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Migration and Infant Immunization Timeliness in New Zealand: Evidence from the Growing Up in New Zealand Study

Immunization is widely recognized as one of the most cost-effective methods for preventing infectious diseases [1], [2], especially among young children. This age group is particularly vulnerable to severe diseases caused by vaccine-preventable infections and also plays a significant role in the spread of infections through households and communities.

Vaccine coverage is used as a measure to estimate the potential population protection offered by an immunization program. However, it is important to note that high coverage for individual vaccines may still be insufficient to fully prevent diseases [3]-[5]. In fact, when it comes to preventing diseases in young children, the *timeliness* of vaccine receipt is a key factor [6]-[8].

Outbreaks of vaccine-preventable diseases can occur if a sufficient proportion of the population does not receive *timely* vaccination, even if the overall population coverage rates are high [6], [8].

Timeliness of vaccination is particularly important for the primary infant vaccine series and serves as a key indicator of health care system performance and the accessibility of health services across different sectors of the community.

Studies conducted in developed countries have highlighted migration as an important determinant of child health outcomes, including childhood vaccination status [1], [9], [10]. Children from immigrant families are often at an elevated risk of not being adequately immunized [1], [11]-[13], leaving them more susceptible to vaccine-preventable diseases [14]-[16].

Barriers to immunization for migrant children encompass various factors, including differences in healthcare systems between the source and destination countries [17], language proficiency, cultural differences, and financial constraints [18], [19]. Recent immigrants encounter additional challenges as catch-up immunization may be overlooked upon arrival due to competing settlement

24 priorities. Additionally, during the early stage of settlement, there may be missed opportunities to
25 complete immunization schedules on time [20]. These challenges place children of recent
26 immigrants at an elevated risk of not being fully immunized or immunized on time [9], [20].

27 Lower rates of timely vaccination among children of foreign-born parents compared with children
28 of native-born parents has been documented previously [9], [23]. However, the evidence remains
29 inconclusive, as some studies have reported no significant association between parental migration
30 and children's timely vaccination [21], [22], while others have found that children of foreign-born
31 parents were more likely to be immunized than children of native-born parents [23]-[25].

32 These discrepancies in studies of immigrant children may arise from differences in how children's
33 migration status is defined. While some studies classify foreign-born children as migrant children
34 [26], [27], others include children born in the host country to migrant parents [26]-[29]. The
35 variation in definitions can lead to differences in the composition of study populations and may
36 influence the interpretation of findings.

37 An example of such research conducted in New Zealand (NZ) investigated differences in age-
38 appropriate immunization coverage rates among children with and without migrant backgrounds.
39 The study found that foreign-born children had lower recorded age-appropriate vaccination rates
40 for all vaccines included in the NZ National Immunization Schedule compared with NZ-born
41 children from migrant or non-migrant families [11]. Utilizing data from the NZ National
42 Immunization Register (NIR), this study provided valuable insights into immunization inequities
43 particularly for foreign-born children. However, it is important to note some limitations of the
44 study. For example, less than half (45%) of foreign-born children had an immunization record in
45 the NIR dataset compared to ~ 95% of NZ-born children with or without a migration background.
46 This significant disparity highlights potential concerns about the completeness of vaccination data

for foreign-born children in the NIR. Moreover, difficulties in translating immunization schedules from the origin countries of migrants who vaccinated their children in their home country may contribute to inaccuracies in recording, potentially leading to an underestimation of migrant children's vaccination coverage. Such speculation is supported by another published research using the same sample/datasets [26], which found significantly lower hospitalization rates among foreign-born children compared with NZ-born non-migrant children for a wide range of vaccine-preventable diseases. Further research is warranted to explore and confirm these contradictory findings and to address the immunization inequalities among migrant children in New Zealand. New Zealand has an estimated 25.2% of the resident population born overseas. Additionally, there has been a significant increase in the immigrant population, including children, over the last decade [30]. While vaccine coverage and timeliness disparities by ethnicity in NZ have been described [31], little is known about the role of parental migration status on child health outcomes, such as childhood immunization in NZ.

