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# Evidence of suboptimal maternal vaccination coverage in pregnant New Zealand women and increasing inequity over time: A nationwide retrospective cohort study



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## ARTICLE INFO

### Article history:

Received 9 December 2021

Received in revised form 12 February 2022

Accepted 23 February 2022

Available online 2 March 2022

## ABSTRACT

**Background:** Adequate maternal vaccination coverage is critical for the prevention and control of infectious disease outbreaks such as pertussis, influenza, and more recently COVID-19. To guide efforts to increase vaccination coverage this study examined the extent of vaccination coverage in pregnant New Zealand women over time by area-level deprivation and ethnicity.

**Methods:** A retrospective cohort study was used consisting of all pregnant women who delivered between 01 January 2013 and 31 December 2018, using administrative health datasets. Outcomes were defined as receipt of influenza or pertussis vaccination in any one of the relevant data sources (National Immunisation Register, Proclaims, or Pharmaceutical collection) during their eligible pregnancy. Ethnicity was prioritised as Māori (NZ indigenous), Pacific, Asian, and Other or NZ European and deprivation was defined using New Zealand Index of Multiple Deprivation (IMD).

**Results:** Between 2013 and 2018, Asian women had the highest maternal vaccination coverage (36%) for pertussis, while Māori and Pacific women had the lowest, 13% and 15% respectively. Coverage of pertussis vaccination during pregnancy in low deprivation Māori women was 24% and 28% in Pacific women. This is in comparison to 30% and 25% in high deprivation Asian and European/Other women, respectively. Similar trends were seen for influenza.

**Conclusion:** Between 2013 and 2018 maternal vaccination coverage increased for pertussis and influenza. Despite this coverage remains suboptimal, and existing ethnic and deprivation inequities increased. There is an urgent need to focus on equity, to engage and support ethnic communities by creating genuinely accessible, culturally appropriate health services.

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## 1. Introduction

Globally, vaccination is recognised as a critical to the prevention and control of infectious-disease outbreaks [1]. Pertussis and influenza are highly contagious communicable diseases which are significant public health issues globally and in New Zealand (NZ) [2]. In 2018, greater than 150,000 cases of pertussis occurred globally [3] and pertussis remains one of the top 10 causes of infant

mortality worldwide with an estimated 24 million cases and 160,000 deaths annually in children younger than 5 years [4,5]. NZ has a pertussis epidemic cycle every four to five years, the last one in 2017–2018 resulted in over 4,200 cases. The highest burden was in infants less than 1 year old (274 per 100,000), 50% of which required hospitalisation. A disproportionately higher rate was seen Māori (~400 per 100,000) and Pacific infants (~550 per 100,000) [6]. The burden from influenza is also substantial, particularly among young children, older adults, pregnant women, and those with underlying conditions [7]. However, both diseases are vaccine preventable and these vaccines are available on the NZ vaccine schedule free to pregnant women. Vaccines for both influenza

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and pertussis have strong safety data and well-established efficacy profiles in pregnant and non-pregnant populations [8–13]. Thus, pertussis and influenza vaccines represent a safe and effective way to reduce morbidity and mortality caused by these diseases in pregnant women and their infants.

Immunisation is an important public health measure, but it is only effective if it is being used. Therefore, measuring coverage helps to identify gaps and monitor trends [14]. Maternal vaccination coverage in NZ has increased between 2013 and 2018 for both influenza and pertussis vaccines [14]. Influenza coverage increased from 11% to 31% by 2018 and pertussis coverage from 10% to 44% however, maternal vaccination status remains sub-optimal with evidence of socioeconomic and geographic variation [15]. Moreover, there is recent evidence that childhood coverage may be declining in some parts of NZ [15]. More broadly, low vaccine uptake during pregnancy is a major public health challenge for many high-income countries [16]. Understanding how we could increase vaccination during pregnancy is particularly timely with the current pandemic and the recommendation of the COVID-19 vaccine for pregnant women.

Few international studies have assessed pregnancy vaccination coverage according to ethnicity and socio-economic deprivation. A large cross-sectional population-based study assessing racial disparities in influenza vaccine coverage in the United States, included 131,743 women and found vaccination coverage ranged from 39% in Black women to 55% in Asian women [46]. Overall, Black women were 30% (95% CL 0.65–0.74) less likely to receive maternal influenza vaccination compared with White women [17]. Similarly in the UK a linear gradient of decreasing coverage with increasing deprivation was found after adjusting for ethnicity, with coverage 14% lower in the most deprived quintile compared with the least deprived. Crude coverage was highest in White-British women (63%, 95% CI 62–63) compared with all other ethnicities whose crude coverage ranging from – 0.4% (Chinese) to – 25% (black-other) lower. However, after adjusting for deprivation quintile and local teams, coverage differences according to ethnicity reduced. This was most evident among Indian, Bangladeshi and Chinese ethnicities, who, after adjusting, had higher coverage than white-British women [18]. In NZ, significant inequities exist in childhood vaccination coverage according to ethnicity and socio-economic deprivation [19]. Children living in areas of low deprivation and who are of Māori and Pacific ethnicity have the lowest coverage, both in terms of timeliness and completeness [20]. However, it is unknown if these trends extend to maternal vaccinations. Furthermore, the inequitable burden of pertussis infections is in Māori and Pacific infants [6], so inequities in maternal vaccination coverage may exacerbate this burden. As such there is a need to determine the extent of ethnic and socio-economic inequities in maternal vaccination coverage in NZ to add to an emerging body of international evidence [17,18].

While maternal coverage in NZ has been previously described [14], the aim of this study was to further explore how maternal vaccination coverage varies according to ethnicity and socio-economic status. Pertussis is endemic worldwide and is still difficult to control, despite decades of universal childhood vaccination [21]. In addition to this, greater than 60 national vaccine programs have been disrupted or suspended due to COVID-19 [22]. NZ hasn't been exempt, with timely childhood coverage at 6 months of age falling over the last 24 months from 78% to 75%, this fall has been particularly stark for Māori infants (62% to 55%) [23]. Consequently, our study aims to first describe how maternal vaccination coverage has changed over time, according to delivery year. Second, we will assess differences in maternal vaccination coverage according to ethnicity. Third, we describe how maternal vaccination coverage varies according to socio-economic deprivation using the New Zealand Deprivation Index 2013 and Indices of Multiple

Deprivation. Finally, we will investigate differences between ethnicity by deprivation.

## 2. Method

### 2.1. Study design

This was a retrospective cohort study. The study population consisted of all pregnant women with a delivery between 01 January 2013 and 31 December 2018. Women were excluded if the gestational age at delivery was less than 20 weeks or greater than 45 weeks (most women are induced at 43 weeks or earlier), were missing date of last menstrual period or a gestational age at delivery, if maternal age at delivery was less than 12 years of age or greater than 50 years of age, and if they were flagged as being a non-resident.

