MMR vaccine coverage and associated factors among overseas-born refugee children resettled in Aotearoa New Zealand: a national retrospective cohort study

Nadia A. Charania,[a,b,*] Janine Paynter,[c] and Nikki Turner[d]

[a]Department of Public Health, Auckland University of Technology, 640 Great South Road, Manukau, 2025, Auckland, New Zealand
[b]Migrant and Refugee Research Health Centre, Auckland University of Technology, Auckland, New Zealand
[c]Department of General Practice and Primary Health Care, University of Auckland, 28 Park Ave, Grafton, 1023, Auckland, New Zealand
[d]The Immunisation Advisory Centre, University of Auckland, Auckland, New Zealand

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Summary

Background Refugee children may be under-immunised against common vaccine-preventable diseases due to a myriad of factors related to their migration journey.

Methods This retrospective cohort study explored the rates and determinants of enrolment on the National Immunisation Register (NIR) and measles, mumps and rubella (MMR) coverage among refugee children up to 18 years old who resettled in Aotearoa New Zealand (NZ) from 2006 to 2013. Univariate and multivariable logistic regression were conducted to determine associations.

Findings Of the cohort (N = 2796), two thirds of the children (69%) were enrolled on the NIR. Among this sub-cohort (n = 1926), less than one third (30%) were age-appropriately vaccinated with MMR. MMR coverage was highest among younger children and improved over time. Logistic modelling revealed that visa category, year of arrival, and age group were significant factors that influenced NIR enrolment and MMR vaccine uptake. Those arriving via asylum seeking, family reunification and humanitarian pathways were less likely to be enrolled and vaccinated compared to refugees who entered under the national quota programme. More recent arrivals and younger children were more likely to be enrolled and vaccinated compared to children who arrived in NZ longer ago and were older.

Interpretation Resettled refugee children have suboptimal NIR enrolment and MMR coverage rates which varied significantly by visa category, highlighting the need for immunisation services to better engage with all refugee families. These findings suggest that broad structural factors related to policy and immunisation service delivery may influence the differentials seen.

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Keywords: Immunisation; Vaccine; Equity; Child; Data-linking; Refugee; New Zealand

Introduction

The number of refugees fleeing their homes has considerably increased over recent years due to ongoing conflict and political persecution.[1] Disparities in vaccine-preventable disease (VPD) burden and immunisation coverage between migrants and refugees and their host populations have been reported globally.[2] For instance, a review reported that migrants in Europe have been involved in VPD outbreaks with varying vulnerability based on disease, setting, and demographics.[3] Moreover, a recent retrospective cross-sectional study of UK-bound refugees revealed suboptimal vaccination coverage that varied by age, nationality, country of health assessment, and by disease.[4] A scoping review revealed that a complex myriad of factors influenced these inequities among migrants and refugees, including their nativity, country of origin, citizenship status, duration of residence, and language proficiency, to name a few.[2] A recent systematic review further investigated the relative contribution of these factors on suboptimal vaccine

*Corresponding author. Department of Public Health, Auckland University of Technology, New Zealand.
E-mail address: nadia.charania@aut.ac.nz (N.A. Charania).

Research in context

Evidence before this study

We have conducted two scoping reviews of international literature to understand the burden of vaccine-preventable diseases (VPDs), immunisation coverage, and interventions to reduce VPD burden among migrants and refugees. The available evidence suggests that migrant populations generally experience higher VPD burden and lower immunisation rates compared to their host populations due to a myriad of factors. Our previous research in Aotearoa New Zealand (NZ) reported that more than half of overseas-born children with a migrant or refugee background (54%) were not enrolled on the National Immunisation Register (NIR). Of those enrolled on the NIR, they had lower reported age-appropriate vaccination rates by vaccine of interest, ethnicity and visa category compared to NZ-born children. Overseas-born children with refugee backgrounds who resettled in NZ had particularly low age-appropriate vaccination coverage rates, warranting further study into coverage rates and associated factors.

Added value of this study

Our study of measles, mumps and rubella (MMR) vaccine coverage in NZ from 2006 to 2013 provides population-level insights about vaccine uptake among overseas-born children of refugee backgrounds. Among the study cohort (N = 2796), two thirds of children (69%) were enrolled on the NIR. Of those children who were enrolled on the NIR, only 30% were age-appropriately vaccinated with MMR. However, protection was highest for younger children and had improved over time. Among this sub-cohort of children based on age group, 89% (258/291) of 0–<2 year olds, 47% (240/516) of 2–<6 year olds, and 8% (66/843) of 6–<19 years old were age-appropriately vaccinated against measles. This study explored the influence of numerous factors on NIR enrolment and coverage rates, including visa category, age, arrival year, United Nations region of nationality, ethnicity, number of dependent children, household income, parent's level of education, family type, and parent's ability to converse in English. This study showed that register enrolment and MMR coverage were significantly associated with visa category, year of arrival and age group.