Understanding the health-related behaviors of this group is of paramount importance to both medical and public health professionals. This information is of particular importance as rates of immunizations for many infectious diseases, across various age groups, are declining in NZ. Additionally, some preventable diseases, such as measles and pertussis, continue to cause serious outbreaks, morbidity, and mortality [31]. Furthermore, immunization timeliness remains suboptimal, with delays in the receipt of scheduled immunizations continuing to limit the potential benefits that immunization could offer to population health in NZ [7], [20], [32].

Identifying groups with lower immunization uptake or untimely vaccination, as well as the factors associated with their immunization outcomes, is imperative for the success of immunization programs and the efficient allocation of public health resources [33].

To date, most studies in this field have primarily categorized children into two groups: migrant and non-migrant [11]. However, data from some studies [21], [34] suggest that a more refined stratification of the immigrant population into settled and recent immigrants could provide a more nuanced understanding of the impact of migration-related factors on the immunization status of immigrant children. By distinguishing between settled immigrants, who have resided in the host country for an extended period, and recent immigrants, who have arrived more recently, researchers can better assess the temporal aspects of migration and their influence on vaccination outcomes.

Furthermore, most of the research in this field has been predominantly focused on the role of mother's migration status on children's health outcomes. However, there is a paucity of research investigating how father's migration status might be influencing children's outcomes.

Current study

Using data from a large, representative population-based cohort study in NZ, the present research aims to: a) explore disparities in vaccination timeliness among NZ-born children from immigrant and non-immigrant families; b) examine the role of residential duration of immigrant families on children's vaccination timeliness; c) investigate whether maternal versus paternal migration status has a different impact on child vaccination timeliness; and d) describe the differences in vaccination timeliness between children of one and two foreign-born parents versus children of two native-born parents.

Methods

Participants

The data used in this study was taken from the Growing Up in New Zealand (GUiNZ) study, the largest contemporary longitudinal study of child development in NZ. The GUiNZ study has been designed and conducted by a team of researchers led by the University of Auckland. Detailed information regarding the study's design, conceptual framework, and recruitment procedures can be found elsewhere [35], [36]. A total of 6,822 pregnant women with an estimated delivery date between April 2009 and March 2010 were recruited from the Auckland, Counties Manukau, and Waikato District Health Board regions of NZ.

All participating women provided written informed consent. Partners were enrolled if the enrolled women provided consent for their participation. A total of 4,404 partners were enrolled in the study.

The child cohort (n=6853) comprised ~ 11% of births in NZ during the recruitment period. The characteristics of the cohort at birth generally aligned with the national birth cohort in NZ from 2007 to 2010 [36]. Ethical approval for the study was granted by the NZ Ministry of Health Northern Y Regional Ethics Committee (NTY/08106/055).

The current study utilizes data collected during the first data collection wave (antenatal) from the nine data collection waves conducted between 2009 and 2022. The antenatal data was linked with the National Immunization Register (NIR) dataset, a process carried out by the study team (the linkage between the child's unique identifier and NIR had been previously conducted by the GUiNZ team). Data collection waves used face-to-face and phone interviews to gather information. The antenatal interview was completed separately for mothers and partners. To avoid dependent observations, only one cohort child from each family was included in our analyses. As a result, the data for second-order children of 93 multiple births were deleted. Additionally, data

for a further 430 children were deleted due to not having any NIR data for linkage. The data for another 143 children were also deleted because their mothers or caregivers did not provide consent to collect data from external health agencies. This resulted in a final sample size of 6,156 children and their parents for this study.

Measures

The main outcome of interest

Each child's immunization record was obtained via each child's National Health Index (NHI) number linked with the NIR. The NHI number is a unique identifier assigned to every person having contact with health services in NZ [37]. Over the time the cohort was born, the infant immunization schedule included doses at 6-week, 3-month, and 5-month for two vaccines: a diphtheria/tetanus/acellular pertussis/*Haemophilus influenzae* type B/hepatitis B/poliovirus vaccine and a pneumococcal conjugate vaccine [37]. We refer to the three doses of these two vaccines as all six doses of vaccines in this paper.

