]. We found parents may prioritise different vaccines based on their perceived importance and previous research has also found that parents delaying vaccines may be because they do not perceive the diseases vaccines protect against to be significant health risks to their children [45]. The UKHSA also reported that 32% of parents who were unsatisfied by their children's vaccine appointments felt that they were not given enough information before the vaccinations [21]. Similarly we found one in four parents were unhappy with the information they were given or wanted more opportunity to ask questions of health professionals before vaccinations. The UKHSA also reported some parents found appointments too rushed, which is consistent with our findings and supports parents' experiences of vaccine appointments impacting future vaccine decisions. We found that over half of parents surveyed thought offering vaccines in alternative locations might make it easier to get their children vaccinated, however in the focus groups parents had

much more mixed views. Parents wanted their children vaccinated by known, trusted health professionals even if they were going to alternative locations. In comparison, the UKHSA reported parents have a strong preference to having their children vaccinated at their own GP surgery. Our findings that access and availability of information more than anti-vaccination sentiment causes children not to be vaccinated in the UK is also supported by work by Edelstein et al. that found that anti-vaccination sentiment was not the primary driver of declining childhood vaccine uptake [26]. Focusing on ensuring high vaccine confidence among parents and reducing vaccine misinformation [46] should remain a public health priority, particularly post Covid-19 [47]. However, for policy makers, our research suggests UK children are more likely to be unvaccinated due to programmatic issues as opposed to parents' anti-vaccination views, which is also the case globally [48].

4.2. Implications for policy and practice

Increasing childhood vaccine uptake in the UK is an urgent public health priority given the measles and pertussis outbreaks of 2024 [1,49]. We found some parents still have concerns about the MMR vaccine and autism and that MMR vaccines are still the most common to be delayed or refused, reflecting the low national uptake and current resultant outbreaks [2]. In some parts of England, the, such as inner-city London areas, 4 in 10 children are have not had two MMR vaccines by 5 years [2]. In response, opportunistic vaccine clinics in locations such as schools, are being offered to catch up children who may have missed out on their MMR vaccines [1]. This is a crucial step in increasing access, though our findings suggest parents may prefer trusted, known health professionals to vaccinate their children, which may be difficult to offer at vaccine clinics set up in alternative locations. However, we did find over two thirds of parents thought drop-in clinics would make it easier to vaccinate their children. We found conversations with health professionals were key factors that influenced parents vaccinating their children as opposed to information online or leaflets. This suggests that in response to the measles outbreaks as well as more convenient vaccine clinics, parents need easier access to trusted health professionals to answer vaccine questions. Health visitors were mentioned as important sources of vaccine information therefore reversing cuts in the health visiting workforce and increasing their contacts with expectant and new parents could be important. [50] Our findings also support England's NHS's national vaccine strategy's focus on improving access to and convenience of routine vaccinations [28]. However, our key finding that parents value healthcare professionals taking the time to talk to them suggests that implementing the strategy will require high levels of resource from an already over-stretched primary healthcare workforce [51]. Extra resource will particularly be needed to deliver the targeted outreach suggested in the strategy in areas of low vaccine uptake. Our findings suggest the importance of using trusted, known local community translators, where appropriate, to deliver vaccine information to ethnic minority parents through conversations in their own languages. Such outreach interventions will need to consider the multiple dimensions of local religious, cultural and ethnicity networks [27,52]. Greater resourcing and staffing in primary care in more deprived areas of the country with lower vaccine uptake and less existing resource [53] will be needed to ensure future outbreaks are prevented. Our findings support the need for robust call and recall but any targeted interventions must ensure that they do not worsen existing inequalities [45].

4.3. Strengths and weaknesses

Our study's main strength is that by partnering with Mosaic we targeted recruitment in an area of North-West London with an historically low vaccine uptake, with a quarter of parents surveyed from ethnic minority groups. This is higher proportion than previous UK parental vaccine surveys [17,21,54]. We also included more parents from London compared to previous surveys [21] which is another strength given

London's historically lower vaccine uptake and rising measles cases [1]. Our mixed-methods approach of a questionnaire followed by focus groups also allowed greater insight into parents' attitudes and experiences. In the UK, children belonging to ethnic minorities are less likely to be vaccinated [55], however we were underpowered to describe parental attitudes and experiences by ethnicity subgroup. The aggregation of non-white ethnicity into one group is a significant limitation and fails to appreciate the heterogeneity of groups classified as ethnic minorities in the UK and the multi-dimensional concept of ethnicity [56]. Future research should seek to unpick variation between different ethnic minorities groups' attitudes and experiences of childhood vaccination and how interventions can be tailored to address inequalities. There were also varying numbers of parents completing each question in the survey; those that chose not to answer certain questions may be different to those that did, thus biasing the results. Due to the questionnaire responses being anonymised another limitation is that non UK residents may have fraudulently completed it, which is a risk with internet based research [57]. To limit this respondents were asked to confirm eligibility and that they were a UK resident at the start and freetext responses were also checked for repeated phrases, duplication and similarity, however this may not have completely eliminated the risk of fraudulent responses.

5. Conclusion

Most parents in England choose to have their children vaccinated. However, access barriers such as difficulties booking and attending vaccine appointments mean some children miss out on vaccines or are vaccinated late. Parents also want more information provided or more opportunities to ask questions before their children's vaccine appointments ideally by having a conversation with a trusted, known health professional. Health professionals need time, resource, and training to be able to confidently answer parents' questions about routine vaccinations at every contact with families, including during pregnancy. Even in the resource-constrained public health environment currently being experienced, by England and the UK, preventing further disease outbreaks requires investment in and prioritisation of vaccine services to ensure it is easy and convenient for parents to get their children vaccinated.

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CRedit authorship contribution statement

H. Skirrow: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Funding

acquisition, Formal analysis, Data curation, Conceptualization. C. Lewis: Writing – review & editing, Supervision, Methodology, Investigation, Formal analysis. H. Haque: Writing – review & editing, Investigation, Funding acquisition, Conceptualization. L. Choudhary-Salter: Writing – review & editing, Investigation, Funding acquisition, Formal analysis, Conceptualization. K. Foley: Writing – review & editing, Formal analysis. E. Whittaker: Writing – review & editing, Methodology, Formal analysis, Conceptualization. C. Costelloe: Writing – review & editing, Funding acquisition, Conceptualization. H. Bedford: Writing – review & editing, Supervision, Methodology, Investigation, Formal analysis. S. Saxena: Writing – review & editing, Supervision, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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Data availability

The authors do not have permission to share data.