Implications of all the available evidence

Despite a publicly funded national childhood schedule and comprehensive immunisation targets, this study demonstrates suboptimal register enrolment and MMR coverage among overseas-born refugee children. Whilst immunisation services have improved over time, there is still room for improvement with enrolment of refugees, particularly for older children and adolescents. The significant association of refugee visa category with both register enrolment and MMR coverage clearly demonstrate that policy- and service-level factors influence vaccine uptake among overseas-born children more than individual or family characteristics. Minimising epidemic risk in NZ requires engagement with all families with migrant and refugee backgrounds upon their arrival to ensure their health and immunisation needs are addressed. To meet the objectives of the World Health Organisation's new Immunisation Agenda 2030, tailored and targeted interventions to improve equitable access to vaccines for refugee children, particularly for older children and adolescents, are required.

uptake among migrants in Europe and identified 23 significant determinants, including geographic origin, recent migration, income, and being a refugee or asylum seeker.[5]

The World Health Organisation's new Immunisation Agenda 2030 (IA2030) sets out a global vision and strategic priorities for vaccines and immunisations.[6] Underpinning the IA2030's strategy is "to leave no one behind" and recommends that migrants and other marginalised groups have equitable access to immunisation services.[6] To meet the IA2030's vision, it is imperative that national immunisation policies and programmes are strengthened to better include the needs of migrants and refugees, particularly with improving access to catch-up vaccines across the life course.[6]

While a refugee is encompassed within the umbrella 'migrant' term as being a person who has left their country of origin, by definition, a refugee has been forced to flee their home because of a well-founded fear of persecution.[7] There are three main pathways in which refugees arrive in Aotearoa New Zealand (NZ), including via the United Nations High Commissioner for Refugees (UNHCR)-mandated government-supported quota programme (quota refugees), the refugee family support category (family reunification refugees), or the refugee and protection status category (asylum seekers, who are then known as convention refugees if their claim is successful).[8] NZ has a long-standing history of accepting refugees with recent increases in annual quotas up to 1500 quota refugees and 600 sponsored family members.[8–10] Every year, approximately 300 claims for refugee status from asylum seekers are received with about a third to half of these being approved.[9]

In NZ, all children under the age of 18 years old are eligible to receive a series of publicly funded vaccinations according to the National Immunisation Schedule (NIS), regardless of their immigration and citizenship status.[11] The newly designed national Health System

Indicators aim for 92% of children being fully immunised by 24 months of age.[12] Despite this target, national childhood immunisation coverage rates are suboptimal with marked inequities by ethnicity and geographic region.[13] Moreover, the magnitude and global scale of disruption to routine immunisation services during the COVID-19 pandemic highlights the urgent need to improve immunisation coverage to prevent the resurgence of VPDs.[14] Recent NZ data shows that fully immunised children aged 24 months old dropped from 91% before the pandemic (reporting period April 2019 to March 2020) to 84.4% (April 2021 to March 2022).[13] The 2019/2020 measles outbreak in NZ and surrounding Pacific islands demonstrated the importance of achieving high immunisation coverage required to maintain herd immunity.[15,16]

National coverage rates may mask immunisation inequities among population sub-groups. A retrospective cohort study of migrant and non-migrant children reported relatively low coverage rates among migrant children, particularly those with refugee backgrounds.[17] One of the health and wellbeing outcomes of NZ's Refugee Resettlement Strategy (RRS) is to increase the proportion of quota refugee children receiving age-appropriate immunisations.[18] Data reports that the percent of quota refugee children receiving one or more schedules vaccines within 12 months of arrival has increased from 86% in 2015/16 to 99% in 2017/18.[18] While this demonstrates high vaccine uptake that has improved over time, this data only represents quota refugee children and does not specify which vaccine(s) were received. Moreover, it is not currently known if refugee children entering NZ via different pathways adhere to catch-up immunisation schedules and sustain age-appropriate vaccinations post-resettlement. If we are to meet the goals of WHO's IA2030 from an equity perspective, it is imperative to investigate vaccine uptake among refugee children to inform improvements to immunisation programmes and to minimise epidemic risk in NZ. The presented retrospective cohort study explored factors influencing enrolment on the National Immunisation Register (NIR) and measles, mumps and rubella (MMR) coverage among overseas-born children of refugee backgrounds who resettled in NZ.

Methods

This study is part of a larger multimethod study[19] comprising of a programme of quantitative and qualitative studies to explore factors associated with the access and uptake of immunisations and develop strategies to improve age-appropriate vaccinations among refugee children post-resettlement in NZ. Ethical approval to conduct this study was granted by the Auckland University of Technology Ethics Committee (AUTEC, ref: 18/322).

Study design and population

This retrospective cohort study focused on a cohort of children born overseas who arrived in NZ on a refugee visa prior to their 18th birthday from 1 January 2006 to 31 December 2018. These children were identified by selecting all individuals with a birth date between 1 January 1989 and 31 December 2018 whose first travel record was an arrival to NZ on a refugee (quota, convention, or family reunification), humanitarian, or overstayer visa. The humanitarian visa category primarily included visas related to asylum seekers, ministerial directions, and victims of domestic violence and human trafficking. The overstayer category refers to those who stayed in NZ after their visa expired and applied for a temporary or resident visa under Section 61 of the Immigration Act.[20]

Children were excluded if they stayed in NZ less than six months, died, opted off the NIR and/or had logical data inconsistencies (e.g., a birth date occurring after a travel date). To enable the use of variables associated with VPD burden and immunisation uptake among migrants and refugees, such as household income and language proficiency,[2,5] children without data available in the 2013 Census were subsequently excluded.