Timely immunization was defined as vaccinations received within 30 days of their due date [38]. This definition has been previously used in the United States and Australia [39]. The estimate of immunization timeliness utilizing this method for the GUiNZ cohort (70%) closely mirrors the NZ's national immunization coverage at six months of age (71%), thereby confirming the validity of this measure [7].

Main exposure of interest

Immigration status

All children included in the study cohort were born in NZ. Immigrant children were identified based on parental immigration status rather than the children's immigration status. Recent versus

settled immigrants were identified based on maternal residential duration. Recent immigrants were identified as mothers residing in NZ for less than five years at the time of antenatal data collection wave, while settled immigrants were identified as mothers who had been residing in the country for more than five years at the time of the antenatal data collection wave. This five-year residency benchmark was chosen following the guidelines of the NZ Ministry of Business, Innovation & Employment to differentiate between recent and settled immigrants [40]. Repeating the analyses with different criteria to define recent and settled immigrants (less than three years versus more than three years) yielded similar results.

Sociodemographic characteristics

Potential covariates for inclusion in multivariable analyses were selected based on prior research on factors associated with immunization timeliness in New Zealand [7], [8] and included: maternal age at pregnancy, maternal education (categorized into four groups: no secondary school, secondary school, diploma/trade, tertiary), household crowding index group [41] (classified into three categories: low [less than one person per bedroom], medium [one to less than two people per bedroom], and high [two or more people per bedroom] crowding score), language spoken at home (English, non-English), household annual income groups (categorized into three categories: < \$50K, \$50-\$70K, > \$70K), receipt of income tested benefit (yes/no), and area-level deprivation index (NZDep2006).

The NZDep2006 index of deprivation was used to measure neighborhood area deprivation [42]. This index is derived from the household geographical location and is measured at the meshblock level, which is the smallest census tract unit. It combines census data from 2006 relating to various factors including income, home ownership, employment, qualifications, family structure, housing,

and access to transport and communications [42]. The index scores are organized into deciles, with decile one representing the least deprived 10% of areas in NZ, and decile 10 indicating the most deprived 10% of areas. For the current analysis, deprivation scores were categorized into three groups: low deprivation (deciles 1 to 3), medium deprivation (deciles 4 to 7), and high deprivation areas (deciles 8 to 10).

Analytical procedures

All analyses were conducted using Stata 14.2 [43]. Sociodemographic characteristics of the whole sample and stratified by maternal immigration status (immigrant versus non-immigrant), and maternal residential duration in NZ (recent versus settled immigrants) are presented in **Table 1**.

The prevalence rate of timely immunization of all studied vaccines (all doses of six-week, three-month, five-month vaccines, and all six doses of studied vaccines) for the overall sample and by maternal migration status and maternal residential duration in NZ are presented in **Table 3**. The same analyses were repeated for paternal immigration status (foreign-born father vs NZ-born father) and one and two foreign-born parents versus two NZ-born parents (**Table 3**).

Distribution of infant timely vaccination across sociodemographic factors are presented in **Supplementary Table 1**.

Chi-square tests were used to assess the associations between sociodemographic variables and maternal migration status and residential duration in NZ (**Table 1**). Similarly, chi-square tests were employed to examine the associations between sociodemographic variables and infant immunization timeliness (**Table 2**).

The bivariate associations between maternal immigration status, maternal residential duration, and infant vaccination timeliness at age six-week, three-month, and five-month were also examined

using univariate logistic regression models with results presented as unadjusted odds ratios (ORs) with 95% confidence intervals (CIs) (**Table 4**).

Then, to determine if the noted differences in the prevalence rates of timely infant vaccination between children of immigrant and non-immigrant families found in the univariate analyses remained significant after controlling for sociodemographic characteristics, the following steps were taken:

First, the bivariate association between each sociodemographic characteristic and infant vaccination status (timeliness) at age 6-weeks, three-months, and five-months (timely or not) was explored using univariate logistic regression models with results presented as unadjusted odds ratios (ORs) with 95% CIs (**Table 2**).