Appendix A. Supplementary data

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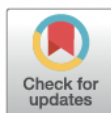
RESEARCH ARTICLE

The impact of the COVID-19 pandemic on UK parents' attitudes towards routine childhood vaccines: A mixed-methods study

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Data Availability Statement: All raw data used to build the figures is included. Only a portion of the survey and focus group data was used in the reported study. The raw data cannot be shared without restriction due to data containing potentially identifiable information and the study participants agreed that their anonymised survey and focus group data could only be used by researchers. This level of data access was approved by the Imperial College London Research

Abstract

Background

COVID-19 vaccines were key to controlling the pandemic and vaccination has been discussed extensively by the media and the public since 2020. We aimed to explore parents' attitudes towards routine childhood vaccination since COVID-19 and how the pandemic impacted their experiences of getting their child vaccinated.

Methods

We used a mixed-methods approach—involving a questionnaire survey followed by focus groups. We partnered with The Mosaic Community Trust, an ethnic minority women's group based in a deprived area of North-West London, United Kingdom (UK) with historically low childhood vaccine uptake. Descriptive findings from the questionnaires were reported and chi-square analyses performed to examine differences by ethnicity. Thematic analysis of the free-text questionnaire responses and focus groups was undertaken, guided by the COM-B model of Capability, Opportunity, and Motivation.

Results

Between Jun-Oct 2022, 518 parents completed the questionnaire (25% from ethnic minorities). Between March-May 2023 we held four focus groups with 22 parents (45% from ethnic minorities). Most parents (>90%) thought routine childhood vaccines for children were important. Over a third (38%) of all parents reported having more questions about childhood vaccines since COVID-19, though among parents belonging to an ethnicity group other than white, 59% said they had more questions compared to those of any white ethnicity group (30%, ($p = <0.0001$)). Difficulties accessing vaccine appointments were commoner reasons for children's vaccinations being delayed than parents increased concerns about vaccines.

Ethics Committee (study reference ICREC 22IC7458 email: rgtic.coordinator@imperial.ac.uk).

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Since COVID-19 some parents felt vaccinations were even more important, and a very small minority felt the pandemic had made them mistrust vaccinations.

Conclusion

Following COVID-19, we found parents remain confident in childhood vaccines. However, some parents, particularly from ethnic minority groups may have more questions about childhood vaccines than pre-pandemic. Post COVID-19, to address declining vaccine uptake, parents need easy access to healthcare professionals to answer questions about childhood vaccinations.

Background

The United Kingdom's (UK) longstanding universal and free childhood vaccination programme currently protects children by age 5 years against 14 infectious diseases, however the pandemic may have changed parents' attitudes to vaccinating their child [1]. The UK's COVID-19 vaccination programme commenced in December 2020 [2] and has been instrumental in controlling morbidity and mortality caused by the SARS CoV-2 virus [3]. The pandemic and vaccination programme have been widely covered by both mainstream [4] and social media [5], potentially exposing the public to a high volume of vaccine information [6]. The World Health Organization warned in 2020 that the world was facing not only a pandemic, but also an 'infodemic' through the widespread dissemination of medical and scientific information to the public, including misinformation [7]. There has been concerns that this overload of information could increase vaccine hesitancy [8]—defined as indecisiveness about a vaccination decision [9].

The COVID-19 pandemic caused a decline in routine childhood vaccination uptake globally [10], with disruption to routine vaccine services reported across 170 countries [10]. For example, a survey of Indonesian parents found that childhood vaccinations were delayed due to both vaccine services ceasing and parents choosing to delay vaccines during the pandemic [11]. In the UK the declines in childhood vaccine uptake have persisted past the initial stages of the pandemic [12–14]. In the UK, parents experienced difficulties accessing routine childhood vaccines during the first wave of the pandemic and confusion about whether routine vaccines were continuing [15, 16]. Pre-existing inequalities in childhood vaccine uptake between different ethnicity groups and among more disadvantaged areas were also exacerbated by the pandemic [17]. In the United States, parents' attitudes to routine childhood vaccines were found to have been impacted by the pandemic [18], including some parents being more hesitant about vaccines recommended by healthcare workers [19].

In the UK, regular surveys conducted by public health bodies pre and post pandemic report high confidence in routine childhood vaccinations with the most recent (2022) survey reporting for example that 90% of parents 'trust' vaccines [20]. However, the 2022 United Kingdom's Health Security Agency (UKHSA) survey recruited parents registered with the commercial marketing parent app 'Bounty' and under-represented parents from London and from ethnic minorities [20], groups who are less likely to have their children vaccinated [14, 21, 22]. As inequities in vaccine uptake among ethnic minorities appear to be widening, exploring perspectives about the impact of the pandemic on routine childhood vaccine attitudes among these groups is an urgent priority to inform interventions to address declining routine childhood vaccine uptake and address inequalities [14].

We partnered with The Mosaic Community Trust (Mosaic) [23, 24] who are based in a more deprived, ethnically diverse area of London with historically low childhood vaccine uptake—for example in the local area only 74% of 5 year olds have received the recommended two doses of measles, mumps and rubella (MMR) vaccines compared to 84% in England [14]. Using a mixed-methods approach, including a parental survey using a questionnaire followed by focus groups, we aimed to explore and describe how the COVID-19 pandemic had impacted parents' attitudes towards, and experiences of, accessing routine childhood vaccinations. Given inequities in childhood vaccine uptake have increased since the pandemic in the UK [17], we also examined differences in responses between ethnic minority respondents and non-ethnic minority respondents.

Methods

Partnership with The Mosaic Community Trust

Our public partners The Mosaic Community Trust [23] were involved from the study's start, building on a pre-existing collaboration [25]. The partnership between the study investigators and the Mosaic Community Trust involved shared power, reciprocity and respect throughout [26]. Mosaic is a community support group of around 100 ethnic minority, predominantly Asian or British Asian or Arabic women, the majority of whom are Muslim. Mosaic provides health and wellbeing support and links into local healthcare and mental health services through regular community meetings [23]. Mosaic named this study "Why has nobody asked us?!" to acknowledge that the views of ethnic minority parents living in an area of high deprivation with low vaccine uptake had not been previously considered. A mixed-methods approach was agreed on comprising a survey using a questionnaire followed by focus groups. In this paper we draw on data gathered from both the survey and focus groups on the impact of the COVID-19 pandemic on parents' attitudes and experiences of routine childhood vaccines. These are part of the findings from the wider study aimed at investigating why some children in the UK are unvaccinated or vaccinated late.