Sources of data and variables

De-identified data were linked from multiple sources using Statistics New Zealand's Integrated Data Infrastructure (IDI). Data included were: Ministry of Health's National Health Index (NHI) for demographic data; Statistic New Zealand's Census 2013 for demographic data; Ministry of Business, Innovation and Employment (MBIE) and New Zealand Customs Journey datasets for immigration and travel data; Department of Internal Affairs for life event data; and the National Immunisation Register (NIR) for immunisation data. Refugee children who enter under the quota programme complete an orientation and health screening programme at the Mangere Refugee Resettlement Centre in which documented vaccination status is assessed and serology is undertaken to assess immunity for certain VPDs, including hepatitis B, rubella and measles; age-appropriate vaccines are offered to start any required catch-up immunisation schedule to align with the NIS.[21,22] Quota refugees are also screened for tuberculosis.[21,22] Refugee children who arrive from overseas via other pathways should have their documented history of vaccination assessed when they engage with a general practice to determine their immunisation catch-up schedule.[11]

Variables used or investigated included: month and year of birth, month and year of death (if applicable), sex, ethnicity, nationality (i.e., the country that issued their passport), visa category, time spent in NZ, number of dependent children, household income, parent's education level, family type, and parent's ability to converse

in English. If an individual had multiple nationalities, the earliest recorded nationality was reported. Ethnicity was self-reported by parents and based on that recorded in the NHI dataset (as it provides more detail) and grouped according to Statistics New Zealand Level 1 ethnicity classifications.

The two outcome variables were enrolment on the NIR (yes/no) and MMR vaccination status (fully vaccinated or not for their age at the end of the study period). MMR was chosen since it is one of the most infectious VPDs and achieving high herd immunity is particularly important to prevent measles transmission.[11] Previous NZ research noted that coverage amongst children with and without a migrant or refugee background was highest for MMR and pertussis-containing vaccines.[17] Focusing on MMR coverage is important given the widespread misinformation about the link with autism and implications for vaccine uptake,[23] particularly amongst certain refugee background communities (e.g., Somali Minnesotan community).[24] To support our findings about MMR coverage, we also included supplementary descriptive analyses of children's pertussis-containing vaccination status.

Data linking and statistical analyses

A NHI number is allocated to overseas-born individuals the first time they access any health or disability support services in NZ. NHI numbers enabled deterministic linkage across health-related data sources. Linking the NIR with the NHI dataset was done using the encrypted NHI index (snz_moh_uid). Data that did not have a standard identifier, such as immigration and travel data, were linked to the health datasets and life events datasets using probabilistic linking originally by Statistics New Zealand, who assigned an encrypted identifier that was then used in this study (snz_uid) to link the data. The June 2020 refresh version of the IDI was used, noting that the NIR data within this dataset included all NIR registrations up to June 2019.

The cohort is described using counts and percentages, summarised according to each variable of interest and outcome variables. To explore MMR vaccine coverage, the recorded vaccination rates based on the child's age at the end of the study period are presented. Univariate logistic regression was conducted to determine associations between enrolment on the NIR and MMR vaccination status, and the included variables of interest. To identify significant associations, multivariable logistic regression was subsequently undertaken and presented. A p-value of <0.05 was considered significant. 95% confidence intervals for proportions are presented. Unadjusted and adjusted odds ratios (OR) are also presented. All analyses were performed using SAS.

Role of funding source

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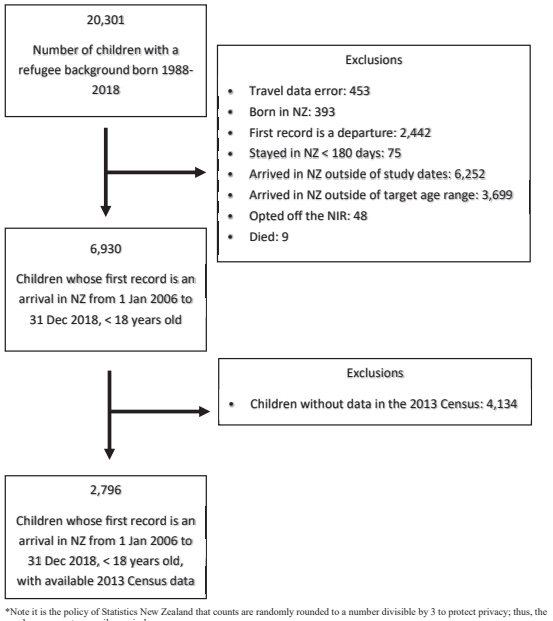
Results

Description of cohort

Fig. 1 shows the number of children included in the cohort after applying exclusions (N = 2796). Of the study population, the majority were quota refugees (n = 1815, 65%), followed by humanitarian (n = 504, 18%), convention refugees (n = 213, 8%), overstayers (people who overstayed their visa) (n = 150, 5%), and family reunification (n = 117, 4%). Just under half of the children were between six and under 14 years old (n = 1329, 48%) when they arrived in NZ. A relatively stable number of children arrived each year (noting limited data available for 2013 when the Census was conducted). Just over half of the children were of Asian (n = 1512, 54%) ethnicity and one third were of Middle Eastern, Latin American, or African (MELAA) ethnicity (n = 936, 33%). Accordingly, most children came from Asia (n = 1704, 61%) and African (n = 456, 16%) UN Regions. More specifically, children arrived from Myanmar (n = 681, 24%), Bhutan (n = 198, 7%), Afghanistan (n = 192, 7%), and Iraq (n = 174, 6%). Nearly half of the parents had an education qualification (n = 1269, 45%), more than half could converse in



*Note it is the policy of Statistics New Zealand that counts are randomly rounded to a number divisible by 3 to protect privacy; thus, the numbers may not reconcile precisely

Fig. 1: **Participant flow chart with exclusions***.