Second, multivariable logistic regression analyses were conducted, with maternal immigration status and sociodemographic characteristics included as exposures and infant vaccination status as the outcome variable. The results were presented as adjusted odds ratios (AOR) with 95% CIs. The same analyses were repeated with maternal residential duration as the main exposure variable (**Table 4**). Due to the high correlation between the “language spoken at home” variable and the main exposure variable (immigration status), “language spoken at home” was excluded from the multivariable regression analyses.

Results

Sociodemographic characteristics of the study sample by maternal immigration status and maternal residential duration

The study sample consisted of 6,156 mothers, of whom 36.4% (2,241) were born outside NZ. Among foreign-born mothers, 43.2% had attained tertiary education, compared to 35.6% of NZ-born mothers. There was a larger proportion of mothers aged less than 20 years in the NZ-born group compared to the foreign-born group (6.6% versus 1.8% respectively). Additionally, a larger proportion of foreign-born mothers (42.5%) resided in highly deprived areas compared to NZ-born mothers (36.7%). Over half of the foreign-born mothers (51.7%) lived in households with an income exceeding \$70k, in contrast to 64.6% of NZ-born mothers (**Table 1**).

Moreover, a higher proportion of foreign-born mothers lived in crowded households compared to NZ-born mothers (21.6% versus 10.1% respectively) and a larger proportion reported speaking a language other than English at home compared to NZ-born mothers (52% versus 2.4% respectively) (**Table 1**).

No significant differences were found between recent and settled immigrants regarding maternal education levels and household deprivation index. However, a higher proportion of recent immigrants were residing in crowded households compared to settled immigrants (24.6% versus 19.2% respectively). Conversely, a smaller proportion of recent immigrants lived in households with incomes exceeding \$70k, compared to settled immigrants (43.8% versus 57.5%, respectively), and a smaller proportion of recent immigrants reported receiving an income tested benefit compared to settled immigrants (7% versus 12.4%, respectively) (**Table 1**).

A smaller proportion of recent immigrants (37%) reported speaking a language other than English at home, compared to settled immigrants (55%) (**Table 1**).

Insert Table 1 here

Association between sociodemographic factors and infant timely vaccination

Maternal age at pregnancy was not found to be associated with timely infant vaccination at any time point. However, all indicators of higher socio-economic status among mothers, including attaining some level of education, having a household income exceeding \$70K, residing in less deprived areas, living in a household with low to medium crowding scores, or not receiving an income tested benefit, were significantly associated with increased odds of infant vaccinations being received on time. Additionally, speaking a language other than English was associated with an increased odd of timely infant vaccination (**Table 2**).

Insert Table 2 here

Prevalence of timely completion of infant vaccinations by maternal immigration status

A larger proportion of children born to foreign-born mothers had timely receipt of all six-week, three-month, and five-month vaccine series as well as all six doses of vaccines, with rates ranging from 95.9% to 85.8%, compared to children of NZ-born mothers, where rates ranged from 91.4% to 79.8% for the same vaccine series (**Table 3**).

A larger proportion of children born to recent immigrants achieved timely completion of all six-week, three-month, and five-month vaccine series, as well as all six doses of vaccines, compared to children of settled immigrants (**Table 3**).

For all child groups, the proportion of timely receipt of age-specific vaccines decreased with increasing infant age, from the six-week to the 5-month vaccinations. The largest decrease was observed for infants of foreign-born mothers who had resided in the country for more than five years (settled immigrants), with a difference of 12.2 percentage points between their timely completion rate for six-week and 5-month doses (95.5% and 83.3% respectively). However, their counterparts who resided in the country for less than five years (recent immigrants) experienced

the smallest decrease, with a difference of 7.5 percentage points from six weeks to five months (96.5% and 89.0% respectively) (**Table 3**).

Insert Table 3 here

Maternal migration status and infant vaccination timeliness

The results of bivariate logistic regressions (**Table 4**) were consistent with those presented in **Table 3**, indicating that children of foreign-born mothers had higher odds of being vaccinated on time compared to children of NZ-born mothers. Unadjusted odds ratios ranged from 2.22 to 1.46 for all doses of vaccines from six weeks to five months of age.