Survey

Questionnaire design. We co-developed a questionnaire based on brainstorming sessions with Mosaic and previous surveys of parental vaccine attitudes and hesitancy [27–30]. The COM-B model [31], previously applied to vaccination behaviour [30, 32, 33], was also used to guide topic development. The COM-B model suggests that '*Capability*' (knowledge and skills), '*Opportunity*' (physical access & convenience, availability of information) and '*Motivation*' (Attitudes, values, emotions) are needed to perform a certain '*Behaviour*' such as vaccination (B) [31]. Other stakeholders in North-West London such as the Maternity Champions, Community Champions, and the local public health department were also involved in informing question topics. Questions were developed, tested, and refined for acceptability and understanding among Mosaic members and other stakeholders. Some question topics were also considered to be better suited to be included in the subsequent focus groups to allow more in-depth exploration.

The questionnaire consisted of the following sections: 1) demographics, 2) routine vaccines for children in the UK 3) experiences of accessing information about routine vaccines for children in the UK and 4) routine vaccines for children in the UK and the COVID-19 pandemic. Demographic questions included age, ethnicity, religion, gender, geographical location, education, household composition and number of children. Respondents were asked a series of questions regarding their perceived importance of routine vaccination of their child/ren and whether they had ever delayed or refused a vaccine. For each discrete statement, respondents

indicated their level of agreement/disagreement on a 7-point Likert scale between *Strongly disagree* to *Strongly agree*. There was also a free-text response option for respondents to make any other comments about routine vaccines recommended for children in the UK. They were then asked about information they received before their children's vaccination and their experiences of accessing routine vaccine appointments for their children. Then there were questions about the impact of the COVID-19 pandemic on their views and experiences of childhood vaccines again using a Likert scale of agreement/disagreement. At the end of the questionnaire, respondents were provided with another opportunity to add any additional comments. The full questionnaire can be found in the S1 File in [S1 Data](#).

Survey recruitment. Participants were recruited to the study through either through online promotion or by Mosaic who promoted the study in North-West London through local networks of parents and families. Mosaic promoted both online and paper questionnaire completion. Paper questionnaires were distributed in person by Mosaic Community Health workers to parents who attended the Mosaic community group meetings. Online promotion also involved a link to the questionnaire being emailed to community organisations including Maternity Champions, Maternity Voices Partnership, Community Champions, and Connecting Care for Children who were invited to share and promote it through their networks by email and social media. By approaching a range of community groups embedded among local peer support networks, our recruitment strategy sought to recruit particularly from grass roots organisations and therefore recruit underrepresented groups. The questionnaire was also advertised and promoted using Instagram paid for promotion which was geographically targeted to adults living North-West London. The questionnaire was also shared and distributed via the research team's personal twitter accounts, including linking to other researchers and organisations interested in vaccine uptake.

Eligible participants were required to be aged 18 years or over, resident in the UK with children aged 10 years or younger at the time of completing the questionnaire. The questionnaire was live online and promoted from 7th June 2022 until 6th November 2022 though online promotion by Instagram was only between 12th August– 28th September 2022. The questionnaire was prefaced by an information page explaining the study, and how the data was to be used. Participants were informed that by taking part they agreed for their responses to be used for research purposes. Participants were required to confirm (by tick-box) at the start that they met the eligibility criteria and that they consented to participate in the study. Apart from the question confirming their eligibility, answers to the questions were optional. At the end of the questionnaire participants were invited to indicate their willingness to take part in a follow-up focus group by leaving their contact details.

Focus groups

Recruitment and data collection. Respondents who included their details at the end of the questionnaire were contacted later and invited to take part in focus groups. They were given a choice of taking part in either in-person or online focus groups. Written informed consent was obtained from each participant. Depending on the preference of the participant, the consent form was sent and returned completed via email or in person. For the final fourth focus group participants were recruited from local parents among Mosaic's network, as data saturation had not been reached by recruiting from the questionnaire respondents alone after three focus groups. Four focus groups were conducted in total, two in person at a community venue used by Mosaic for meetings in Westminster, North-West London and two online via Zoom. The topic guide (see S2 File in [S1 Data](#)) was informed by the questionnaire responses and included topics such as attitudes to vaccination, experiences of accessing vaccinations and

how the pandemic had impacted participants' views on routine childhood vaccination. Participants received a £10 gift voucher in recognition of their time and contribution. Focus groups were conducted between the 15th March and 24th May 2023 and lasted between 60 and 90 minutes. All the four focus groups, both online and in person, were conducted with both HS and HH acting as facilitators with HB, CL and EW acting as co-facilitators at different focus groups.

Questionnaire analysis. Descriptive statistics of discrete choice question responses are reported for all COVID-19 questions and the question on the importance of vaccinating children. Given the longstanding disparity in childhood vaccine uptake between different ethnicity groups [17, 21], Chi-square analyses were then conducted to test for significant associations between ethnicity and agreement/disagreement with the statements on how their attitudes to routine childhood vaccines had been impacted by the COVID-19 pandemic. Respondents were split into two ethnicity groups as we were underpowered to analyse by different ethnicity subgroups. Parents who answered which of the following best describes your ethnicity? as 'White, White Irish or Other White background' were compared to those that answered any of 'Any Mixed background, Black or Black British or any Black background, Asian or British Asian or any Asian background, Chinese or other or prefer not to say'. Likert responses were then also dichotomised into 'Agreed' (Strongly Agree, Agree or Somewhat Agree) and 'Disagreed' (Neither Agree or Disagree, Somewhat Disagree, Disagree or Strongly Disagree). Parents who left the question about ethnicity blank were not included in the chi-square analysis.

Focus group analysis. Focus group recordings were transcribed verbatim by an external professional transcription service used by Imperial College London. Both the questionnaire free-text responses and the data collected in the focus groups were analysed using a codebook thematic analysis [34, 35], following an inductive and deductive coding scheme. Deductive codes were based on the COM-B model [31] as well as the study objectives and previous literature, while inductive codes were developed from the data. To enhance the rigour of the analysis, coding approaches and data interpretations were discussed between HH, HB, CL, and EW, with CL also double coding to check for agreement.

Ethical approval. Ethics approval was granted on 26th January 2022 by the Imperial College Research Ethics Committee (study reference: 22IC7458).