English (n = 1611, 58%), and two thirds represented low and medium household income brackets (n = 1848, 66%).

Enrolment on the National Immunisation Register

Almost two thirds of children (n = 1926, 69%) were enrolled on the NIR (Table 1). Of the different visa categories, children who arrived via the quota refugee pathway had the highest rates for being enrolled in the NIR (n = 1317, 73%) and the rest of the categories had similar rates (ranging from 59% to 62%). There was a decrease in the proportion of children who were on the NIR as age increased. For instance, most of the children under 2 years old were on the NIR (n = 291, 97%) compared to less than half of the children between 14 and under 19 years old (n = 276, 46%). The proportion of children enrolled in the NIR generally increased as arrival year increased, although noting particularly low rates in 2006 as the NIR first began recording information on children in 2005[11,25] and in 2013 when the Census data was collected. Among the ethnicities, almost three quarters of children of Asian (n = 1083, 72%) and MELAA (n = 630, 67%) ethnicities were enrolled on the NIR.

Recorded vaccination status for measles, mumps and rubella (MMR) vaccine

Among the sub-cohort of children who were enrolled on the NIR (n = 1926), less than one third of children (n = 573, 30%) were age-appropriately vaccinated with MMR at the end of the study period. Immunisation coverage steadily increased over time from 15% in 2006 to 50% in 2013. Younger children (0–<2 year olds) had the highest coverage rates. Age-appropriate vaccination status improved over time but remained better for younger children overall (Fig. 2). There were differences by visa category, ranging from 21% for convention refugees to 38% for overstayers. There were no trends noted between vaccination status and household income, parental education level or ability to converse in English. A similar pattern was noticeable for age-appropriate vaccination status of a pertussis-containing vaccine (Supplementary Table S1). At the end of the study period, 18% (n = 345) of children were age-appropriately vaccinated with a pertussis-containing vaccine, with coverage differences noted amongst age groups, arrival year, and visa groups.

Factors associated with enrolment on the National Immunisation Register (NIR) and measles, mumps and rubella (MMR) coverage

To explore factors that influenced enrolment on the NIR and MMR vaccination status, unadjusted and adjusted odds ratios are presented (Table 2). Univariate logistic regression showed that all variables were significantly associated with being enrolled on the NIR except for parental education level and their ability to converse in English. After adjusting for confounding, variables that remained significantly associated with being enrolled on the NIR were visa category, age group and arrival year in NZ. Those arriving via family reunification (p = 0.0021) and humanitarian (p = 0.024) pathways were less likely to be enrolled on the NIR compared to quota refugees. Children who arrived later in the study period (2011–2012) had approximately double the odds of being enrolled on the NIR compared to children who arrived in 2006. Younger children were more likely to be enrolled on the NIR compared to older children.

A similar pattern was found for age-appropriate MMR vaccination status (Table 2). Univariate logistic regression showed that all variables were significantly associated with MMR status except for parental ability to converse in English. Multivariable logistic regression identified a significant association between MMR status and visa category, age group at arrival, and arrival year. Those arriving via asylum seeking (p = 0.0085), family reunification (p = 0.016) and humanitarian (p = 0.0087) pathways were less likely to be age-appropriately vaccinated compared to quota refugees. Children arriving later in the study period (2009–2013) were more likely to be age-appropriately vaccinated than children who arrived in NZ in 2006. As with enrolment on the NIR, the youngest age group (birth to less than 2 years old) had significantly higher odds of being age-appropriately vaccinated with MMR compared to older age groups. In addition, UN region and number of dependent children were significantly associated with MMR vaccination status. Children from African and European UN regions were significantly more likely to be age-appropriately vaccinated compared to children from the Oceania region. Lastly, families with two or three dependent children had twice the odds of being age-appropriately vaccinated compared to families with one child.

Discussion

This national retrospective cohort study revealed that immunisation register enrolment and receipt of the MMR vaccine are suboptimal for overseas-born refugee children. While less than 1% of NZ children opt-off the NIR,[13] in this study, over one quarter (31%) of overseas-born refugee children did not have a record on the NIR, so their vaccination status is not able to be discerned. As mentioned, all refugees are encouraged to register with a general practice upon arrival for their vaccination status to be assessed and recorded on the NIR and be given an individualised immunisation catch-up programme.[11] Thus, these results likely reflect failures of NZ health services to engage in a timely fashion with overseas refugee families upon their arrival in NZ and/or a failure of the services to enrol these children on the NIR on engagement.