### 2.2. Data sources

NZ administrative health data sources were used to undertake this research.

#### 2.2.1. National maternity collection (MAT)

The MAT is a collection of the demographic and clinical features of women in NZ using publicly funded maternity/newborn services from 9 months before birth to 3 months postpartum. Coverage is estimated to be around 80% of births in NZ, as of 2011 [24]. Relevant data fields included National Health Index number (NHI) (encrypted), mother's date of birth, mother's prioritised ethnicity, District Health Board, socioeconomic deprivation level, delivery date, date of last menstrual period, gestational age, lead maternity carer, parity, and number of antenatal visits.

#### 2.2.2. National health Index (NHI)

The NHI database contains demographic information for all people born in NZ and for people born outside of NZ who access the healthcare system (note: the NHI database includes records for travellers and other people who do not live in NZ). A person's unique NHI number, date of birth, date of death, and sex are static; however, the remaining data fields may change over time. Data fields relevant to this study include NHI (encrypted), date of birth, prioritised ethnicity, geographic area of residence (district health board), and socioeconomic deprivation level decile (NZ Deprivation Index 13).

#### 2.2.3. Primary health organisation enrolments (PHO)

The PHO Enrolment Collection provides data on patient enrolment with primary care health care providers. Data fields relevant to this study include NHI (encrypted), 2013 meshblock of residence, PHO registration, and date of last general practice consultation or interaction which includes services provided by practice nurses.

#### 2.2.4. National Immunisation register (NIR)

A register of all immunisation enrolments and events as per the National Immunisation Schedule in NZ. Relevant data fields include NHI (encrypted), vaccine type, vaccination date, and provider type. Providers enter the vaccination details into this register electronically.

#### 2.2.5. Proclaims

A claims dataset that contains the fee-for-service payments made to general practices for patient visits. Relevant data fields include NHI (encrypted), vaccination type, and date of service (vac-

ination date). Any claim made for the vaccination administration is automatically captured by this database.

#### 2.2.6. Pharmaceutical collection

Claims dataset for community pharmacy that contains claim and payment information from pharmacists for subsidised dispensing. Relevant data fields include NHI (encrypted), claim type (vaccine type), and dispensing date (vaccination date).

#### 2.3. Outcomes

The outcomes of interest were receipt of influenza or pertussis vaccination during pregnancy, both as binary variables (N/Y). Vaccination status for each woman was determined as having a valid entry for a pertussis vaccine and/or influenza vaccine in any one of the relevant data sources (NIR, Proclaims, or Pharmaceutical Collection), during their eligible pregnancy. Due to the number of data sources available with vaccination information, they were prioritised in the following order: NIR, Proclaims, and Pharmaceutical Collection. If multiple vaccinations events were reported during a woman's eligible pregnancy, only the first valid entry was selected. A vaccination was considered valid if it occurred between last menstrual period and censoring (delivery date or end of assigned study period whichever came first).

Ethnicity was prioritised (Māori, Pacific, Asian, Other, and NZ European) and area level socioeconomic deprivation (NZ Deprivation Index 13 (NZDep13) and the Indices of Multiple Deprivation (IMD)) were categorised from deciles to quintiles (1 (least deprived) to 5 (most deprived)) and categories (low deprivation = 1–3, medium = 4–7, and high = 8–10). If district health board, ethnicity, NZDep13 were missing in the MAT collection, then the NHI dataset was used to fill-in missing values where available.

#### 2.4. Area-level deprivation

The NZDep13 Index of Deprivation is a small area measure of deprivation that is derived from variables collected at the national census which describe household socioeconomic characteristics. NZDep13 combines nine variables from the 2013 census which reflect eight dimensions of deprivation (communication, income, employment, qualifications, home ownership, support, household crowding, transport) [25]. The NZ IMD 2013 is an alternative to NZDep which uses 28 deprivation indicators to form seven deprivation domains [26]. In contrast to NZDep, the NZ IMD gathers data from numerous providers including MoH, NZ Police, Inland Revenue and MSD and has the additional advantage of being updated regularly, rather than five yearly [26]. The NZ IMD measures deprivation at the neighbourhood level using custom designed data zones, with each zone having a mean of 712 people per zone [26]. The index values are the same as for NZDep – 1 (least deprived), 10 (most deprived). The major advantage of the NZ IMD is that unlike NZDep which provides an overall deprivation rating, the NZ IMD provides an insight into the facets or components of deprivation at a neighbourhood level [26].

In this study, three NZ IMD categories were examined separately to assess how vaccination coverage varied according to different deprivation domains. Health, access, education, income, and housing were the NZ IMD categories chosen to be examined in greater detail. The health domain identifies areas that have a greater level of morbidity and mortality than expected for the age profile of their population [26]. This domain was chosen as maternal vaccination directly influences maternal and infant morbidity and mortality [27]. The access domain is a measure of the cost and convenience involved in accessing basic amenities including General Practice services [26], and was examined as it was

highlighted in the literature as an important determinant of vaccination likelihood [18,28]. The education domain identifies young people who are not in employment, education or training (NEET), as well as the proportion of people without a formal qualification in the working population [26]. The literature review found low educational attainment was a risk factor associated with low maternal vaccine uptake internationally [28,29]. Thus, education was analysed separately to assess if the trend seen overseas, also applies in NZ. We additionally examined the income and housing domain.

PHO registration data was used to help ascertain a woman's IMD score by providing the 2013 meshblock of residence. Date of last GP consultation, or PHO registration, was matched to within 5 years of a woman's delivery date, thus providing their meshblock around the time of pregnancy which in turn linked to an IMD data-zone that provided the IMD score for area of residence related to each of a woman's pregnancies [26]. For the cohort, 7,706 pregnancies were missing IMD data of which 1,744 were missing PHO enrolment data and while the remaining had PHO data they lacked linkable meshblock data.

#### 2.5. Statistical analysis

Demographic variables (deprivation, ethnicity, and district health board) were imputed using the NHI dataset and if gestational age or last menstrual period date were missing then they were imputed using delivery date and if both were missing the woman's pregnancy was excluded. Descriptive variables are presented as counts and percentages. Rates were calculated per 100 pregnant women, with the population denominator calculated as the total number of women in the cohort. The association between pertussis or influenza receipt and exposures was explored using logistic regression. Specifically, the SAS procedure GENMOD with a binomial distribution and logit link and autoregressive structure accounting for repeated subjects. Main exposures were maternal ethnicity and deprivation. Models were additionally adjusted for: year of delivery, maternal age at last menstrual period, parity, model of antenatal care, and area of residence (DHB). Odds ratios (OR) and 95% confidence intervals are presented. Effect modification was examined with inclusion of an interaction between ethnicity and deprivation. Where a significant Wald test indicated an interaction, separate logistic regression models were run. All tests for assessing statistical significance were two-sided with a  $p$  less than 0.05. All statistical analyses were undertaken using SAS Enterprise Guide (9.4) statistical software (SAS Institute Inc., Cary, NC, USA). This study was approved by the University of Auckland Human Participants Ethics Committee (Ref. 022536).