Results

Questionnaire sample

A total of 518 parents completed the questionnaire, 476 online and 42 on paper (paper respondents). The total number of respondents answering each question, differs. Of the 50 paper questionnaires given to Mosaic community health workers to distribute, 42 were completed. The response rate of the online questionnaire is not known due to wide promotion, but the paid promotion feature on Instagram was used from 12th August 2022 to 28th September 2022 and reached 27,352 accounts and achieved 317 link click engagements. Characteristics of participants in the survey are shown in Table 1. Demographic characteristics between paper and online respondents differed. The average age of all respondents was 37 years (median and mean) and ranged between 19–57 years though paper respondents had a lower median age of 35 years. Among all respondents, 25% were from ethnic minority groups, though among paper respondents, the majority (83%, 35/42) were from ethnic minorities. The most common ethnicity among paper respondents was 'Asian or British Asian' (n = 17) and the 14 paper respondents who described themselves as 'Other ethnicity group' gave their ethnicity as 'Arabic'. Among paper respondents the majority were Muslim (88%, n = 37/42). Only 31% (n = 13) of paper respondents were university educated with the majority completing

Table 1. Characteristics of questionnaire respondents.

z	Respondents (n)	%
Gender		
Female	456	88
Male	11	2
Not given	51	10
Geographical location		
North-West London	203	39
All London	330	64
Outside London	72	14
Not given	116	22
Country of birth		
United Kingdom (UK)	267	51
Non-UK	149	29
Not given	102	20
Ethnicity		
White or White British	320	62
Mixed	28	5
Black or Black British	21	4
Asian or Asian British	43	9
Other, ethnic group	38	7
Not given	68	13
Religion		
No religion	219	42
Christian	164	32
Muslim	71	14
Hindu	8	2
Jewish	8	2
Not given	48	9
Education		
Educated to primary school level, secondary school up to 16 years or 18 years	48	9
Educated beyond 18 years at college, university or to post-graduate level	415	80
Not given	55	11
Household structure		
Raising children with partner	428	83
Single parent or other	47	9
Not given	43	8
Number of children		
1	206	40
2	206	40
3 or more	48	9
Not given	58	11

Demographic characteristics of both paper (n = 42) and online (n = 476) questionnaire respondents (total n = 518).

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secondary school education to either 16 years (29%, n = 12) or 18 years (26%, n = 11). Paper respondents also differed from online respondents with respect to family size: over a third of the paper respondents who answered the question had 3 or more children (55%, n = 15/42) compared with only 7% (n = 33) of on-line respondents. Very few respondents answered that

they were living with extended family members, 7% ($n = 35$) though among paper respondents this was higher (17%, $n = 7/42$).

Focus group sample

In total 19% ($n = 100$) of all questionnaire respondents provided their details to be contacted for a follow-up focus group and were contacted by email by HS, or by phone by HH, to participate. Twenty-two responded to the invitation, with 16 taking part in one of the first three focus groups. The remaining six parents opted out prior to the focus groups. Mosaic recruited a further six women to take part in the final focus group from among the local parents who use Mosaic services but who had not completed the questionnaire. The characteristics of focus groups participants are outlined in Table 2, (100% were women) of whom 10 were from ethnic minority groups. The focus groups included parents who had chosen to delay or decline some childhood vaccinations (see Table 2).

COM-B model

The following sections present data according to the COM-B model [31], which was used as guide for analysing how the COVID-19 pandemic has impacted routine childhood attitudes

Table 2. Characteristics of focus group participants.

No	Ethnicity	Online or in person focus group in North-West London	Vaccines ever delayed or refused for the child/ren (not including childhood Covid-19 vaccine)
1	White (other)	In person (FG1)	None
2	White (British)	In person (FG1)	Flu, whooping cough & additional polio booster
3	Asian or Asian British	In person (FG1)	None
4	Asian or Asian British	In person (FG1)	None
5	Other ethnic group (Arab)	In person (FG1)	MMR
6	White (British)	Online (FG2)	None
7	White (British)	Online (FG2)	Paid for some vaccines separately.
8	Mixed	Online (FG2)	None
9	White (Other)	Online (FG2)	None
10	White (Other)	Online (FG2)	Delayed MMR and paid privately for other vaccinations to be spaced out.
11	White (British)	Online (FG2)	None
12	White (British)	Online (FG2)	None
13	White (British)	Online (FG2)	None but chose to have 1 year old vaccines at separate appointments.
14	White (Other)	Online (FG2)	Preschool booster
15	Asian or Asian British	Online (FG2)	MMR—both 1 year and preschool booster declined.
16	White (British)	Online (FG2)	None
17	White (British)	In person (FG2)	None
18	Asian or Asian British	In person (FG2)	MMR vaccine
19	Asian or Asian British	In person (FG2)	None
20	Asian or Asian British	In person (FG2)	None
21	Other ethnic group (Arab)	In person (FG2)	MMR vaccine

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Figure 1. Questionnaire free-text responses and focus group quotes illustrating components of the COM-B model.