	In the NIR[a]	Total N	MMR[b] vaccination	Total n
	Yes[c] (%)		Fully vaccinated[d,e] (%)	
Total number in the cohort	1926 (69)	2796	573 (30)	1923
Visa category				
Convention refugee	132 (62)	213	27 (21)	132
Family reunification	69 (59)	117	21 (30)	69
Humanitarian	315 (63)	504	66 (21)	312
Overstayer	96 (64)	150	36 (38)	96
Quota refugee	1317 (73)	1815	426 (32)	1317
Age group at arrival				
0–<2 years	291 (97)	300	258 (89)	291
2–<6 years	513 (91)	561	240 (47)	516
6–<14 years	843 (63)	1329	66 (8)	843
14–<19 years	276 (46)	606	Added to 6–<14 years due to low numbers	
Arrival year				
2006	243 (70)	345	36 (15)	243
2007	270 (63)	432	57 (21)	270
2008	291 (65)	447	60 (20)	294
2009	276 (69)	402	87 (31)	279
2010	234 (67)	348	75 (32)	234
2011	246 (77)	321	84 (34)	246
2012	300 (72)	417	138 (46)	300
2013	48 (76)	63	24 (50)	48
United nations region				
Africa	294 (65)	456	72 (25)	294
America	171 (76)	225	39 (23)	171
Asia	1203 (71)	1704	390 (32)	1203
Europe	60 (65)	93	12 (20)	60
Oceania	156 (61)	258	42 (28)	153
Missing	45 (71)	63	15 (36)	42
Ethnicity[f]				
Asian	1083 (72)	1512	336 (31)	1083
Māori, European & Other	108 (67)	162	21 (20)	105
MELAA[g]	630 (67)	936	180 (29)	630
Pacific Peoples	108 (59)	183	36 (34)	105
Dependent children in family				
None	60 (44)	138	S (S)	60
One	366 (65)	567	90 (25)	366
Two	600 (71)	849	207 (35)	600
Three	450 (76)	591	141 (31)	450
Four or more	324 (69)	468	108 (33)	327
Missing	129 (68)	189	S (S)	129
Household income[h]				
Low	672 (74)	912	237 (35)	672
Medium	645 (69)	936	201 (31)	645
High	132 (62)	213	24 (18)	132
Missing	474 (64)	738	111 (23)	474
Parent education (usually mother)				
No reported qualification	738 (68)	1086	231 (31)	738
Overseas secondary qualification	401 (69)	579	132 (33)	402
NZ secondary qualification to diploma	312 (69)	453	78 (25)	312
Undergraduate degree	138 (74)	186	45 (33)	138
Postgraduate degree	36 (71)	51	12 (36)	33
Missing	300 (68)	444	75 (25)	300

(Table 1 continues on next page)

	In the NIR[a]	Total N	MMR[b] vaccination	Total n
	Yes[c] (%)		Fully vaccinated[d,e] (%)	
(Continued from previous page)				
Parent's ability to converse in English				
Yes	1110 (69)	1611	327 (30)	1110
No	738 (69)	1074	219 (30)	738
Missing	78 (70)	111	30 (39)	78
Family structure				
Couple	1419 (71)	2013	459 (32)	1419
Sole parent	468 (64)	726	102 (22)	468
Missing	39 (5)	783	12 (33)	36

*Note it is the policy of Statistics New Zealand that counts are randomly rounded to a number divisible by 3 to protect privacy; thus, the numbers may not reconcile precisely. [a]National Immunisation Register. [b]Measles, mumps and rubella vaccine. [c]Yes = child was enrolled on the National Immunisation Register by the end of the study period. [d]Vaccinated if child's age was ≥1 year and <5 years old and the child received at least one dose, or the child was ≥5 years and received two doses (MOH, 2020). Although children <1 year old are not eligible for MMR, we considered them to be age-appropriately vaccinated as they may have received a dose. [e]Vaccination status based on child's age at the end of the study period. [f]Ethnicity is self-reported by parents as per the National Health Index dataset and grouped according to Level 1 ethnic categories as per statistics New Zealand. [g]Middle Eastern, Latin American, or African. [h]Household income: Low (<$25,000), Medium ($25,001–$70,000), High ($70,001–$150,001 or more).

Table 1: **Demographic characteristics and enrolment on the National Immunisation Register of cohort of overseas-born refugee children (N = 2796) and age-appropriate measles, mumps and rubella vaccination status among a sub-cohort of children on the NIR (n = 1923).**

Of those enrolled on the NIR, less than one third (30%) of overseas-born refugee children had recorded age-appropriate MMR vaccination status. MMR coverage rates were highest among younger children and steadily increased over time for all age groups. The majority (89%) of children in the youngest age group (under 2 years old) had received their two MMR vaccines, which is just below the required 95% of immune people in the population to prevent a measles outbreak.[11] Amongst overseas-born children under 5 years old living in NZ with migrant or refugee backgrounds who were enrolled on the NIR, 69% were fully vaccinated on-time with two MMR vaccines.[17] International studies have also reported suboptimal immunisation coverage for schedule vaccines among children with refugee backgrounds, including asylum-seeking[26] and refugee children in Denmark,[27] and refugee children in Greece,[28] and UK-bound refugee children.[4] Moreover, studies have reported the influence of nativity for children and their parents with lower vaccination coverage rates among those that are born overseas.[2]