### 3. Results

#### 3.1. Descriptive statistics

Our cohort of women included 323,622 pregnancies between 2013 and 2018, of which 26.3% were to women who identified as Māori and 9.6% pregnancies to Pacific women (Fig. 1). The cohort flowchart and further characteristic descriptors can be found in online [supplementary materials Figure S1](#) and Table S1.

#### 3.2. Maternal vaccination coverage has changed over time

Between 2013 and 2018, influenza vaccination coverage has increased from 11.2% to 30.8%, and pertussis 10.2% to 43.6% (Table S1). More detailed has been previously published [14].

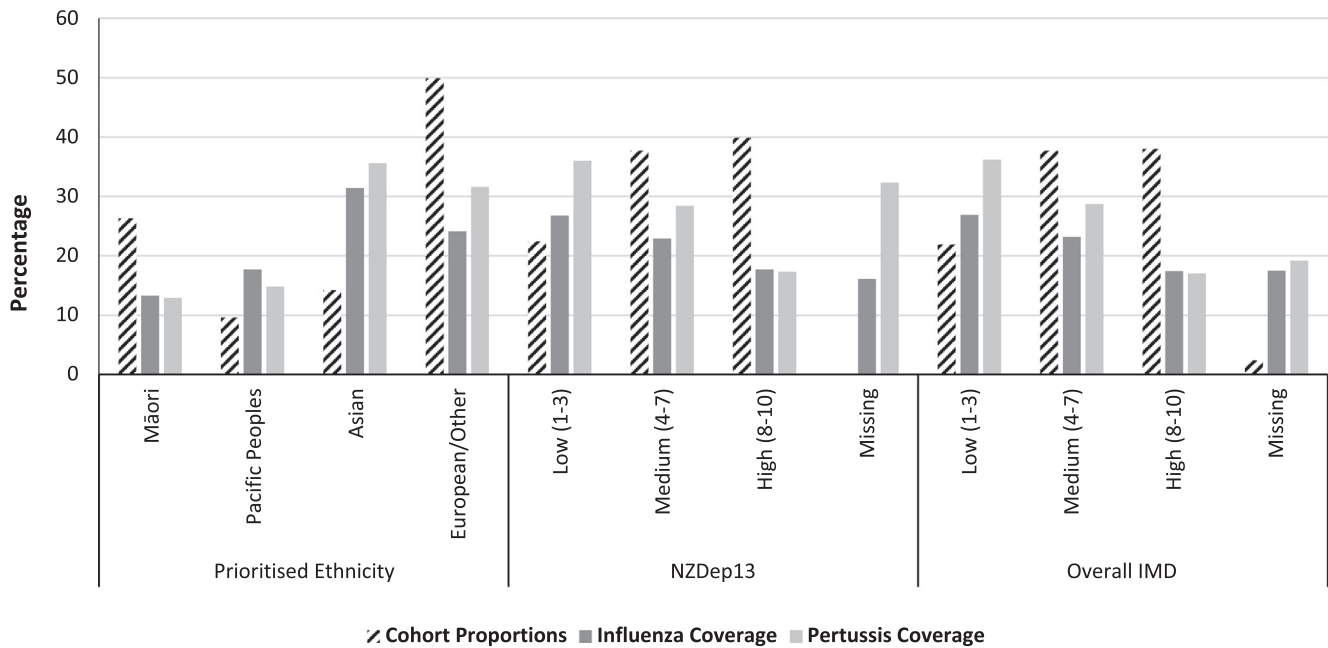


Fig. 1. Proportion of the cohort and maternal coverage, by ethnicity and deprivation.

### 3.3. Maternal vaccination coverage according to ethnicity

As shown in Fig. 1, women who identified as Asian or European/Other had the highest maternal coverage with 31.4% and 24.1% for influenza and 35.6% and 31.6% for pertussis, respectively. In comparison, only 13.3% of women who identified as Māori and 17.7% of Pacific women received an influenza vaccination during their pregnancies, and 12.9% and 14.8%, respectively for pertussis vaccination.

### 3.4. Maternal vaccination coverage according to socio-economic deprivation

Overall, a deprivation gradient was observed over the time period (Table 1). Maternal coverage decreased with increasing deprivation for overall indicators and the specific IMD domains, with the exception of the Access domain for pertussis maternal coverage which ranged very little between the deprivation categories (24.3% to 26.4%) (Table 1). No discernible difference was seen between

Table 1

Vaccination status by different domains of deprivation, as measured by the IMD, in New Zealand pregnant women (2013–2018) (n = 323,622).

	Total Cohort n	(%)	Influenza Vaccinated n	(%)	Pertussis Vaccinated n	(%)
<b>Access Deprivation</b>						
Low (1–3)	102,488	(31.7)	23,780	(23.2)	27,019	(26.3)
Medium (4–7)	131,528	(40.6)	28,958	(22.0)	34,823	(26.4)
High (8–10)	81,900	(25.3)	16,256	(19.8)	19,907	(24.3)
Missing	7,706	(2.4)	1,349	(17.5)	1,481	(19.2)
<b>Education Deprivation</b>						
Low (1–3)	73,436	(22.7)	20,677	(28.1)	27,728	(37.7)
Medium (4–7)	123,701	(38.2)	27,979	(22.6)	33,749	(27.2)
High (8–10)	118,779	(36.7)	20,338	(17.1)	20,272	(17.0)
Missing	7,706	(2.4)	1,349	(17.5)	1,481	(19.2)
<b>Health Deprivation</b>						
Low (1–3)	72,248	(22.3)	18,725	(25.9)	24,722	(34.2)
Medium (4–7)	121,836	(37.6)	28,236	(23.1)	34,977	(28.7)
High (8–10)	121,832	(37.6)	22,033	(18.0)	22,050	(18.0)
Missing	7,706	(2.4)	1,349	(17.5)	1,481	(19.2)
<b>Housing Deprivation</b>						
Low (1–3)	71,668	(22.1)	17,690	(24.6)	23,227	(32.4)
Medium (4–7)	124,350	(38.4)	27,706	(22.2)	34,171	(27.4)
High (8–10)	119,898	(37.0)	23,598	(19.6)	24,351	(20.3)
Missing	7,706	(2.4)	1,349	(17.5)	1,481	(19.2)
<b>Income Deprivation</b>						
Low (1–3)	70,835	(21.9)	19,262	(27.1)	25,724	(36.3)
Medium (4–7)	121,377	(37.5)	27,980	(23.0)	34,771	(28.6)
High (8–10)	123,704	(38.2)	21,752	(17.5)	21,254	(17.1)
Missing	7,706	(2.4)	1,349	(17.5)	1,481	(19.2)

overall area level deprivation between NZDep13 and the IMD (Table 1). The 7,706 pregnancies missing IMD data were more likely to be in the two least deprived quintiles of the NZDep13 and less likely to have received a vaccination during the pregnancy compared to those with IMD data (online supplementary materials: Table S2).