Com-B Model Component: CAPABILITY (Knowledge & skills)	
Theme	Example quotes
Increased questions about vaccines	'Since covid, we know... side-effect from the vaccines. So, when you're thinking like that, you don't know if kids aren't having... side effects to vaccines but we're not aware of it.' (FG1 participant) 'I feel that covid has created a lot of fear and confusion around standard jabs' (Questionnaire respondent n22) 'But it's (covid) definitely made me listen to the voices more. And then... navigate to my own decision.' (FG2 participant) 'I am also questioning things as well.' (FG3 participant)
Covid-19 vaccine viewed similarly to flu vaccine	'I don't give them the flu jab or COVID jabs, haven't done them.' (FG1 participant) 'Refused to have the optional flu jab via nasal spray.' (Questionnaire respondent n88)
Covid-19 vaccination for children viewed differently	'I see the Covid vaccine as different to other vaccines as children aren't usually massively affected by Covid.' (Questionnaire respondent n31) 'I done vaccine for my children, flu. Just COVID, no vaccinated.' (FG4 participant) 'I have chosen not to vaccinate my 5 yr old re covid as the benefits appear to be aimed at protecting others rather than her' (Questionnaire respondent 118)
Covid-19 vaccination, pregnancy, and fertility	'So apparently, some people don't get pregnant, or it affects a woman's ovulation as well.' (FG4 participant) 'And it was a really big thing having the COVID vaccine or not when you were pregnant'. (FG3 participant)
Covid-19 didn't change perception of childhood vaccines.	'I'm not sure COVID changed my opinion on childhood vaccines. I think I question everything.' (FG2 participant) 'held the same views pre-covid'. (Questionnaire respondent n10)
Com-B Model Component: OPPORTUNITY (Physical: Access, convenience, availability of information)	
Reduced contact/conversations/face-to-face appointments with healthcare professionals during covid	'My child's first year of vaccines took place from March 2020 and this is why I sometimes felt... there was no time for questions - at the 16-week vaccination they didn't even fill in the red book due to wanting to get people in and out quickly'. (Questionnaire respondent 108) 'Reduced availability of face to face GP appointments due to the pandemic (i.e., in lockdown)' (Questionnaire respondent 118)
Difficulties in making/attending routine childhood vaccine appointments during covid	'And I remember the first one, I think the first few, it was quite hard to get appointments. And I don't know if that has to do with COVID, because my daughter's two'. (FG2 participant) 'Some of my children's vaccinations were delayed due to medical centre closures during the pandemic but I was proactive in ensuring they were up to date once normal operations resumed'. (Questionnaire respondent n15) 'Access to getting the vaccination is the hardest part. During COVID many GP surgeries were not offering routine vaccination appointments.' (Questionnaire respondent 151)
Covid-19 vaccinations & availability at different locations.	'Supposedly they were obviously offering them to children, there was a drive to encourage the younger years to get the vaccinations, the communication was almost non-existent. Booking was extremely hard. We had to drive for an hour to get it.' (FG2 participant) 'Need better availability of Covid 19 vaccine' (for children) (Questionnaire respondent 132)
Com-B Model Component: MOTIVATION (Attitudes, values, emotions)	
Increased belief and trust in vaccinations due to Covid-19	'I feel more aware now. And I don't know if that's because of COVID, just because of vaccine information being more widely available and discussed. But, if anything, it's probably encouraged me more down the vaccine front.' (FG2 participant) 'I think it's made me even keener to prevent any illnesses that my children could get. So, my kids have had COVID vaccines, and I vaccinate them against the flu. And that's offered and things like that. So, for me it's more like giving them the best possible odds, given that the future is uncertain.' (FG2 participant)
Increased vaccine misinformation	'I think there's a lot of misinformation out there, which has become a lot more of it in the last three years.' (FG2 participant) 'It confuses us because there's people who are for it and who are against it and they're very strong views. So, you're in the middle and it's so cloudy.' (FG1 participant)
Mistrust in Covid-19 vaccines (for adults)	'Because I don't trust the vaccination. I no COVID vaccine and my husband no COVID vaccine.' (FG4 participant) 'Explain why and how the covid vaccine was approved quicker than normal (no red tape, years to find funding etc)' (Questionnaire respondent 203)
Increased mistrust in vaccines now	'All of the nonsense with the COVID-19 vaccines came up, and the mandates, and firing people. And now have basically guaranteed I'll never get a vaccine again.' (Questionnaire respondent 177) 'Makes me wonder what other lies we've been told to safeguard people's opinions on vaccines, right. So, I do wonder if we've been told tales about the safety and efficacy of other medications, not just vaccines, to line people's pockets maybe.' (FG3 respondent)

Key to icons:
 1 Redaction codes on a print out (excluding some from previous iterations)
 2 Order developed from questions to
 3 Redaction codes from original focus group

Fig 1. Example quotes from the questionnaire free-text responses and focus groups illustrating different themes of the COM-B model.

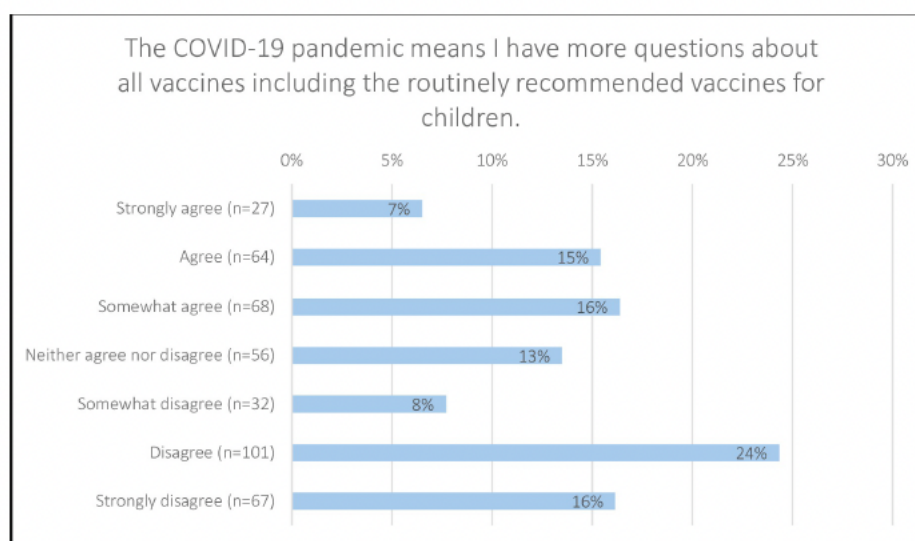
<https://doi.org/10.1371/journal.pone.0306484.g001>

and experiences (see Fig 1). The themes draw on a combination of discrete question responses from the questionnaire, free-text questionnaire answers and data from the focus groups (see S3 File in S1 Data for number of questionnaire free-text responses). Given the variation in the number of respondents per question descriptive statistics and chi square analysis report on the percentages among those who chose to answer each question. Quotes from focus group participants and free-text responses are provided in Fig 1 to illustrate the key themes. Themes were developed from either deductive codes based on the a priori study objectives and some were inductive either developed from the questionnaire responses or from the focus group data. For example, attitudes specifically towards COVID-19 vaccination for children or adults were not explored but many free-text responses and focus groups participants discussed COVID-19 vaccines so were included as inductive themes.

Capability

Knowledge and skills. Over a half (52%) of respondents agreed to some extent that their knowledge about routine vaccines had been increased by the pandemic (S4 File in S1 Data). However, just over a quarter (26%) disagreed, with the remainder (23%) neither agreeing nor disagreeing (S4 File in S1 Data). There was no difference between responses by ethnicity (S5 File in S1 Data).

Increased questions about vaccines. Over a third of questionnaire respondents (38%, $n = 159/415$) agreed to some degree that they had more questions about routine childhood vaccines since COVID-19 (Fig 2). Parents who described their ethnicity as "Any Mixed background, Black or Black British or any Black background, Asian or British Asian or any Asian background, Chinese or Other or Prefer not to say" were more likely to have questions following COVID-19—59% ($n = 71/120$) agreed that they had more questions since the pandemic about



Total respondents answering question: n=415

Fig 2. Respondents level of agreement/disagreement on a 7-point Likert scale between Strongly disagree to Strongly agree with the statement: 'The COVID-19 pandemic means I have more questions about all vaccines including the routinely recommended vaccines for children'.

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routine childhood vaccines compared to 30% (n = 84/281) of parents who identified as white ethnicity ($p < 0.0001$, S5 File in [S1 Data](#)). Among paper respondents 63% (n = 26/41) agreed to some extent that the pandemic had increased their questions about routine vaccines compared to only 36% (n = 133/374) of online respondents.