The results of multivariable logistic regressions indicated that after controlling for socio-demographic differences between immigrant and non-immigrant families, the odds of receiving all doses of vaccines on time increased and remained significant (adjusted odds ratios ranging from 2.55 to 1.54 for all doses of vaccines from age six weeks to 5 months). A steady decrease in the magnitude of both unadjusted and adjusted odds ratios with increasing infant age was observed, indicating that the gap in child vaccination timeliness narrowed between immigrant and non-immigrant groups as children aged. However, by the age of five months, differences were still statistically significant, with children of immigrants having higher odds of receiving the 5-month vaccine doses on time (**Table 4**).

Insert table 4 here

Maternal residential duration and infant vaccination timeliness

The children of recent immigrants had increased odds of being vaccinated on time compared with children of settled immigrants. The only exception was for the 6-week vaccine series where odds

ratios did not reach significance. After adjusting for socio-demographic characteristics, children of recent immigrants had increased odds of receiving the three-month and five-month vaccine doses on time compared to those of settled immigrants (AOR=1.52, 95%CI 1.05-2.22 and AOR=1.72, 95%CI 1.28-2.33 respectively) (**Table 4**).

The impact of paternal immigration status and having both foreign-born parents on infant vaccination timeliness

Having a foreign-born father was associated with identical timeliness rates of all vaccination series compared to those with a foreign-born mother (83 versus 83%). Additionally, having a foreign-born father was positively and significantly associated with timely completion of all six doses of vaccines (83% versus 80% among children with a NZ-born father, $p<0.001$). Moreover, children with both parents born overseas had the highest rates of timely vaccination for all six doses of vaccines (85.2%), followed by those with one foreign-born parent (82.1%). Conversely, children with both parents born in NZ had the lowest rates of timely vaccination for all six doses of vaccines (79.3%). (**Table 3**).

Discussion

The study utilized data from a large representative population-based study in NZ to investigate the impact of parental migration status and residential duration on the timely vaccination of infants. The findings revealed that even after accounting for sociodemographic variations, infants born to foreign-born parents were more likely to receive vaccination on schedule compared to those born to native-born parents. Moreover, the findings showed that infants of recent immigrants, who had lived in NZ for less than five years, had higher odds of receiving timely vaccinations compared to

infants of settled immigrants who had been residing in the country for five years or longer. These findings underscore the importance of considering migration status and residential duration when designing interventions to promote timely vaccination among infants in diverse populations.

Timely infant vaccination among children of immigrant and non-immigrant families

Our findings indicated that regardless of residential duration, infants with foreign-born mothers were more likely to have timely receipt of the six week, three-month, and five-month vaccinations as well as for all six doses of studied vaccines, compared to infants with native-born mothers. The same pattern was observed for infants with foreign-born fathers. Furthermore, infants with two immigrant parents demonstrated higher odds of receiving timely vaccinations for all scheduled vaccines compared to children with two native-born parents.

These findings align with several US-based studies [23]-[25] which similarly found that children of foreign-born parents, particularly those originating from African countries (excluding Somalia), Central and South America and the Caribbean, Mexico, or India, exhibited higher rates of immunization compared to children of US-born parents. However, it is worth noting that our findings contrast with certain other US studies [9], [23] that reported children of foreign-born parents were less likely to be vaccinated on time compared to children of native-born parents.

Differences in the composition of immigrant samples, such as inclusion of foreign-born children who may have been vaccinated overseas, into immigrant categories in some studies but not in others might have contributed to the noted inconsistencies between studies. Inclusion of such children within the immigrant category might result in underestimation of their true vaccination records due to factors such as insufficient documentation of vaccines or memory effects [11], [25], [44]. Such nuances highlight the importance of carefully considering sample composition when interpreting and comparing findings across studies.

Moreover, even after accounting for socio-demographic factors linked to children's timely vaccination, our findings indicate that children from immigrant families had higher odds of receiving vaccinations on schedule, despite the economic disadvantages often faced by immigrant families compared to non-immigrant families. This suggests the existence of potentially significant factors beyond economic barriers that contribute to the timely vaccination of children from immigrant backgrounds. To gain deeper insights into these dynamics, qualitative and in-depth research is warranted. Such research could shed light on the specific mechanisms and strategies employed by immigrant families to overcome economic barriers and ensure their children receive vaccinations on time.