### 3.5. Differences between ethnicity by deprivation

An ethnicity by deprivation interaction was found, with women who identified as Māori or Pacific living in areas of low overall deprivation (IMD) having similar rates of maternal vaccination coverage as Asian or European women living in areas of high deprivation (Figs. 2 and 3). Coverage of pertussis vaccination in low deprivation Māori women was 24.4% (95% CI: 23.3, 25.5) and in Pacific women 27.8% (25.4, 30.2) compared to 29.9% (29.0, 30.9)

and 25.0% (24.5, 25.5) in high deprivation Asian and European/Other women, respectively (Fig. 2). Similar trends were seen for influenza vaccination (Fig. 3). Ethnicity by deprivation results by year are presented in online supplementary materials Tables S3 and S4

Tables 2 and 3 show trends in coverage rates by ethnicity and the health, education, and income domains of deprivation. Coverage for Māori and Pacific women fell with increasing deprivation in these domains, with coverage rates in the areas of lowest deprivation for these women similar to women of European/Other ethnicity in areas of high deprivation (Tables 2 and 3).

Very little difference in maternal vaccination rates were seen by deprivation for the ‘Access to Services’ domain, with Asian or European/Other women having nearly twice the rate of coverage as women who identified as Māori and Pacific (Tables 2 and 3). Annual rates between 2013 and 2018 by ethnicity and deprivation

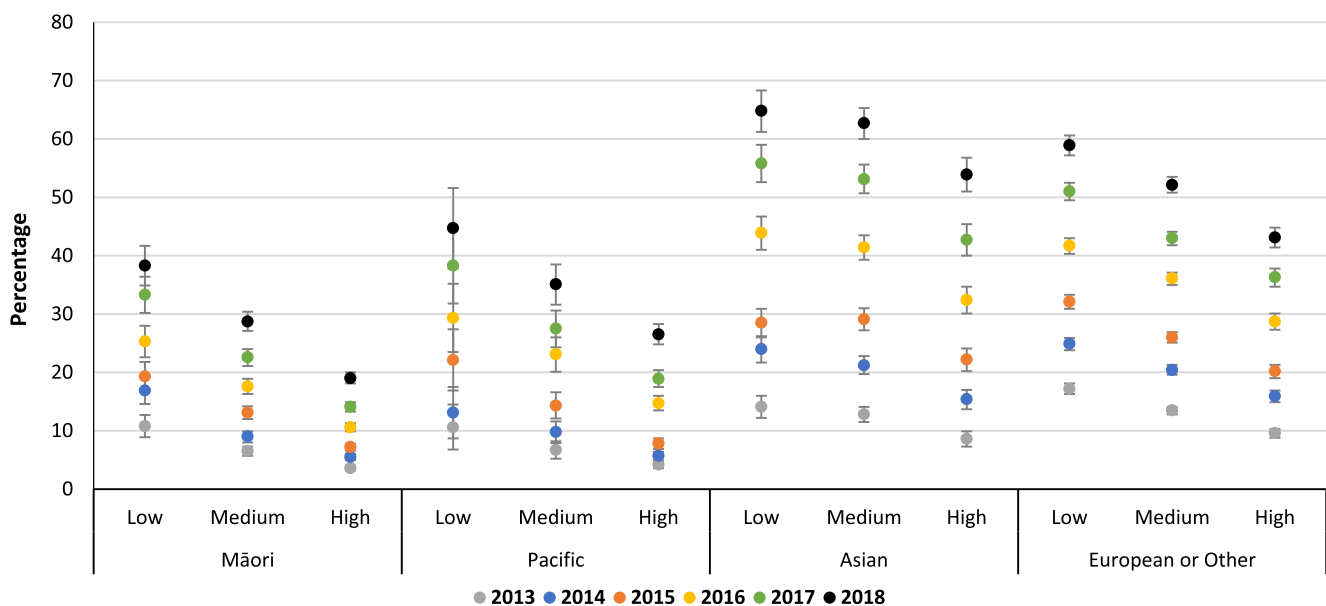


Fig. 2. Annual maternal pertussis vaccination coverage, by ethnicity and overall IMD deprivation.

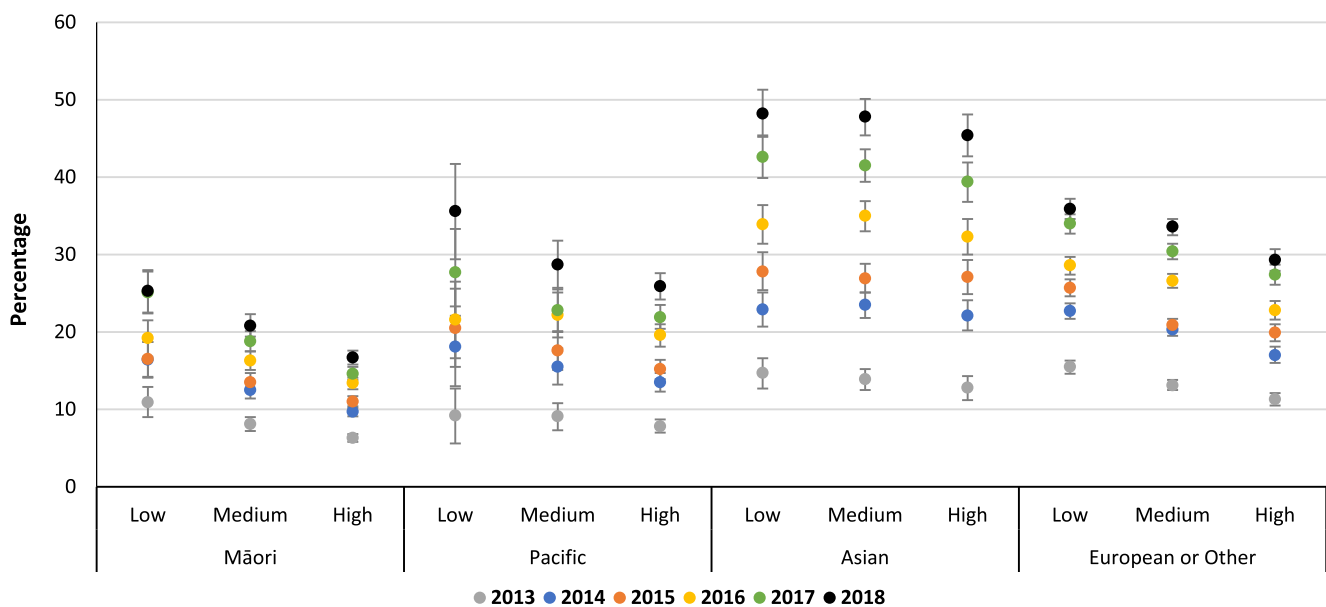


Fig. 3. Annual maternal influenza vaccination coverage, by ethnicity and overall IMD deprivation.