In the focus groups some parents reported having more questions about routine childhood vaccines since the COVID-19 pandemic ([Fig 1](#)). Parents might now see vaccination as a choice compared with before the pandemic when they viewed it as something they did automatically for their children—'I think the impact of Covid, for me, has made me think that vaccinations are a choice. So, you're actively choosing to do something, or you're choosing not to do something. And it's made it less compulsory and more voluntary' (Focus Group (FG) 2 participant).

COVID-19 vaccine viewed similarly to flu vaccine. Although not specifically questioned about COVID-19 vaccines for their children, several questionnaire respondents and focus group participants discussed this and in doing so drew parallels with the childhood nasal flu vaccine ([Fig 1](#)). Both were seen as additional or optional by some parents, and not viewed as being part of the routine childhood vaccination offered in the UK. For example, one questionnaire respondent (questionnaire respondent n122) commented 'I chose not to get my son the flu vaccine or the current Covid vaccine. I feel both are not essential.' Another parent felt that getting the flu vaccine during the pandemic was not needed 'Getting flu nasal was an unnecessary outing during lockdown and risks from it are minimal compared to other illnesses vaccines are offered for' (questionnaire respondent n40).

COVID-19 vaccination for children viewed differently. Several parents mentioned their attitudes to COVID-19 vaccination for their children in either the questionnaire's free-text

responses or during the focus groups. COVID-19 vaccination was not viewed as important or necessary for children compared to adults, and parents often cited less severe symptoms of COVID-19 in children compared to adults as their rationale for not wanting the vaccine for their children (Fig 1). For example, one parent reported, *'The Covid 19 jab was never needed for children as children were not even getting bad symptoms so why did they need a vaccine for covid if it didn't even affect them much in the first place?'* (Questionnaire respondent n26).

COVID-19 vaccine and pregnancy and fertility. In the survey, a few parents expressed their own or other parents in their circle concerns about COVID-19 vaccines impacting on fertility; this issue was also raised in the focus groups (Fig 1). Additionally, in the focus groups, several participants mentioned their confusion about whether to have the COVID-19 vaccines during pregnancy. For example, one focus group participant said: *'Had both COVID vaccines whilst I was pregnant, which was a huge decision for me. Because at the time, they were like we don't know what it's going to do to you if you're pregnant.'* (FG3 participant). Another commented on midwives not recommending COVID-19 vaccine strongly enough for pregnant women *'most midwives didn't advocate strongly enough for pregnant women to have the covid vaccine'* (Questionnaire respondent n24).

COVID-19 did not change perception of childhood vaccines. Several respondents to the online questionnaire commented that the pandemic had no impact on their views and attitudes to childhood vaccines and that they had the same beliefs as pre-pandemic (Fig 1). For example, one questionnaire respondent wrote directly after the COVID-19 questions: *'Hasn't changed my view'* (Questionnaire respondent n3).

Discrete choice answers indicated that most respondents felt that the pandemic had made them think it was more important for children to receive the routine vaccines (total 62% (n = 250/405) either strongly agreed, agreed, or somewhat agreed—S6 File in S1 Data) with only a minority of total respondents (13%, n = 57/405) disagreeing to any extent with this statement (S6 File in S1 Data). There was no difference between the different ethnicity groups about whether the pandemic had made them think routine vaccines were more important (S5 File in S1 Data).

Opportunity

Reduced contact/conversations/face-to-face appointments with healthcare professionals during COVID-19. Questionnaire respondents and focus group participants both mentioned that the reduction in face-to-face appointments with different healthcare professionals during the pandemic—including midwives, health visitors and general practice staff—had given them fewer opportunities than they would have liked, to ask questions about routine childhood vaccines (Fig 1). *'I had my baby during the end of COVID, so—so I felt like I didn't get that much information and I was left out.'* (FG1 participant). That parent went on to describe the questions they wanted answering including: *'There's so many vaccines and I feel like it's too much. . . . Why does a baby need to have all of these?'* (FG1 participant).

Difficulties in making/attending routine childhood vaccine appointments during pandemic. In the free-text questionnaire responses, many respondents reported their children's routine vaccines had been delayed due to COVID-19 and finding it difficult to either schedule or attend an appointment (Fig 1). Access difficulties during COVID-19 were more frequently cited as a reason for a delayed vaccination than choosing to delay the vaccine because the pandemic made them question/doubt vaccines. For example, one parent commented: *'For me personally in the height of the pandemic my GP services made it difficult to book any appointments so there was a lot of confusion on whether I could book vaccinations, my children missed the vaccinations they were due to have during the lockdown'* (questionnaire respondent n28).

The majority (47% $n = 194/414$) strongly disagreed that following COVID-19 they were more likely to refuse or delay a vaccine for their child (S7 File in [S1 Data](#)), with a further 32% ($n = 134/414$) disagreeing or somewhat disagreeing and only 13% ($n = 55/414$) agreeing (S7 File in [S1 Data](#)). Similarly, 81% ($n = 319/394$) disagreed to some degree that the pandemic had made them refuse or delay a vaccine for their child (S8 File in [S1 Data](#)). Chi-square analyses however suggested that parents who answered that they belonged to an ethnicity group other than White ethnicity were more likely to refuse a vaccine ($p = <0.0001$) or had actually refused a vaccine for their child since the pandemic ($p = 0.0031$) compared to parents in the White ethnicity group (S5 File in [S1 Data](#)).

COVID-19 vaccinations and availability at different locations. Several parents reported via the free-text comments that although they wanted their children to have the COVID-19 vaccine, they had struggled to get an appointment. This was also raised in the focus groups where parents discussed the lack of availability of COVID-19 vaccines as well as not wanting to have routine childhood vaccines in some of the locations where COVID-19 vaccines had been offered ([Fig 1](#)). For example, 'With covid, ... we all get jabbed by some randomest people in some random locations. We had ours in Westminster Abbey. Nice location but I wouldn't take my child for his first vaccination there' (FG1 participant). This was generally perceived to be because they would rather go to a healthcare setting, including pharmacies, with a trusted healthcare professional giving their children's vaccines. For example, one parent commented 'it's reassuring that when you're at the GP you have it, because then you can ask any questions that you think of there and then. ... I remember having my Covid vaccine in a leisure centre and, yes, I don't know that I would want to take (them) to a leisure centre to. ... not somebody that I know that's vaccinating him either. Whereas even if it's a nurse that I'm not familiar with at the GP surgery, at least this is my GP surgery that I go to, they reassure me, I ask them questions. I've got that bit of a relationship' (FG3 participant).