These findings highlight that health providers must appropriately engage, enrol, and assess the immunisation needs of overseas-born refugee children immediately upon their arrival and provide catch-up immunisations based on their age to align with the

Fig. 2: **Percent of overseas-born refugee children who are age-appropriately vaccinated with measles, mumps and rubella by age group and year of arrival.**

	In the NIR[a,c]		Age appropriately received MMR[b,d,e] vaccine	
	Unadjusted OR estimate (95% confidence range)	Adjusted OR estimate (95% confidence range)	Unadjusted OR estimate (95% confidence range)	Adjusted OR estimate (95% confidence range)
Visa category				
Quota refugee	REF	REF	REF	REF
Convention refugee	0.58 (0.42–0.79)	0.63 (0.40–1.01)	0.47 (0.31–0.73)	0.30 (0.12–0.74)*
Humanitarian	0.65 (0.52–0.81)	0.62 (0.41–0.94)*	0.5 (0.37–0.67)	0.41 (0.21–0.80)*
Overstayer	0.73 (0.49–1.08)	0.68 (0.32–1.45)	0.96 (0.63–1.48)	0.61 (0.19–1.89)
Family reunification	0.45 (0.30–0.67)*	0.38 (0.20–0.70)*	0.5 (0.29–0.87)	0.26 (0.08–0.78)*
Age group at arrival				
0–<2 years	2.2 (0.88–5.53)	2.11 (0.83–5.34)	7.94 (4.97–12.69)*	15.35 (8.59–27.4)*
2–<6 years	REF	REF	REF	REF
6–<14 years	0.12 (0.08–0.19)*	0.12 (0.08–0.19)*	0.05 (0.04–0.08)*	0.03 (0.02–0.05)*
14–19 years	0.05 (0.03–0.09)*	0.05 (0.03–0.08)*	0.009 (0.002–0.036)*	0.005 (0.001–0.02)*
Arrival year				
2006	REF	REF	REF	REF
2007	0.75 (0.54–1.05)	0.64 (0.39–1.06)	1.32 (0.84–2.1)	0.83 (0.35–1.96)
2008	0.81 (0.58–1.12)	1.14 (0.70–1.85)	1.2 (0.76–1.89)	1.84 (0.77–4.36)
2009	0.95 (0.68–1.34)	1.08 (0.65–1.78)	2.19 (1.43–3.37)	4.58 (1.96–10.74)*
2010	0.82 (0.58–1.16)	1.00 (0.60–1.68)	2.18 (1.41–3.37)	8.03 (3.33–19.36)*
2011	1.29 (0.90–1.86)	2.11 (1.21–3.68)*	2.67 (1.73–4.13)	9.87 (4.07–23.93)*
2012	1.07 (0.76–1.50)	1.70 (1.01–2.84)*	4.16 (2.76–6.27)*	20.17 (8.60–47.30)*
2013	1.40 (0.72–2.73)	1.55 (0.62–3.86)	4.43 (2.35–8.37)*	6.71 (1.96–22.97)*
United Nations region				
Oceania	REF	REF	REF	REF
Africa	1.13 (0.80–1.60)	1.60 (0.66–3.88)	0.89 (0.57–1.4)	7.65 (1.46–40.12)*
America	2.09 (1.36–3.21)*	1.79 (0.69–4.64)	1.06 (0.64–1.75)	1.28 (0.23–7.10)
Asia	1.57 (1.16–2.12)	0.91 (0.41–2.00)	1.54 (1.06–2.25)*	2.61 (0.60–11.36)
Europe	1.41 (0.82–2.44)	1.79 (0.56–5.77)	0.88 (0.44–1.75)	11.69 (1.30–105.4)*
Ethnicity[f]				
Māori, European & Other	REF	REF	REF	REF
Pacific Peoples	0.68 (0.42–1.11)	1.23 (0.39–3.88)	1.89 (0.99–3.60)	5.35 (0.64–44.63)
Asian	1.27 (0.87–1.87)*	1.99 (0.88–4.52)	2.21 (1.31–3.7)*	2.76 (0.60–12.75)
MELAA[g]	0.97 (0.66–1.43)	0.95 (0.44–2.03)	1.74 (1.02–2.98)	2.04 (0.47–8.87)
Dependent children in family[h]				
One	REF	REF	REF	REF
Two	1.35 (1.07–1.69)	0.95 (0.69–1.31)	1.74 (1.31–2.29)*	1.94 (1.10–3.43)*
Three	1.77 (1.37–2.29)*	1.32 (0.89–1.96)	1.7 (1.26–2.29)	1.94 (1.04–3.62)*
Four or more	1.26 (0.97–1.64)	0.83 (0.54–1.25)	1.62 (1.18–2.22)	1.47 (0.75–2.88)
Household income[i]				
High	REF	REF	REF	REF
Low	1.57 (1.12–2.20)*	1.16 (0.71–1.90)	2.58 (1.64–4.07)*	1.60 (0.67–3.82)
Medium	1.25 (0.90–1.76)	0.92 (0.57–1.47)	2.06 (1.3–3.26)	1.80 (0.78–4.13)
Parent education (usually mother)				
No reported qualification	REF	REF	REF	REF
Undergraduate degree	1.35 (0.93–1.96)	1.53 (0.88–2.64)	1.17 (0.81–1.71)	0.92 (0.43–1.94)
NZ secondary qualification to diploma	1.05 (0.81–1.36)	1.32 (0.90–1.94)	0.8 (0.6–1.08)	1.40 (0.76–2.56)
Overseas secondary qualification	1.11 (0.88–1.40)	1.07 (0.75–1.54)	1.13 (0.88–1.45)	0.96 (0.57–1.60)
Postgraduate degree	1.06 (0.55–2.05)	0.87 (0.36–2.11)	1.16 (0.57–2.33)	2.81 (0.77–10.21)
Parent's ability to converse in English				
Yes	REF	REF	REF	REF
No	0.94 (0.79–1.13)	0.95 (0.70–1.31)	1.03 (0.84–1.26)	1.44 (0.90–2.32)