**Table 2**  
Examination of association between maternal pertussis vaccination coverage and ethnicity by deprivation category, for New Zealand pregnant women (2013 – 2018).

	Cases	Population	Rate <sup>1</sup>	(95 %CI)	OR <sup>2</sup>	(95 %CI)
<b>Overall Deprivation</b>						
<i>Māori</i>						
Low	1,826	7,475	24.4	(23.3, 25.5)	0.67	(0.63, 0.71)
Medium	3,980	24,443	16.3	(15.8, 16.8)	0.51	(0.49, 0.53)
High	5,046	51,074	9.9	(9.6, 10.2)	0.37	(0.36, 0.39)
<i>Pacific</i>						
Low	520	1,872	27.8	(25.4, 30.2)	0.68	(0.61, 0.76)
Medium	1,262	6,518	19.4	(18.3, 20.4)	0.54	(0.50, 0.58)
High	2,790	22,220	12.6	(12.1, 13.0)	0.43	(0.41, 0.45)
<i>Asian</i>						
Low	4,543	11,306	40.2	(39.0, 41.4)	1.01	(0.97, 1.06)
Medium	7,421	19,822	37.4	(36.6, 38.3)	0.99	(0.95, 1.03)
High	4,040	13,499	29.9	(29.0, 30.9)	0.77	(0.74, 0.81)
<i>European or Other</i>						
Low	18,798	50,132	37.5	(37.0, 38.0)	ref	–
Medium	22,455	71,232	31.5	(31.1, 31.9)	0.89	(0.86, 0.91)
High	9,068	36,322	25.0	(24.5, 25.5)	0.74	(0.72, 0.77)
<b>Access Deprivation</b>						
<i>Māori</i>						
Low	3,404	24,962	13.6	(13.2, 14.1)	0.56	(0.53, 0.58)
Medium	4,569	35,446	12.9	(12.5, 13.3)	0.51	(0.49, 0.53)
High	2,879	22,584	12.7	(12.3, 13.2)	0.42	(0.40, 0.44)
<i>Pacific</i>						
Low	2,403	16,586	14.5	(13.9, 15.1)	0.61	(0.58, 0.64)
Medium	1,812	12,015	15.1	(14.4, 15.8)	0.53	(0.50, 0.56)
High	357	2,009	17.8	(15.9, 19.6)	0.43	(0.38, 0.49)
<i>Asian</i>						
Low	7,405	20,522	36.1	(35.3, 36.9)	1.05	(1.01, 1.09)
Medium	7,198	20,058	35.9	(35.1, 36.7)	0.91	(0.87, 0.95)
High	1,401	4,047	34.6	(32.8, 36.4)	0.68	(0.63, 0.74)
<i>European or Other</i>						
Low	13,807	40,417	34.2	(33.6, 34.7)	ref	–
Medium	21,244	64,009	33.2	(32.7, 33.6)	0.94	(0.91, 0.97)
High	15,270	53,260	28.7	(28.2, 29.1)	0.68	(0.66, 0.70)
<b>Education Deprivation</b>						
<i>Māori</i>						
Low	1,829	7,225	25.3	(24.2, 26.5)	0.66	(0.62, 0.70)
Medium	3,958	25,214	15.7	(15.2, 16.2)	0.48	(0.46, 0.51)
High	5,065	50,553	10.0	(9.7, 10.3)	0.39	(0.37, 0.41)
<i>Pacific</i>						
Low	763	3,002	25.4	(23.6, 27.2)	0.64	(0.59, 0.70)
Medium	1,601	9,464	16.9	(16.1, 17.7)	0.52	(0.49, 0.56)
High	2,208	18,144	12.2	(11.7, 12.7)	0.44	(0.41, 0.46)
<i>Asian</i>						
Low	6,928	17,311	40.0	(39.1, 41.0)	1.01	(0.97, 1.05)
Medium	6,429	18,368	35.0	(34.1, 35.9)	0.92	(0.88, 0.96)
High	2,647	8,948	29.6	(28.5, 30.7)	0.78	(0.74, 0.83)
<i>European or Other</i>						
Low	18,208	45,898	39.7	(39.1, 40.2)	ref	–
Medium	21,761	70,655	30.8	(30.4, 31.2)	0.83	(0.80, 0.85)
High	10,352	41,133	25.2	(24.7, 25.7)	0.76	(0.73, 0.79)
<b>Health Deprivation</b>						
<i>Māori</i>						
Low	2,093	9,664	21.7	(20.7, 22.6)	0.67	(0.63, 0.71)
Medium	4,071	26,052	15.6	(15.1, 16.1)	0.63	(0.60, 0.66)
High	4,688	47,276	9.9	(9.6, 10.2)	0.55	(0.52, 0.57)
<i>Pacific</i>						
Low	514	1,989	25.8	(23.6, 28.1)	0.71	(0.63, 0.79)
Medium	1,302	6,601	19.7	(18.7, 20.8)	0.68	(0.64, 0.73)
High	2,756	22,020	12.5	(12.0, 13.0)	0.62	(0.59, 0.66)
<i>Asian</i>						
Low	4,433	11,016	40.2	(39.1, 41.4)	1.09	(1.04, 1.14)
Medium	7,031	19,004	37.0	(36.1, 37.9)	1.17	(1.12, 1.22)
High	4,540	14,607	31.1	(30.2, 32.0)	1.12	(1.07, 1.18)
<i>European or Other</i>						
Low	17,682	49,579	35.7	(35.1, 36.2)	ref	–
Medium	22,573	70,179	32.2	(31.7, 32.6)	1.08	(1.04, 1.11)
High	10,066	37,928	26.5	(26.0, 27.1)	1.10	(1.06, 1.15)
<b>Housing Deprivation</b>						
<i>Māori</i>						
Low	2,088	10,247	20.4	(19.5, 21.3)	0.66	(0.62, 0.69)
Medium	4,310	29,799	14.5	(14.0, 14.9)	0.69	(0.66, 0.72)

(continued on next page)

Table 2 (continued)

