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# 1 Migration and Infant Immunization Timeliness in New Zealand: Evidence from the Growing 2 Up in New Zealand Study

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

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

11 Outbreaks of vaccine-preventable diseases can occur if a sufficient proportion of the population  
12 does not receive *timely* vaccination, even if the overall population coverage rates are high [6], [8].  
13 Timeliness of vaccination is particularly important for the primary infant vaccine series and serves  
14 as a key indicator of health care system performance and the accessibility of health services across  
15 different sectors of the community.

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

20 Barriers to immunization for migrant children encompass various factors, including differences in  
21 healthcare systems between the source and destination countries [17], language proficiency,  
22 cultural differences, and financial constraints [18], [19]. Recent immigrants encounter additional  
23 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

47 for foreign-born children in the NIR. Moreover, difficulties in translating immunization schedules  
48 from the origin countries of migrants who vaccinated their children in their home country may  
49 contribute to inaccuracies in recording, potentially leading to an underestimation of migrant  
50 children's vaccination coverage. Such speculation is supported by another published research using  
51 the same sample/datasets [26], which found significantly lower hospitalization rates among  
52 foreign-born children compared with NZ-born non-migrant children for a wide range of vaccine-  
53 preventable diseases. Further research is warranted to explore and confirm these contradictory  
54 findings and to address the immunization inequalities among migrant children in New Zealand.

55 New Zealand has an estimated 25.2% of the resident population born overseas. Additionally, there  
56 has been a significant increase in the immigrant population, including children, over the last decade  
57 [30]. While vaccine coverage and timeliness disparities by ethnicity in NZ have been described  
58 [31], little is known about the role of parental migration status on child health outcomes, such as  
59 childhood immunization in NZ.

60 Understanding the health-related behaviors of this group is of paramount importance to both  
61 medical and public health professionals. This information is of particular importance as rates of  
62 immunizations for many infectious diseases, across various age groups, are declining in NZ.

63 Additionally, some preventable diseases, such as measles and pertussis, continue to cause serious  
64 outbreaks, morbidity, and mortality [31]. Furthermore, immunization timeliness remains  
65 suboptimal, with delays in the receipt of scheduled immunizations continuing to limit the potential  
66 benefits that immunization could offer to population health in NZ [7], [20], [32].

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

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

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

81

## 82 **Current study**

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

## 90 **Methods**

91 *Participants*

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

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

102 The child cohort (n=6853) comprised ~ 11% of births in NZ during the recruitment period. The  
103 characteristics of the cohort at birth generally aligned with the national birth cohort in NZ from  
104 2007 to 2010 [36]. Ethical approval for the study was granted by the NZ Ministry of Health  
105 Northern Y Regional Ethics Committee (NTY/08106/055).

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

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

## 118 **Measures**

### 119 **The main outcome of interest**

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

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

132

### 133 **Main exposure of interest**

#### 134 **Immigration status**

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

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

145

#### 146 **Sociodemographic characteristics**

147 Potential covariates for inclusion in multivariable analyses were selected based on prior research  
148 on factors associated with immunization timeliness in New Zealand [7], [8] and included: maternal  
149 age at pregnancy, maternal education (categorized into four groups: no secondary school,  
150 secondary school, diploma/trade, tertiary), household crowding index group [41] (classified into  
151 three categories: low [less than one person per bedroom], medium [one to less than two people per  
152 bedroom], and high [two or more people per bedroom] crowding score), language spoken at home  
153 (English, non-English), household annual income groups (categorized into three categories: <  
154 \$50K, \$50-\$70K, > \$70K), receipt of income tested benefit (yes/no), and area-level deprivation  
155 index (NZDep2006).

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

160 and access to transport and communications [42]. The index scores are organized into deciles, with  
161 decile one representing the least deprived 10% of areas in NZ, and decile 10 indicating the most  
162 deprived 10% of areas. For the current analysis, deprivation scores were categorized into three  
163 groups: low deprivation (deciles 1 to 3), medium deprivation (deciles 4 to7), and high deprivation  
164 areas (deciles 8 to10).

165

### 166 **Analytical procedures**

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

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

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

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

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

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

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

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

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

200

201

## 202 **Results**

### 203 **Sociodemographic characteristics of the study sample by maternal immigration status and** 204 **maternal residential duration**

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

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

216 No significant differences were found between recent and settled immigrants regarding maternal  
217 education levels and household deprivation index. However, a higher proportion of recent  
218 immigrants were residing in crowded households compared to settled immigrants (24.6% versus  
219 19.2% respectively). Conversely, a smaller proportion of recent immigrants lived in households  
220 with incomes exceeding \$70k, compared to settled immigrants (43.8% versus 57.5%,  
221 respectively), and a smaller proportion of recent immigrants reported receiving an income tested  
222 benefit compared to settled immigrants (7% versus 12.4%, respectively) (**Table 1**).

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

225 **Insert Table 1 here**

226 **Association between sociodemographic factors and infant timely vaccination**

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

234

235 **Insert Table 2 here**

### 236 **Prevalence of timely completion of infant vaccinations by maternal immigration status**

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

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

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

250 the smallest decrease, with a difference of 7.5 percentage points from six weeks to five months  
251 (96.5% and 89.0% respectively) (**Table 3**).

