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RESEARCH PAPER

Vaccination information fathers receive during pregnancy and determinants of infant vaccination timeliness

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ABSTRACT

The information fathers receive about infant vaccination may influence their decision to vaccinate. We describe fathers' sources of vaccination information and paternal determinants of timely infant vaccinations. Participants were from a child cohort study in New Zealand. The child cohort was established by enrolling pregnant women and their partners. During pregnancy, fathers (n = 4017) of the cohort children born 2009–2010 described information sources that encouraged or discouraged infant vaccination. The National Immunization Register provided infant vaccination data. Independent associations of the vaccination information received by fathers with the timeliness of their infant's vaccination were determined using multivariable logistic regression. Associations were described using adjusted odds ratios and 95% confidence intervals. One-third of fathers (1430/4017 [36%]) recalled receiving vaccination information, 64% of which encouraged vaccination. Most infants (2900/4017 [72%]) received all their vaccinations on time, however only 58% of Māori infants were vaccinated on time. Paternal determinants of vaccination timeliness were the father receiving discouraging or conflicting information about vaccination, father's ethnicity, father's vaccination hesitancy, and whether the mother received vaccination information. To improve vaccination uptake and timeliness, a vaccination conversation with mothers, fathers and whānau could be included in routine antenatal care, informing and supporting decision-making, and addressing concerns. Vaccination education should address present and historic distrust of the health system. Framing vaccination within a Māori model of health and including fathers and whānau in decision-making will address vaccination inequities in New Zealand.

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Introduction

Vaccination is one of the world's most effective public health interventions.[1] Timely infant vaccinations are essential to achieve the full population health benefits of national vaccination programs. Delayed receipt of infant vaccinations increases the risk of hospital admission with vaccine-preventable diseases during infancy.[2,3]

Most parents make decisions about their infant's vaccinations during pregnancy.[4–8] In a New Zealand (NZ) study, 86% of mothers and 78% of fathers reported deciding about infant vaccination during pregnancy.[7] Most Australian mothers (81%) reported deciding about vaccination during pregnancy.[8] However, mothers' and fathers' vaccination intentions are independently associated with vaccination timeliness.[7,8] Infants of mothers and fathers who intend to fully vaccinate their child have increased odds of receiving their infant vaccinations on time, independent of the other parent's intentions.[7]

Parents receive information about vaccination from multiple sources, including family/friends, healthcare providers, and the media.[9] This information may encourage or discourage vaccination. Recently, we found that only 44% of mothers recalled receiving any information about infant vaccinations during pregnancy.[10] Timely infant vaccination was less likely when mothers received discouraging or conflicting (i.e. encouraging and discouraging) information about vaccination. Surprisingly, receiving information that encouraged vaccination was not associated with vaccination timeliness.[10]

Most studies investigating vaccination education, infant vaccination uptake, and timeliness have focused on expectant mothers. However, fathers can influence mothers' health decisions during pregnancy, such as prenatal care, smoking, and alcohol intake.[11,12] Educational interventions targeting fathers can improve infant outcomes. For example, breastfeeding education that targets fathers is associated with improved breastfeeding initiation, exclusivity, and continuation.[13] Similarly, the information that fathers receive about vaccination during pregnancy could influence vaccination decision-making. In this study, we describe information fathers receive about vaccination during pregnancy and paternal determinants of timely infant vaccinations.

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Methods

Study design and setting

This project occurred within NZ's contemporary child cohort study, *Growing Up in New Zealand* (*GUiNZ*) (www.growingup.co.nz). The study recruited pregnant women with an expected due date between 25-April-2009 and 25-March-2010, and their partners.[14] Participants were resident in a geographically defined region of NZ chosen for its population diversity. The enrolled cohort (11% of all children born in NZ during the study period) is generalizable to all NZ births from 2007–2010.[15] The GUiNZ cohort has adequate explanatory power to undertake complex longitudinal analyses, both across the whole cohort, and within ethnic and socioeconomic subgroups.[14] Ethical approval was from the NZ Ministry of Health Ethics Committee. All enrolled mothers and fathers provided written informed consent.

Study population and sample

Upon study enrollment, pregnant women provided contact details for their current partner (defined as the partner she was currently in a 'significant social relationship with'). Interviewers contacted partners independently to invite their participation in the study.[14] Most (99%) of the participating partners stated that they were the child's biological father.[16] There were no exclusion criteria.