	Cases	Population	Rate <sup>1</sup>	(95 %CI)	OR <sup>2</sup>	(95 %CI)
High	4,454	42,946	10.4	(10.1, 10.7)	0.71	(0.67, 0.75)
<i>Pacific</i>						
Low	473	1,910	24.8	(22.5, 27.0)	0.69	(0.61, 0.77)
Medium	1,084	5,584	19.4	(18.3, 20.6)	0.73	(0.68, 0.79)
High	3,015	23,116	13.0	(12.6, 13.5)	0.81	(0.76, 0.85)
<i>Asian</i>						
Low	3,012	7,734	38.9	(37.6, 40.3)	1.01	(0.96, 1.07)
Medium	6,048	16,483	36.7	(35.8, 37.6)	1.24	(1.18, 1.29)
High	6,944	20,410	34.0	(33.2, 34.8)	1.46	(1.39, 1.53)
<i>European or Other</i>						
Low	17,654	51,777	34.1	(33.6, 34.6)	ref	–
Medium	22,729	72,484	31.4	(30.9, 31.8)	1.21	(1.17, 1.25)
High	9,938	33,425	29.7	(29.1, 30.3)	1.40	(1.34, 1.45)
<b>Income Deprivation</b>						
<i>Māori</i>						
Low	1,879	7,917	23.7	(22.7, 24.8)	0.67	(0.63, 0.71)
Medium	3,869	24,152	16.0	(15.5, 16.5)	0.56	(0.53, 0.59)
High	5,104	50,923	10.0	(9.7, 10.3)	0.46	(0.44, 0.49)
<i>Pacific</i>						
Low	577	2,068	27.9	(25.6, 30.2)	0.71	(0.64, 0.80)
Medium	1,287	6,751	19.1	(18.0, 20.1)	0.60	(0.56, 0.65)
High	2,708	21,791	12.4	(12.0, 12.9)	0.52	(0.49, 0.56)
<i>Asian</i>						
Low	4,834	11,909	40.6	(39.4, 41.7)	1.03	(0.98, 1.07)
Medium	7,380	20,024	36.9	(36.0, 37.7)	1.08	(1.03, 1.12)
High	3,790	12,694	29.9	(28.9, 30.8)	0.95	(0.89, 1.00)
<i>European or Other</i>						
Low	18,434	48,941	37.7	(37.1, 38.2)	ref	–
Medium	22,235	70,450	31.6	(31.1, 32.0)	0.97	(0.94, 1.00)
High	9,652	38,295	25.2	(24.7, 25.7)	0.91	(0.87, 0.95)

<sup>1</sup> Rate per 100 pregnant women.

<sup>2</sup> Adjusted for delivery year, age at last menstrual period, parity, lead maternity carer, district health board, and deprivation.

showed only a slight increase for Māori and Pacific women with no difference between levels of Access deprivation. For example, Māori women with low Access deprivation in 2013 had 7.6% influenza vaccination coverage compared to 7.1% for those with high Access deprivation, this increased to 20.8% and 16.5% by 2018, respectively (Table S4).

#### 4. Discussion

This nationwide retrospective cohort study aimed to examine the extent to which maternal vaccination coverage in pregnancy varies according to ethnicity and socio-economic status in NZ from 2013 to 2018. It extends evidence by illustrating a widening inequity in maternal vaccination coverage over time despite notable increases over time. Our study found that maternal vaccination has increased for all ethnic groups between 2013 and 2018 however, over the same period socioeconomic and ethnic inequities have increased. Asian and European women had the highest rates and odds of receiving pregnancy vaccines, while Māori and Pacific women had lowest.

Our study found significant disparities in coverage by ethnicity. While coverage was found to be uniformly low, the relative difference did not change overtime between the groups with the lowest and highest coverage (~a factor of 3), while the absolute margin did change. We found Māori living in low deprivation areas had a coverage increase of only 15 percentage points between 2013 and 2018 compared to 50 percentage points for those who identify as Asian living in low deprivation areas. The causes of ethnic inequities in maternal vaccination coverage are multifactorial. Causes can include barriers to accessing primary and maternity care, geographical access [15], and systems barriers [20]. There is often a tendency to explain health inequities by focusing on the

role of the broader socioeconomic status or to take a victim blaming approach [30]. Socioeconomic status does undoubtedly have a role in determining the financial and physical access a person has to vaccination and therefore does contribute to ethnic disparities [31]. However, this study found ethnic inequities in maternal vaccination coverage persisted across the social gradient, with Māori and Pacific women living in the least deprived areas having lower odds of vaccination compared with other non-Māori women living in the least deprived areas. Consequently, wider systemic factors such as racism and the ongoing impacts of the colonisation process, must be considered as causes for ethnic inequities [20,32]. Consideration of appropriate delivery of information to Māori and Pacific women, for example kanohi ki te kanohi kōrero (face-to-face discussion) may be more acceptable or meaningful than provision of written material as commonly occurs. Vaccinating outside of general practice, e.g. in schools, community outreach [33,34], or pharmacy [35] aids access by Māori.

The lack of culturally appropriate antenatal engagement and care are important factors contributing to health inequities for pregnant Māori and Pacific women [30]. Qualitative research exploring the lived realities of pregnant Māori women found the majority of participants were pro-active and engaged early with primary health services to confirm their pregnancy [30]. Thus, dispelling the victim blaming discourse of Māori women booking late in pregnancy as a reason for inequities [30]. Makowharemahihi, et al., [30] found the health system failed participants as they transitioned to an LMC. During this transition, women experienced a lack of information regarding the antenatal process, were not given assistance to find an LMC and struggled to find LMCs with availability, let alone an LMC who provided culturally sensitive care [30]. This led to a long lag time between confirmation of pregnancy and first LMC visit. When women do not receive early antenatal care (defined as having LMC care during the first trimester) or have



**Table 3**  
Examination of association between maternal influenza vaccination coverage and ethnicity by deprivation category, for New Zealand pregnant women (2013 – 2018).