(Table 2 continues on next page)

	In the NIR[a,c]		Age appropriately received MMR[b,d,e] vaccine	
	Unadjusted OR estimate (95% confidence range)	Adjusted OR estimate (95% confidence range)	Unadjusted OR estimate (95% confidence range)	Adjusted OR estimate (95% confidence range)
(Continued from previous page)				
Family structure				
Sole parent	REF	REF	REF	REF
Couple	1.33 (1.10–1.62)*	1.14 (0.83–1.57)	1.78 (1.4–2.26)*	1.23 (0.72–2.11)

*p-value < 0.05. [a]National Immunisation Register. [b]Yes = child was enrolled on the National Immunisation Register by the end of the study period. [c]Measles, mumps and rubella vaccine. [d]Vaccinated if child's age was ≥1 year and <5 years old and the child received at least one dose, or the child was ≥5 years and received two doses (MOH, 2020). Although children <1 year old are not eligible for MMR, we considered them to be age-appropriately vaccinated as they may have received a dose. [e]Vaccination status based on child's age at the end of the study period. [f]Ethnicity is self-reported by parents as per the National Health Index dataset and grouped according to Level 1 ethnic categories as per Statistics New Zealand. [g]Middle Eastern, Latin American, or African. [h]The 'none' group has been removed from the modelling as they are likely to be young adults at the end of the study period who filled out the Census and thus are inconsistent with the rest of the cohort who were dependent children. [i]Household income: Low (<$25,000), Medium ($25,001–$70,000), High ($70,001–$150,001 or more).

Table 2: **Univariate and multivariable logistic regression estimates for enrolment on the National Immunisation Register and age-appropriate measles, mumps and rubella vaccination status by demographic characteristics (n = 2796).**

NIS[11] and provide optimal protection against VPDs. However, the suboptimal MMR coverage rates recorded in the NIR may underestimate actual coverage. Some overseas-born children may have received measles-containing vaccines in their country of origin or while transiting and these may not have been accurately recorded in the NIR because they are not a component of the NZ schedule. While the NIR data is generally accurate amongst the general NZ population, especially for schedule vaccines, the challenges of entering overseas vaccination records may account for some discrepancies.[29]

Determinants of NIR enrolment and MMR coverage

This study revealed that both NIR enrolment and MMR coverage rates were significantly associated with age, year of arrival, and visa category. Children who arrived later in the study period were more likely to be enrolled and be age-appropriately vaccinated with MMR than children who arrived at the start of the study. This likely reflects the concerted efforts that have been ongoing for the past two decades to improve immunisation coverage and reduce inequities in NZ.[25]

Older refugee children were less likely to be enrolled on the register and receive MMR vaccination. Similarly, a Danish study among asylum seeking children reported that younger children were more likely to be vaccinated compared to older children.[26] Also, UK-bound refugee children were more likely to have recorded vaccinations compared to adolescent and adult refugees.[4] There are notable barriers to improving vaccination coverage among adolescents, including lack of health provider recommendations, parental vaccine refusal, vaccine misinformation available on the Internet and social media platforms, and financial difficulties.[30] A systematic review and meta-analysis noted that educational interventions, reminders, interventions for providers, financial incentives, and multilevel interventions may improve vaccination coverage for school-aged children and adolescents (5–19 years old) in high-income countries.[31] Adolescent refugees who resettle in high-income countries have complex healthcare needs that reflect their migration journeys[32]; thus, future research is needed to understand which interventions are particularly feasible and effective for improving vaccination coverage among adolescent refugees. For optimum NZ wide protection against a measles epidemic, an integrated approach is likely needed to improve vaccination coverage for older children and adolescents with refugee backgrounds.