Growing Up in New Zealand recruited 6822 pregnant women, 4401 fathers, and their 6853 children born during 2009–2010.[14] These analyses comprise fathers enrolled and interviewed during the mother's pregnancy (n = 4198) and for whom linkage with their child's vaccination records was established (n = 4017) (Figure 1). Analyses on vaccination timeliness only included the first-born child of multiple pregnancies. For all but two of the 62 sets of twins/triplets in the cohort, vaccination coverage and timeliness were identical.

Data collection

We interviewed fathers independently of pregnant women, with each father in this study completing a computer-assisted face-to-face enrollment interview during the pregnancy. We asked fathers if they had received any information encouraging them to, or discouraging them from, vaccinating their child during infancy (see Figure 2 for questions). Fathers then identified all sources of encouraging or discouraging information from the following 13 response options related to general information sources and those specific to pregnancy: family; friends; the family doctor; midwife; obstetrician; dietician or nutritionist; alternative healthcare practitioner; antenatal class; the internet; radio; television; printed media; or other sources (Figure 2). In NZ, there is a choice of pregnancy healthcare provider: family doctor (general practitioner), midwife, or obstetrician. Most women have a midwife as their main pregnancy healthcare provider.[17] Antenatal class attendance is encouraged but not mandatory.

Childhood vaccines on the NZ Vaccination Schedule are free of charge.[18] Vaccination information for children participating in the cohort study was obtained (with parental consent) from the National Immunization Register (NIR).[19] The National Health Index number, a unique identifier assigned

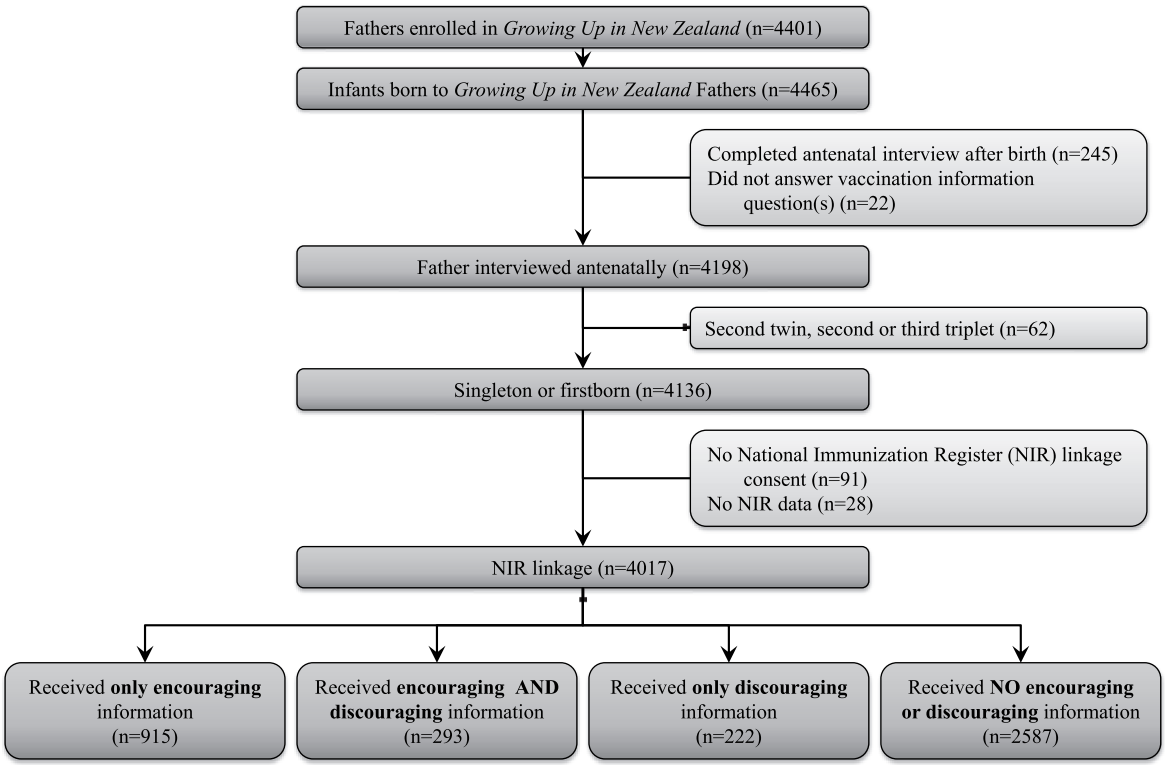

Figure 1. Study recruitment, antenatal interview, and the father's receipt of encouraging and/or discouraging information about infant vaccination during the current pregnancy.