	Cases	Population	Rate <sup>1</sup>	(95 %CI)	OR <sup>2</sup>	(95 %CI)
<b>Overall Deprivation</b>						
<i>Māori</i>						
Low	1,430	7,475	19.1	(18.1, 20.1)	0.76	(0.71, 0.81)
Medium	3,677	24,443	15.0	(14.6, 15.5)	0.67	(0.64, 0.70)
High	6,060	51,074	11.9	(11.6, 12.2)	0.60	(0.58, 0.63)
<i>Pacific</i>						
Low	429	1,872	22.9	(20.7, 25.1)	0.87	(0.78, 0.97)
Medium	1,256	6,518	19.3	(18.2, 20.3)	0.82	(0.77, 0.88)
High	3,774	22,220	17.0	(16.4, 17.5)	0.84	(0.80, 0.87)
<i>Asian</i>						
Low	3,705	11,306	32.8	(31.7, 33.8)	1.24	(1.18, 1.30)
Medium	6,326	19,822	31.9	(31.1, 32.7)	1.27	(1.22, 1.32)
High	4,100	13,499	30.4	(29.4, 31.3)	1.27	(1.21, 1.33)
<i>European or Other</i>						
Low	13,543	50,132	27.0	(26.6, 27.5)	ref	–
Medium	17,089	71,232	24.0	(23.6, 24.4)	0.95	(0.92, 0.97)
High	7,605	36,322	20.9	(20.5, 21.4)	0.89	(0.86, 0.92)
<b>Access Deprivation</b>						
<i>Māori</i>						
Low	3,568	24,962	14.3	(13.8, 14.8)	0.71	(0.68, 0.74)
Medium	4,783	35,446	13.5	(13.1, 13.9)	0.66	(0.64, 0.69)
High	2,816	22,584	12.5	(12.0, 12.9)	0.56	(0.53, 0.59)
<i>Pacific</i>						
Low	3,048	16,586	18.4	(17.7, 19.0)	0.94	(0.90, 0.99)
Medium	2,075	12,015	17.3	(16.5, 18.0)	0.81	(0.77, 0.85)
High	336	2,009	16.7	(14.9, 18.5)	0.63	(0.56, 0.72)
<i>Asian</i>						
Low	6,653	20,522	32.4	(31.6, 33.2)	1.33	(1.28, 1.38)
Medium	6,226	20,058	31.0	(30.3, 31.8)	1.17	(1.13, 1.22)
High	1,252	4,047	30.9	(29.2, 32.7)	1.06	(0.98, 1.14)
<i>European or Other</i>						
Low	10,511	40,417	26.0	(25.5, 26.5)	ref	–
Medium	15,874	64,009	24.8	(24.4, 25.2)	0.94	(0.91, 0.97)
High	11,852	53,260	22.3	(21.9, 22.7)	0.79	(0.77, 0.82)
<b>Education Deprivation</b>						
<i>Māori</i>						
Low	1,402	7,225	19.4	(18.4, 20.4)	0.74	(0.70, 0.79)
Medium	3,775	25,214	15.0	(14.5, 15.4)	0.66	(0.63, 0.69)
High	5,990	50,553	11.8	(11.5, 12.1)	0.59	(0.56, 0.61)
<i>Pacific</i>						
Low	709	3,002	23.6	(21.9, 25.4)	0.94	(0.86, 1.02)
Medium	1,725	9,464	18.2	(17.4, 19.1)	0.81	(0.76, 0.86)
High	3,025	18,144	16.7	(16.1, 17.3)	0.80	(0.76, 0.85)
<i>Asian</i>						
Low	5,717	17,311	33.0	(32.2, 33.9)	1.26	(1.21, 1.31)
Medium	5,739	18,368	31.2	(30.4, 32.1)	1.23	(1.18, 1.28)
High	2,675	8,948	29.9	(28.8, 31.0)	1.21	(1.14, 1.28)
<i>European or Other</i>						
Low	12,849	45,898	28.0	(27.5, 28.5)	ref	–
Medium	16,740	70,655	23.7	(23.3, 24.1)	0.91	(0.88, 0.94)
High	8,648	41,133	21.0	(20.6, 21.5)	0.87	(0.83, 0.90)
<b>Health Deprivation</b>						
<i>Māori</i>						
Low	1,705	9,664	17.6	(16.8, 18.5)	0.76	(0.72, 0.80)
Medium	3,840	26,052	14.7	(14.3, 15.2)	0.73	(0.70, 0.76)
High	5,622	47,276	11.9	(11.6, 12.2)	0.70	(0.66, 0.73)
<i>Pacific</i>						
Low	467	1,989	23.5	(21.3, 25.6)	0.97	(0.87, 1.08)
Medium	1,272	6,601	19.3	(18.2, 20.3)	0.89	(0.83, 0.95)
High	3,720	22,020	16.9	(16.4, 17.4)	0.95	(0.90, 1.00)
<i>Asian</i>						
Low	3,673	11,016	33.3	(32.3, 34.4)	1.32	(1.26, 1.39)
Medium	6,074	19,004	32.0	(31.2, 32.8)	1.37	(1.32, 1.43)
High	4,384	14,607	30.0	(29.1, 30.9)	1.39	(1.32, 1.46)
<i>European or Other</i>						
Low	12,880	49,579	26.0	(25.5, 26.4)	ref	–
Medium	17,050	70,179	24.3	(23.9, 24.7)	1.02	(0.99, 1.05)
High	8,307	37,928	21.9	(21.4, 22.4)	1.04	(1.00, 1.08)
<b>Housing Deprivation</b>						
<i>Māori</i>						
Low	1,711	10,247	16.7	(15.9, 17.5)	0.73	(0.69, 0.77)
Medium	4,147	29,799	13.9	(13.5, 14.3)	0.76	(0.73, 0.79)

(continued on next page)

Table 3 (continued)

	Cases	Population	Rate <sup>1</sup>	(95 %CI)	OR <sup>2</sup>	(95 %CI)
High	5,309	42,946	12.4	(12.0, 12.7)	0.82	(0.78, 0.86)
Pacific						
Low	407	1,910	21.3	(19.2, 23.4)	0.88	(0.79, 0.99)
Medium	1,022	5,584	18.3	(17.2, 19.4)	0.88	(0.81, 0.95)
High	4,030	23,116	17.4	(16.9, 18.0)	1.12	(1.06, 1.18)
Asian						
Low	2,486	7,734	32.1	(30.9, 33.4)	1.25	(1.18, 1.32)
Medium	5,197	16,483	31.5	(30.7, 32.4)	1.40	(1.35, 1.46)
High	6,448	20,410	31.6	(30.8, 32.4)	1.61	(1.53, 1.68)
European or Other						
Low	13,086	51,777	25.3	(24.8, 25.7)	ref	–
Medium	17,340	72,484	23.9	(23.6, 24.3)	1.09	(1.06, 1.12)
High	7,811	33,425	23.4	(22.9, 23.9)	1.17	(1.12, 1.22)
<b>Income Deprivation</b>						
Māori						
Low	1,479	7,917	18.7	(17.7, 19.6)	0.75	(0.70, 0.80)
Medium	3,548	24,152	14.7	(14.2, 15.2)	0.67	(0.64, 0.70)
High	6,140	50,923	12.1	(11.8, 12.4)	0.64	(0.61, 0.68)
Pacific						
Low	488	2,068	23.6	(21.5, 25.7)	0.91	(0.82, 1.01)
Medium	1,272	6,751	18.8	(17.8, 19.9)	0.82	(0.76, 0.88)
High	3,699	21,791	17.0	(16.4, 17.5)	0.88	(0.83, 0.93)
Asian						
Low	3,957	11,909	33.2	(32.2, 34.3)	1.25	(1.19, 1.31)
Medium	6,320	20,024	31.6	(30.8, 32.3)	1.28	(1.22, 1.33)
High	3,854	12,694	30.4	(29.4, 31.3)	1.33	(1.25, 1.41)
European or Other						
Low	13,338	48,941	27.3	(26.8, 27.7)	ref	–
Medium	16,840	70,450	23.9	(23.5, 24.3)	0.95	(0.92, 0.98)
High	8,059	38,295	21.0	(20.6, 21.5)	0.93	(0.88, 0.97)

<sup>1</sup> Rate per 100 pregnant women.