The findings from this study challenge the common notion that immigration universally disrupts immigrants' access to health resources and influences their health seeking behaviors negatively. However, many demographers agree that individuals and families utilize migration as a strategy to enhance their economic [45], social [46], and cultural [47] circumstances in ways that will benefit their own and their children's well-being [48]. In this context, higher rates of timely vaccination observed among children of immigrants in the current study seems plausible, as timely immunization is recognized as a means of enhancing health conditions. This suggests that immigrant families may prioritize health-related behaviors, such as timely vaccination, as part of their efforts to improve their overall quality of life following migration.

A selection effect could also have contributed to the favorable outcomes for immigrant subgroups. It is possible that individuals who migrate are predisposed to good health or are able to demonstrate that they "have an acceptable standard of health", which may increase their likelihood of migrating [49]. Consequently, such individuals may be more inclined to seek and secure vaccinations for their children [50]. In line with this notion, research has indicated that immigrant women are often

characterized by greater motivation, higher aspirations, and stronger intentions compared to their non-immigrant counterparts—factors that could potentially enhance their children’s likelihood of timely vaccination [51].

Another plausible explanation for the higher rates of timely vaccination among immigrants could be attributed to disparities between health systems, immunization policies, and attitudes towards children’s vaccination in the country of origin versus the host country. Immigrants originating from countries where child vaccination is compulsory or culturally emphasized, may carry over these practices and attitudes when they migrate, even if vaccination is not compulsory in the host country, as is the case in NZ.

Recent versus settled immigrants

A finer stratification of immigrants into two exclusive sub-groups, based on their length of residential tenure, revealed that after adjustment for socio-demographic factors, children of recent immigrants who had resided in the country for less than five years exhibited a higher likelihood of receiving timely vaccination compared to children of settled immigrants who had been in the country for five or more years at the time of data collection. This finding holds significance as recent immigrant families tended to have a lower socio-economic status compared to settled immigrants. Despite these socio-economic disadvantages, their children displayed a higher likelihood of timely vaccination. This finding aligns with a study conducted in NZ [26] which revealed that hospitalization rates for a wide range of vaccine preventable disease were significantly lower among children from recent immigrant families compared to children from families without recent migration backgrounds.

Immigrants are known to be less integrated residents and to have competing needs, particularly during the early years following immigration, which might hinder their health seeking behaviors, consequently putting their children at elevated risk of not being fully or timely vaccinated. Indeed, some previous studies indicate that children born to mothers who recently migrated to the USA were at higher risk of not being adequately immunized compared with more settled immigrants [9].

However, recent immigrants are also generally known to be highly motivated, receptive to change, and possess greater social and cultural capital, factors that can to somewhat counteract the lack of social integration in the new country [51] and enhance their health outcomes and health seeking behaviors. This well-documented phenomena is known as the “immigrant paradox” [52], [53]. By analyzing data on recent and established immigrants, as well as data on first- and subsequent-generation immigrants, researchers have found that recent immigrants often outperform more established immigrants and non-immigrants on various health, education, and conduct or crime-related outcomes, despite the numerous barriers they face to successful social integration [54], [55].

Length of stay, which along with language proficiency has been used as a measure of acculturation in some studies [56], could potentially facilitate immigrants’ access to and uptake of primary care and preventive services such as vaccination. However, there is evidence suggesting that acculturation could come with a cost. For example, immigrants often experience a decline in health status as their years in the host community increase [57]. In the context of the current research, lower timely vaccination rates among children of settled immigrants could be due to the fact that the longer immigrant families live in NZ, the more likely they are to come into contact with vaccine-refusing parents. Although the majority of New Zealanders consistently exhibit strong

vaccine confidence, a considerable proportion shows steadily decreasing confidence over time [58].

It is also possible that as the English fluency of immigrant families improves, they become more exposed to anti-vaccine rhetoric through English-speaking media. In this scenario, increased acculturation, indicated by longer residential duration and better language proficiency, could lead to more extensive or prolonged exposure to discouraging information about vaccination. Consequently, this heightened exposure may contribute to lower rates of timely vaccination among settled immigrants.