Motivation

Attitudes, values, emotions. In the survey, the overwhelming majority of parents (91%, $n = 416/459$) either strongly agreed or agreed that it is important to get their children vaccinated (S9 File in [S1 Data](#)). Including parents who somewhat agreed with this statement, increases this percentage to 95% ($n = 435/459$). There was a small ($<10\%$, $p = 0.0017$) difference between the percentage of parents who agreed that it was important to get their child vaccinated who belonged to ethnicity groups other than White ethnicity compared to those who said they were White ethnicity (S5 File in [S1 Data](#)).

Increased belief and trust in vaccinations due to COVID-19. Some parents also discussed how the pandemic had made them believe vaccinations were more important than they had previously thought and that getting their children vaccinated was an even greater priority ([Fig 1](#)). This is linked to the theme about the pandemic having not changed their mind about vaccines—one parent commented after the COVID-19 section of the questionnaire 'I was already a strong proponent for vaccines' (questionnaire respondent 4).

Most respondents (66%) somewhat disagreed, disagreed, or strongly disagreed that the pandemic had made them question the safety of routine vaccinations for children (S10 File in [S1 Data](#)) though 28% somewhat agreed, agreed, or strongly agreed that it had. There were some differences between paper and online responses to this question with more paper respondents, 63% ($n = 26/41$) agreeing to some degree that the pandemic had made them question the safety of routine vaccines compared to only 24% of online respondents ($n = 89/374$). Chi-square analyses suggests that parents who identified as ethnicity groups other than White ethnicity were more likely to question routine vaccine safety post covid (51% $n = 61/120$) compared to

those of White ethnicity ((18%, $n = 50/330$), p value = <0.0001 , S5 File in [S1 Data](#)). Qualitative data revealed concerns such as about side effects to explain why vaccine safety has been questioned (see [Fig 1](#)).

Increased vaccine misinformation. In both the free-text questionnaire responses and the focus groups, parents discussed seeing an increase in vaccine misinformation and feeling that they had to try and make sense of this post-covid ([Fig 1](#)). For example, a parent discussed the impact of social media information on their ideas about vaccines during Covid 'media leave us to change our ideas about vaccinations in Covid. . . Because when I heard a lot of Misinformation or right information or wrong information from the media. . . but because in the phone media everywhere. . . Facebook. So now we. . . Confused. Yes' (FG4 participant). Parents cited 'misinformation on the internet. . . which is then repeated and shared among some peer groups' as being a reason for some people not agreeing with vaccines (questionnaire respondent n71).

Mistrust in COVID-19 vaccines for adults. In the focus groups, particularly the in-person ones, participants discussed actively declining COVID-19 vaccines for themselves and their wider family due to scepticism about COVID-19 vaccines for adults. Some questionnaire respondents mentioned similar feelings. This was despite no specific questions about COVID-19 vaccines for adults or children. They reported not trusting COVID-19 vaccines as they were 'new' and been developed quickly. For example, one questionnaire respondent said they are 'afraid of any new vaccines including covid 19. So, we didn't have it. Nobody knows it's long-term effect' (questionnaire respondent 240). There was also a sentiment expressed by some that they regretted getting the COVID-19 vaccines for example 'Since the pandemic we hear so much about the effects of vaccines. I wish I hadn't got the covid vaccine'. (Questionnaire respondent n330).

Increased mistrust in vaccines now. A very small minority of focus group participants and a few questionnaire respondents discussed the COVID-19 pandemic having increased their mistrust towards all vaccines (and not just specifically routine childhood ones), (see [Fig 1](#)). They cited mistrust in pharmaceutical companies and vaccination being promoted for financial gain for example 'There is a loud silence about conflict of interests of those flag bearing for vaccine production and their financial gain. The research and results done is/was minimal especially during the Covid era and very questionable' (Questionnaire respondent 138).

Discussion

Main findings

In this mixed-methods study, we explored how parents' attitudes towards, and experiences of getting routine childhood vaccinations have been impacted by the COVID-19 pandemic. We used the COM-B model [31, 33] to identify how different aspects of parents' views and experiences have been affected. This provides insights into where action may be needed to tackle the downward trend in childhood vaccine uptake [14] in England, which started prior to the pandemic and has worsened since [12, 36, 37].

We found that post pandemic the majority (over 90%) of parents continue to consider routine childhood vaccination to be important—in keeping with studies conducted pre-pandemic [27, 28], in the early phase of the pandemic in 2020 [15] and subsequently [20]. A smaller majority (62%) reported feeling the pandemic had made them think childhood vaccination was even more important. However, we also found that while most parents still have confidence in routine childhood vaccines, some may have more questions about vaccines post COVID-19; over a third of parents reported that they had more questions post-pandemic. To our knowledge this is the first UK study conducted since the pandemic to examine specifically its impact on attitudes and to find that parents may have more questions. Some parents felt the

pandemic had made them question the safety of routine childhood vaccines, though the majority (66%) did not. A very small minority of parents (<10%) reported that the pandemic had made them more likely to refuse or delay a vaccine, and again a very small minority of parents reported in the qualitative findings that their mistrust in all vaccinations has increased since the pandemic. Our findings are broadly in keeping with studies in the United States that find while parental vaccine confidence remains high, vaccine hesitancy, defined as indecisiveness about vaccination [9], may have increased since COVID-19 [19].

In keeping with previous studies, including one conducted during the first COVID-19 lockdown in 2020 [15, 16], parents reported finding the pandemic had made booking and attending vaccination appointments harder. Parents reported that these difficulties were more common reasons for their children not to be vaccinated or vaccinated late during or since the pandemic than COVID-19 prompting concerns about routine childhood vaccination. Our findings provide further evidence that parents in the UK have confidence in vaccination, and that anti-vaccination sentiment is not the main driver [38] of parents delaying or not vaccinating their children, even since COVID-19.

Though we were underpowered to report differences between different ethnicity sub-groups we found that parents who identified as belonging to ethnicity groups other than white may have more questions about childhood vaccines since the pandemic. More parents who completed the questionnaire on paper were from ethnic minorities (83% compared to 25% of all respondents), which may explain why 63% of paper respondents agreed to some extent that they had more questions since the pandemic compared to only 36% of online respondents. This difference in ethnicity between the online and paper respondents may also explain the differences with regards to other questions, such as more (63%) paper respondents reporting that the pandemic had made them question the safety of routine childhood vaccines compared to online respondents (24%). In the UK children belonging to ethnic minorities are also less likely to be vaccinated and these disparities have only worsened since COVID-19 [17]. During COVID-19 parents from ethnic minorities were also more likely to report confusion about whether routine childhood vaccine services were running [15] or to report difficulties accessing vaccine appointments [16].