<sup>2</sup> Adjusted for delivery year, age at last menstrual period, parity, lead maternity carer, district health board, and deprivation.

less than five antenatal visits, they are less likely to discuss maternal vaccination with their LMC and are consequently less likely to be vaccinated [28]. Thus, the health system's failure to help Māori (and Pacific) women navigate the transition to LMC care, the lack of culturally appropriate maternity care and LMC availability, is likely to underpin ethnic inequities in maternal vaccination coverage.

Internationally, and in New Zealand, health-care provider recommendation to vaccinate has been identified as a key predictor of vaccination uptake amongst pregnant women [36–38]. The importance of health-care provider recommendation is illustrated by the findings of a study where recommendation to vaccinate was associated with higher odds of maternal vaccination (OR:41.89 95% CI: 20.68, 84.86) compared with women who did not receive a vaccination recommendation [37]. Alongside this, several studies have found health-care provider recommendation to vaccinate varies according to patient ethnicity and socioeconomic status [29,39]. For example, in an American study, offers or referrals for maternal vaccination were lowest amongst Black, unmarried and uninsured women, corresponding with these women having the lowest vaccination coverage [29]. An Australian study found Indigenous women were open to vaccination during pregnancy, however ethnic bias among healthcare providers was identified as a possible cause for low maternal vaccine coverage in Indigenous women [39]. Thus, health-care provider bias and failure to provide vaccination recommendations to Māori and Pacific women could be a reason for ethnic inequities in maternal vaccination coverage in NZ. This point is highlighted by the almost non-existent gradient in coverage we found for the 'Access' domain of deprivation, a measure of proximity to basic amenities that includes General Practice [26]. This indicates that physical access to a GP has little effect on increasing maternal coverage, despite GP's being the almost exclusive providers of maternal pertussis immunisation and the lead provider of maternal influenza vaccinations with pharmacy only providing funded maternal influenza

vaccination since 2017. Within the NZ context, while health-care provider recommendations have aided maternal vaccination uptake [38,40], no specific research has identified the impact of health-care provider recommendations and bias on ethnic inequities in maternal vaccination coverage. However, the impact of racism and unconscious bias within the health sector on Māori health is well documented, with Harris and Cormack explaining a person's socially-assigned ethnicity is linked to real health advantage for those who are perceived as European and with tangible health risk for people socially-assigned as Māori [41]. This is illustrated by research that has found Māori experience a much slower and longer pathway through the healthcare system compared with non-Māori [42] and receive care which is of different quality to non-Māori [43]. Examples of differential care include Māori patients being less likely to receive pain relief than non-Māori during childbirth, Māori receiving less screening for and treatment of cardiovascular disease despite having increased rates of disease and Māori being less likely to be diagnosed and treated for depression [43]. These findings, coupled with international evidence of Indigenous women and women from minority groups being less likely to be recommended maternal vaccination, suggest racism and unconscious bias likely to contribute to who does and does not receive a recommendation for maternal vaccination in NZ.

This study has a number of limitations. Firstly, influenza vaccinations delivered in workplaces are not usually captured by governmental claims data or registered in the National Immunisation Register (NIR). Consequently, it is possible pregnant women who received their influenza vaccination through an occupational scheme have not been included in this study and therefore maternal influenza coverage may have been underestimated. A second limitation of this study is that area level deprivation has been analysed, as opposed to individual deprivation. Individual-level deprivation is associated with worse health-related quality of life and results in greater health inequities compared with area

level deprivation [44]. Therefore, the impact of deprivation on maternal vaccination is likely to have been underestimated in this study. Due to the limitations of administrative data, changes to specific enablers and barriers to maternal vaccination, such as health-seeking or health practitioner behaviours, have not been reported on. Lastly, this study does not interpret the odds as risk, it is worth noting that odds ratios calculated using logistic regression can over-estimate the relative risk [45].

## 5. Conclusion

This nationwide retrospective cohort study is one of the first to investigate variation in maternal vaccination coverage in pregnancy women by ethnicity and specific components of deprivation over time. While maternal vaccination coverage increased during 2013 to 2018 it is still suboptimal and inequities by ethnicity and socio-economic deprivation increased. Given the inequitable burden of pertussis infections is in Māori and Pacific infants [46], NZ must commit to solutions that increase maternal vaccination coverage for Māori and Pacific women. This is also crucial in order for NZ to meet obligations to uphold Māori rights under te Tiriti o Waitangi and the United Nations Declaration on the Rights of Indigenous Peoples.

The current model of vaccination in pregnancy relies on women mobilising a range of resources including their own knowledge of antenatal care and finances and overcoming physical and inconvenience access barriers, as well as healthcare bias. The ability to mobilise such resource and overcome such barriers, is less likely to be within reach of Indigenous, ethnic minority and socially deprived women. Understanding how to increase uptake for maternal vaccinations is critical for the health of our mothers and their infants, even more so in this COVID-19 era with unvaccinated pregnant women being at high risk of severe COVID-19 infection. The roll out of COVID-19 vaccinations and the novel solutions being sought to get coverage in hard-to-reach populations provides an opportunity to create a more responsive service with a greater focus on equity. Solutions generated from within Māori and Pacific communities with engaged and responsive health services have been successful in addressing inequities in other public health issues and are needed again to address the inequities found here.

### CRedit authorship contribution statement

**Leah Pointon:** Conceptualization, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, Visualization. **Anna S Howe:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Data curation, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration. **Matthew Hobbs:** Conceptualization, Writing – original draft, Writing – review & editing, Visualization. **Janine Paynter:** Conceptualization, Methodology, Formal analysis, Investigation, Resources, Writing – review & editing, Supervision. **Natalie Gauld:** Conceptualization, Formal analysis, Writing – review & editing. **Nikki Turner:** Conceptualization, Writing – review & editing. **Esther Willing:** Conceptualization, Writing – review & editing.

### Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgements

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. We would like to thank Barbara McArdle, National Influenza Coordinator, Immunisation Advisory Centre, for her invaluable knowledge and advice.

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: NG has received funding from Green Cross Health (a provider of primary health care services including pharmacy and general practice), the Pharmacy Guild of New Zealand and the Pharmaceutical Society of New Zealand for reclassifying vaccinations to allow pharmacist administration. NG has led an investigator-led study funded by GSK. JP and ASH have been investigators on GSK funded studies.

## Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.vaccine.2022.02.079>.

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