Similarly, the higher likelihood of timely vaccination among children of recent immigrants may stem from their shorter exposure to vaccine-discouraging information received from peers or media, as well as the ambiguity created by such information. This explanation aligns with the findings of a study conducted in the USA, which revealed that childhood vaccination coverage was lower in more acculturated Latino families compared to less acculturated Latino families [59], [60]. Additionally, another US-based study found that Hispanic girls residing in predominantly Hispanic neighborhoods were more likely to be vaccinated against human papillomavirus compared to Hispanic girls residing in predominantly white neighborhoods [61].

Strengths and Limitations

One of the strengths of this study is its novelty in the New Zealand context. To date, few NZ studies have explored the impact of parental migration status on children's vaccination outcomes [11]. This study builds upon previous work by utilizing a large, nationally representative sample of children and their families to examine timely vaccination disparities among children of immigrant and non-immigrant families in NZ. Additionally, the study investigates the impact of

residential duration on children's immunization timeliness, contributing to a deeper understanding of vaccination patterns within immigrant populations.

This is unique internationally, as most previous research has examined the effects of parental migration on children's immunization coverage, but little research has been conducted on immunization timeliness among immigrant sub-populations. Another important strength of this study is the utilization of administrative data from the NIR, which was linked with large, representative survey data. This integration allowed for a comprehensive analysis of vaccination patterns and their timeliness among immigrant families, providing valuable insights into the dynamics of immunization within these populations.

Another study strength is the inclusion of the migration status of the mother, father and both parents in the analyses as it provides more nuanced understanding of the impact of parental nativity on children's outcomes. Future studies could extend this work by exploring factors that enable immigrant families, and particularly recent immigrant families, to overcome barriers (such as economic disadvantages) and vaccinate their children on time.

Future studies could also extend this work by exploring disparities in parental vaccination intention during pregnancy among immigrant and non-immigrant families to see if the observed differences in children's vaccination outcomes are due to the initial parental vaccination intentions or are driven by barriers in accessing vaccination services.

Moreover, in this paper, we deliberately refrain from exploring the characteristics of the most common countries of origin from which people migrate to NZ as a factor influencing immunization outcomes. While acknowledging potential differences in health systems, immunization policies, and attitudes towards children's vaccination between countries of origin and the host country, our focus remained on understanding how migration status itself impacts timely vaccination rates. This

deliberate choice enabled us to offer a thorough examination of the influence of migration on immunization outcomes, without confounding factors related to specific countries of origin. Future research may explore country-level factors in greater detail to enrich our understanding of immunization disparities among migrant sub-populations.

This study is subject to several limitations. Due to the study design (observational) and the correlational nature of the analyses, a causal link between the parental migration status and children's timely immunization cannot be inferred. Other limitations include that we did not investigate the relationship of the immigrant families with primary health care in NZ nor with their exposure to discrimination.

Also, we were unable to identify asylum seekers and refugees due to the unavailability of data on visa types in the GUINZ dataset. This is important given that previous studies have shown that refugees are at a particular disadvantage when it comes to successful resettlement in the host society, which could be translated into poorer vaccination outcomes for their children [11], [62].

Conclusion

Our study findings revealed that children of immigrant parents, identified based on both maternal and paternal migration status, in NZ demonstrated a higher likelihood of receiving timely immunization compared to children of non-immigrant parents. This suggests that immigrant groups could play a vital role in promoting vaccination and informing public health programs on strategies to ensure timely vaccine administration for all children.

However, prolonged residency in the country was associated with decreased likelihood of children receiving timely vaccination, highlighting the necessity of providing support to settled immigrants to maintain vaccination rates.

455 Additionally, when studying vaccination among immigrant children, it will be crucial to
456 differentiate between children born overseas and children of overseas-born parents. This
457 differentiation is necessary to understand the unique challenges and factors influencing vaccination
458 uptake and timeliness in these distinct groups and to maximize the population health benefits
459 derived from immunization programs.

460
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471 **Insert Supplementary Table 1 here**

472

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