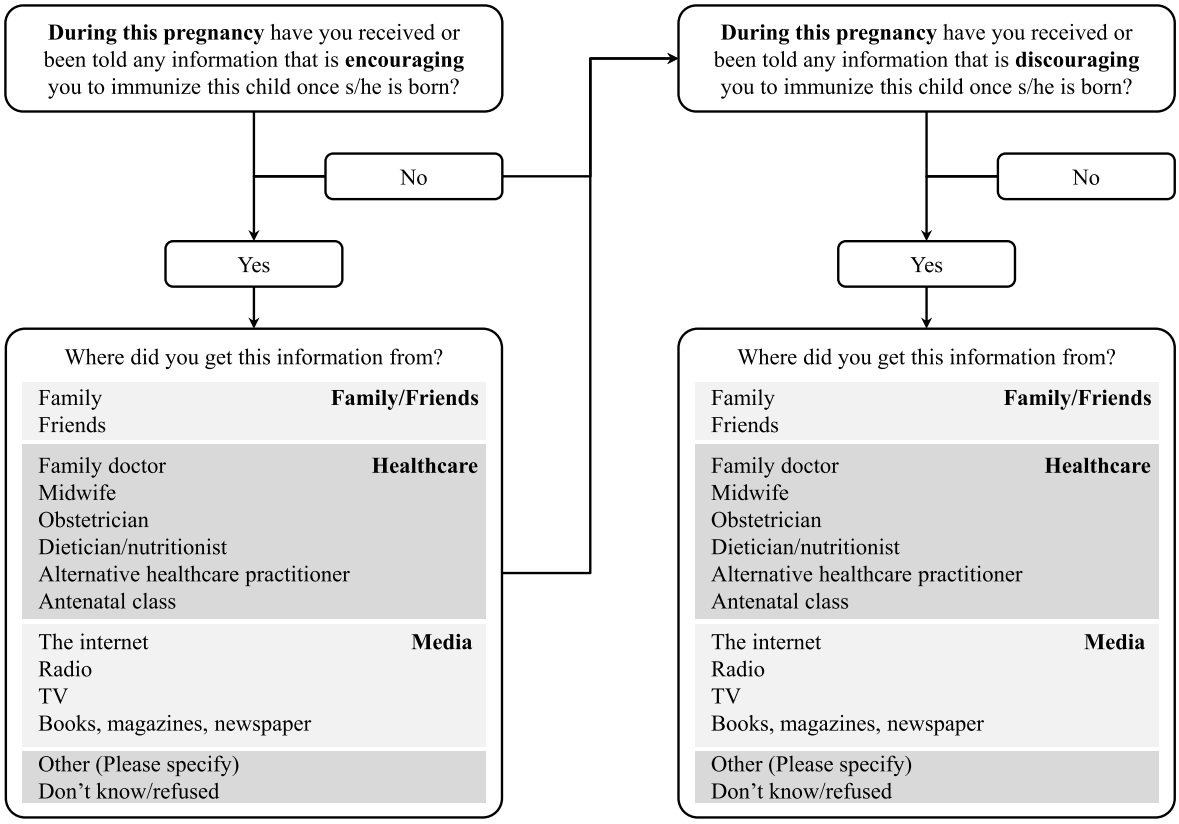

Figure 2. Questions asked of fathers at the antenatal interview regarding whether they had received information encouraging and/or discouraging them to vaccinate their expected child and the sources of this information. Fathers were interviewed independently of pregnant women.

to every person using healthcare services in NZ, established linkage with the NIR. For these analyses, NIR linkage was possible for 4017/4136 (97%) of the eligible infants.

Measurements

When the study children were infants (2009–2010), the NZ vaccination schedule consisted of six-week, three-month, and five-month doses of two vaccines: (i) diphtheria/tetanus/acellular pertussis/*Haemophilus influenzae* type B/hepatitis B/poliovirus; and (ii) pneumococcal conjugate vaccine.[18] Vaccinations were on time if received within 30 days of their recommended date.[20–23] There were three measures of vaccination timeliness used: (i) all vaccinations received on time (primary outcome); (ii) the six-week vaccinations received on time; and (iii) no vaccinations received on time. Timely receipt of the six-week vaccinations was included as a separate outcome due to its strong association with delay in subsequent vaccinations.[24]

Fathers' socioeconomic status and education were collected within the *GUiNZ* study using measures from Statistics NZ's 2006 national census and the 2008 General Social Survey.[25,26] Area-level socio-economic deprivation was measured using the 2006 NZ Index of Deprivation (NZDep06), grouped as quintiles.[27] NZDep06, derived from 2006 census data on nine socioeconomic characteristics, is a well-validated small-area measure of socioeconomic deprivation in NZ.[27]

For analysis purposes, we combined vaccination information sources into three groups: family/friends, healthcare, and media.