Religion, ethnicity and deprivation have been found to intersect with regards to childhood vaccination attitudes and access in the UK [22, 27, 39]. For example, Muslim parents in the UK may refuse the childhood nasal influenza vaccine due to concerns about porcine gelatine content [40]. Though studies in predominantly Muslim countries have found that vaccine acceptance among Muslim populations can be high—for example over 85% of adults surveyed in an Indonesian sample would accept COVID-19 vaccines [41], so making associations between vaccine acceptance and religion requires caution. Over 80% of the paper respondents to our survey were from ethnic minorities and gave their religion as Muslim, of whom 63% thought the pandemic had made them more likely to question the safety of routine childhood vaccines compared to 24% of online respondents.

Future research could consider how local religious networks can be utilised to increase childhood vaccine uptake among predominantly Muslim communities such as where the Mosaic Community Trust is based. For example, targeted interventions to address attitudes and access to childhood vaccinations among UK orthodox Jewish families who have low vaccine uptake have been previously developed [30]. To address declining vaccine uptake tailored interventions and resource are needed which take into account the multiple dimensions of local religious, cultural and ethnicity networks in areas of low vaccine uptake.

Despite our questionnaire not asking specifically about COVID-19 vaccines for children, or adults, many parents volunteered their views. This is unsurprising given the questionnaire becoming live in 2022 which coincided with a recent non-urgent recommendation of COVID-

19 vaccines for 5–11 year olds by the UK's expert body on vaccination [42]. Some parents viewed COVID-19 vaccines for children as non-essential, and some in a similar way to the childhood nasal flu vaccine and therefore 'different' from other routine childhood vaccines. Some parents expressed negative views towards COVID-19 vaccines for children while some, particularly those who completed the online questionnaire, felt that the UK should have recommended COVID-19 vaccines for children earlier as other countries such as the United States had done [43]. Other research has found that parents may be less willing to accept COVID-19 vaccines for their children compared to themselves [44, 45] and in our research this was primarily due to COVID-19 vaccines being seen as 'non-essential' for children. A study in the USA found that parents' main reason for not wanting to vaccinate their children against COVID-19 was due to concerns about vaccine safety and side-effects [46]. A minority of parents we surveyed also discussed feelings of mistrust towards COVID-19 vaccines for adults or concerns about the safety of COVID-19 vaccines for pregnant women or impacts on fertility. Uncertainty and confusion around the advisability of COVID-19 vaccines for women of reproductive age are in keeping with previous research and highlights the importance of clear, timely, tailored communication around vaccination, pregnancy, and fertility [47, 48]. In previous work we have also found that uptake of pertussis vaccine in pregnancy and subsequent childhood vaccine uptake of MMR vaccines are related [49] so it is perhaps unsurprising that in a survey of childhood vaccine attitudes that themes related to vaccination and pregnancy emerged.

Strengths and limitations

The main strength of this study is that partnering with Mosaic enabled targeted recruitment in an area of North-West London with a historically low vaccine uptake, with a quarter of respondents to the survey from ethnic minority groups. The focus groups also consisted of 45% of women from ethnic minorities. This is compared to previous parental surveys/studies that have often included fewer parents from ethnic minorities [15, 27], or from London which has lower vaccine uptake [20]. Our mixed-methods approach using a questionnaire survey followed by the focus groups also allowed greater insight into parents' attitudes to vaccination since the pandemic.

However, there are limitations including varying numbers of parents completing each question and small numbers of parents from different ethnicity sub-groups. This means we are unable to report on differences in attitudes between different ethnicity sub-groups limiting our conclusions about different ethnicities' attitudes towards vaccination since the pandemic. This aggregation of non-white ethnicity into one group is a significant limitation and fails to appreciate the heterogeneity of groups classified as ethnic minorities in the UK and the multi-dimensional concept of ethnicity [50]. Future research should seek to unpick variation between different ethnic minorities groups attitudes and experiences of childhood vaccination and how interventions can be tailored to address inequalities.

The parents we surveyed were not asked their attitudes pre-pandemic therefore another limitation is that we did not directly compare the impact of the pandemic on the study participants individual vaccine attitudes. Also due to eligibility the parents questioned included both those who had children pre-pandemic, whose pre-existing attitudes may have been changed by the pandemic, and also parents who had children during the pandemic, whose vaccine attitudes may have been influenced by giving birth during COVID-19. The questionnaire was live in 2022 and the focus groups took place in 2023 so parents may also have inaccurately recalled the impact of the pandemic on their access to vaccinations. However, researching attitudes two years after the start of the pandemic enabled its longer-term implications on routine vaccine attitudes to be explored.

Implications for policy and practice

Measles outbreaks in London in 2023 [51] and the risk of increasing infectious outbreaks due to England's declining childhood vaccine uptake [14] are a public health concern [37]. Our findings suggest that since the pandemic, parents need easier access to healthcare professionals to answer their questions about routine vaccines. This is in keeping with UKHSA's parents' survey in 2022 that found over a third of parents wanted more information before their child's vaccine appointment, though the nature of the information wanted is unclear [20]. Conversations with healthcare professionals are important influences on vaccine decisions [52] and all staff who see parents and families should be trained in how to answer parents' questions about vaccines. Facilitating parents' easier access to healthcare professionals to answer their questions will need greater resourcing and staffing in primary care. This may be even more important in more deprived areas of the country with lower vaccine uptake and less existing resource [53], and also among ethnic minority parents.

Conclusion

Our findings suggest that although parents remain confident in routine childhood vaccination, since the pandemic they want more information and may have more questions which need addressing before their child's vaccine appointment. This may be particularly the case for parents who belong to ethnic minority groups. Healthcare professionals need time and training to be able to confidently answer parents' questions about routine vaccinations to address declining vaccine uptake in the UK. Providing parents with additional information about vaccination could help families have greater awareness about the importance of vaccination for protecting against infectious diseases throughout life. Interventions post COVID-19 to increase vaccine uptake should be locally tailored and incorporate co-design methodologies.

Supporting information

S1 Data. S1 File: Questionnaire, S2 File: Focus Group Topic guide, S3 File: Number of freetext responses to questionnaire, S4 File: COVID-19 and knowledge about routine vaccines recommended for children, S5 File: Impact of COVID-19 on parents' attitudes to routine childhood vaccinations by Ethnicity, S6 File: COVID-19 pandemic and the importance of routine vaccines, S7 File: COVID-10 pandemic and likelihood of refusing or delaying routine vaccines, S8 File: COVID-10 pandemic and having refused or delayed routine vaccines, S9 File: Importance of getting children vaccinated, S10 File: COVID-19 pandemic and safety of routine vaccines. (DOCX)

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