252 **Insert Table 3 here**

253

### 254 **Maternal migration status and infant vaccination timeliness**

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

259 The results of multivariable logistic regressions indicated that after controlling for socio-  
260 demographic differences between immigrant and non-immigrant families, the odds of receiving  
261 all doses of vaccines on time increased and remained significant (adjusted odds ratios ranging from  
262 2.55 to 1.54 for all doses of vaccines from age six weeks to 5 months). A steady decrease in the  
263 magnitude of both unadjusted and adjusted odds ratios with increasing infant age was observed,  
264 indicating that the gap in child vaccination timeliness narrowed between immigrant and non-  
265 immigrant groups as children aged. However, by the age of five months, differences were still  
266 statistically significant, with children of immigrants having higher odds of receiving the 5-month  
267 vaccine doses on time (**Table 4**).

268 **Insert table 4 here**

269

### 270 **Maternal residential duration and infant vaccination timeliness**

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

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

277

### 278 **The impact of paternal immigration status and having both foreign-born parents on infant** 279 **vaccination timeliness**

280 Having a foreign-born father was associated with identical timeliness rates of all vaccination series  
281 compared to those with a foreign-born mother (83 versus 83%). Additionally, having a foreign-  
282 born father was positively and significantly associated with timely completion of all six doses of  
283 vaccines (83% versus 80% among children with a NZ-born father,  $p < 0.001$ ). Moreover, children  
284 with both parents born overseas had the highest rates of timely vaccination for all six doses of  
285 vaccines (85.2%), followed by those with one foreign-born parent (82.1%). Conversely, children  
286 with both parents born in NZ had the lowest rates of timely vaccination for all six doses of vaccines  
287 (79.3%). (**Table 3**).

288

### 289 **Discussion**

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

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

### 299 **Timely infant vaccination among children of immigrant and non-immigrant families**

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

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

312 Differences in the composition of immigrant samples, such as inclusion of foreign-born children  
313 who may have been vaccinated overseas, into immigrant categories in some studies but not in  
314 others might have contributed to the noted inconsistencies between studies. Inclusion of such  
315 children within the immigrant category might result in underestimation of their true vaccination  
316 records due to factors such as insufficient documentation of vaccines or memory effects [11], [25],  
317 [44]. Such nuances highlight the importance of carefully considering sample composition when  
318 interpreting and comparing findings across studies.

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

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

337 A selection effect could also have contributed to the favorable outcomes for immigrant subgroups.  
338 It is possible that individuals who migrate are predisposed to good health or are able to demonstrate  
339 that they “have an acceptable standard of health”, which may increase their likelihood of migrating  
340 [49]. Consequently, such individuals may be more inclined to seek and secure vaccinations for  
341 their children [50]. In line with this notion, research has indicated that immigrant women are often

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

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

351

### 352 **Recent versus settled immigrants**

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

364 Immigrants are known to be less integrated residents and to have competing needs, particularly  
365 during the early years following immigration, which might hinder their health seeking behaviors,  
366 consequently putting their children at elevated risk of not being fully or timely vaccinated. Indeed,  
367 some previous studies indicate that children born to mothers who recently migrated to the USA  
368 were at higher risk of not being adequately immunized compared with more settled immigrants  
369 [9].

370 However, recent immigrants are also generally known to be highly motivated, receptive to change,  
371 and possess greater social and cultural capital, factors that can to somewhat counteract the lack of  
372 social integration in the new country [51] and enhance their health outcomes and health seeking  
373 behaviors. This well-documented phenomena is known as the “immigrant paradox” [52], [53]. By  
374 analyzing data on recent and established immigrants, as well as data on first- and subsequent-  
375 generation immigrants, researchers have found that recent immigrants often outperform more  
376 established immigrants and non-immigrants on various health, education, and conduct or crime-  
377 related outcomes, despite the numerous barriers they face to successful social integration [54],  
378 [55].

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

387 vaccine confidence, a considerable proportion shows steadily decreasing confidence over time  
388 [58].

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

395 Similarly, the higher likelihood of timely vaccination among children of recent immigrants may  
396 stem from their shorter exposure to vaccine-discouraging information received from peers or  
397 media, as well as the ambiguity created by such information. This explanation aligns with the  
398 findings of a study conducted in the USA, which revealed that childhood vaccination coverage  
399 was lower in more acculturated Latino families compared to less acculturated Latino families [59],  
400 [60]. Additionally, another US-based study found that Hispanic girls residing in predominantly  
401 Hispanic neighborhoods were more likely to be vaccinated against human papillomavirus  
402 compared to Hispanic girls residing in predominantly white neighborhoods [61].

403

#### 404 **Strengths and Limitations**

405 One of the strengths of this study is its novelty in the New Zealand context. To date, few NZ  
406 studies have explored the impact of parental migration status on children's vaccination outcomes  
407 [11]. This study builds upon previous work by utilizing a large, nationally representative sample  
408 of children and their families to examine timely vaccination disparities among children of  
409 immigrant and non-immigrant families in NZ. Additionally, the study investigates the impact of

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

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

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

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

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

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

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

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

#### 446 **Conclusion**

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

452 However, prolonged residency in the country was associated with decreased likelihood of children  
453 receiving timely vaccination, highlighting the necessity of providing support to settled immigrants  
454 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

473

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