Children arriving on other refugee pathways were less likely to be enrolled and vaccinated compared to quota refugee children. A Danish study reported that quota refugees had lower vaccination uptake compared to asylum seeking children.[27] This discrepancy may be explained by NZ's unique quota refugee programme that involves an orientation and health screening programme in which vaccination status is assessed and age-appropriate vaccines are offered at the Mangere Refugee Resettlement Centre.[21,22] Moreover, only quota refugees are included in the RSS and receive support to register with primary care services in the community after leaving the Mangere Refugee Resettlement Centre.[18] Given NZ's commitment to increase the quota, it is planned for this orientation programme to be reduced, and screening and immunisations will now be delivered offshore as part of the new refugee quota health service delivery model.[18] Seamless flow of refugees' immunisation records from offshore to national databases will be essential, otherwise the apparent gains here from early engagement will be lost. Refugees entering via other pathways are not entitled to the same health screening and orientation programme and this has likely contributed to immunisation inequities and inadequate population protection against VPDs.

Previous literature has noted various factors that influence immunisation coverage among people with migrant backgrounds[2,5]; however, most of these were not significant factors in the presented study. For instance, although language has been identified as a

barrier to accessing preventive health services, parent's ability to converse in English was not a significant factor influencing enrolment or MMR vaccination status. Thus, further research is needed to understand the complex interplay of factors underpinning former refugee families' engagement with immunisation services and vaccination coverage.

Implications for policy and practice

So long as there are immunisation inequities within a population, achieving population wide protection against VPDs will not be attainable. There is a continued need for providers to engage with refugee families upon their arrival to assess vaccination records and start catch-up immunisations. Tailored interventions to improve vaccine access and acceptance among refugees are needed that address commonly identified barriers and are sensitive to the heterogeneity within and between migrant and refugee populations.[33] Barriers that contribute to migrants' and refugees' underutilisation of healthcare services are well documented in high-income countries[34–37]; thus, as immunisation services are a part of primary healthcare services, concerted efforts to reduce these disparities are needed. High-income countries that welcome migrants and refugees, such as NZ, are becoming increasingly diverse and as such, health care systems and policies must be increasingly migrant-sensitive to address their health needs.[38] Keeping in mind the WHO's IA2030 focus on equitable vaccination coverage across the life-course,[6] approaches to improve engagement and coverage amongst refugee adolescents is imperative. There are clear immunisation inequities based on refugee visa category, which highlight the need for health services to be equitable for all refugees.[17,39] The current RSS only applies to quota refugees although there is an intention that it will apply to all refugees in the future.[18] An initial first step would be to honour this commitment and include all refugees in the RSS so that all refugees are entitled to the same health and support services. The proportion of overseas-born refugee children who were not enrolled on the NIR and the potential inaccurate recording of overseas vaccines warrants urgent attention. Accurate immunisation register data will be vital to identify and respond with appropriate and timely services.

Strengths and limitations

NZ's unique data collection and linking capabilities within the IDI enabled the presented analyses of NIR enrolment and vaccination coverage among refugee children. The presented findings may be relevant to other marginalised migrant groups resettled in high-income countries. However, as our findings demonstrate immunisation inequities by visa category, future studies should explore the role of different entry pathways and entitlement to health services on vaccination coverage amongst migrant groups. A few assumptions were made as the existing administrative data was used for a purpose other than its original one. It was not possible to control the variables or the value categories available, which may introduce some inaccuracies. Moreover, the analyses were limited to those that had completed the 2013 Census and some categories had small numbers that had to be suppressed thereby limiting the conclusion that can be made. Our cohort includes children from the same family and our logistic model did not adjust for clustering by family, so the confidence limits will slightly underestimate variability in our cohort. Whilst a large proportion of refugee children were missing Census 2013 data (60%) from the total cohort, there were still substantial numbers of children representing those in the outcome groups of interest (i.e., not in the NIR and not vaccinated with MMR) (Supplementary Table S2). We acknowledge that the drivers may be different for the children who were not recorded on the register and unvaccinated, and do not have Census 2013 data available. Lastly, our presented analyses focused on children with refugee backgrounds who had administrative data available in the IDI. Future research should focus on other groups of marginalised children, such as undocumented migrants, to ensure all children have equitable access to vaccines, no matter their migration background.

Conclusion

Despite the availability of publicly funded vaccines, overseas-born refugee children have suboptimal immunisation register enrolment and MMR vaccination coverage. Significant disparities were found between different groups of refugee-background children. Tailored and targeted interventions are required by immunisation service providers to engage with former refugee families post-resettlement to ensure age-appropriate vaccines are offered in a timely manner, particularly for older children and adolescents. A priority is to ensure all refugees are entitled to the same health and support services to reduce inequities between refugees who arrive on different pathways.

Contributors

All authors designed the study. NC did the initial literature reviews, and developed the study plan. JP linked and analysed the data. All authors contributed to the analysis and interpreted the results. NC drafted the initial manuscript, and JP and NT revised the manuscript critically for intellectual content and gave final approval.

Data sharing statement

Summary Statistics New Zealand Security Statement – This study is based on the integration of anonymised population census data from Statistics New Zealand and mortality data from the New Zealand Health Information Service. This project was approved by Statistics New Zealand as a Data Laboratory project under the Microdata Access Protocols in 1997. The datasets created by the integration process are covered by the Statistics Act 1975 and can be used for statistical purposes only. Only approved researchers who have signed Statistics New Zealand's declaration of secrecy can access the integrated data in the

Data Laboratory. For further information about confidentiality matters in regard to this study please contact Statistics New Zealand.

Declaration of interests

The authors have no potential conflict of interest to report.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.lanwpc.2023.100709.

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