Statistical methods

We described the proportion of fathers receiving encouraging and/or discouraging information about vaccination from all sources. Father and household demographics known to be related to vaccination timeliness were described,[21] and the associations of these variables with receipt of only encouraging, both encouraging and discouraging (i.e. conflicting), or only discouraging information were examined using the Chi-square test. For analysis purposes, we combined all healthcare providers into one category because in NZ caregivers seek child healthcare from a wide variety of care providers. In addition, families seek care from complimentary healthcare providers typically as an adjunct rather than an alternative to conventional healthcare.[28] Using multivariable logistic regression, we determined whether receiving only encouraging, conflicting, or only discouraging information were independently associated with vaccination timeliness. Father and household characteristics with a significant two-sided *P*-value of <0.05 were included in the final model and the results reported using adjusted odds ratios (OR) and 95% confidence intervals (CI). We performed statistical analyses using SAS version 9.4 (SAS Institute, Cary, NC).

Results

Fathers' receipt of vaccination information during pregnancy

This study included 4017/4401 (91%) fathers of children enrolled in *GUiNZ* and interviewed during the mother's

pregnancy (Figure 1). Most fathers (2587/4017; 64%) did not recall receiving information about infant vaccination during pregnancy. Of the 1430 (36%) fathers who recalled receiving infant vaccination information during the pregnancy, 915 (64%) fathers received only encouraging information, 222 (16%) received only discouraging information, and 293 (20%) received both encouraging and discouraging (conflicting) vaccination information. Only 824/4017 (21%) mother-father pairs in this study recalled receiving vaccination information during pregnancy.

Fathers' sources of infant vaccination information

About two-thirds (931/1430, 65%) of fathers received vaccination information from multiple sources, 480/915 (52%) received encouraging information, and 83/222 (38%) received discouraging information from two-or-more sources.

Almost two-thirds of fathers who received vaccination information cited healthcare sources (64%), with a smaller proportion citing family/friends (44%) or media sources (46%) (Figure 3). Of those who identified healthcare sources, 87% received information encouraging vaccination. Of the fathers who received vaccination information from each source, this information was discouraging for a significantly larger proportion of those receiving information from family/friends (27%) or media (27%) compared with healthcare sources (5%). Conflicting information was significantly more common from media sources (18%) than healthcare sources (8%).

Encouraging vaccination information was common from friends (71%), family doctors (78%) and midwives (78%) (Table 1). There was a moderate level of conflicting information reported from antenatal classes (31%) and when fathers cited two-or-more information sources from family/friends (43%), healthcare (28%) and media (40%). Discouraging information was mostly from friends (31%) and different media sources (14–27%).

The type of vaccination information received during pregnancy was independently associated with the father's ethnicity, education, household structure, age group, employment and household deprivation; whether the father had decided about vaccinating their expected child; and whether the mother received vaccination information (Supplementary Table 1).

Compared to fathers of European ethnicity, fathers of Māori (OR = 1.49, 95%CI 1.13–1.96), Pacific (OR = 1.83, 95%CI 1.39–2.40) or Asian (OR = 2.53, 95%CI 2.01–3.18) ethnicity had increased odds of receiving encouraging vaccination information; and decreased odds of receiving conflicting vaccination information (Māori: OR = 0.63, 95%CI 0.38–0.99; Pacific: OR = 0.47, 95%CI 0.27–0.78; Asian: OR = 0.39, 95%CI 0.23–0.62) (Table 2). Additionally, fathers of Pacific (OR = 0.26, 95% CI 0.11–0.52) or Asian ethnicity (OR = 0.17, 95%CI 0.07–0.34) had decreased odds of receiving discouraging vaccination information and fathers of Asian ethnicity had decreased odds of receiving no vaccination information (OR = 0.74, 95%CI 0.60–0.92), compared to fathers with European ethnicity.

Compared to fathers with a tertiary education, fathers with a primary (OR = 1.49, 95%CI 1.12–2.01) or secondary (OR = 1.27, 95%CI 1.07–1.51) education had increased odds of receiving no vaccination information. Compared to fathers living in two parent households, fathers living alone or with non-kin had decreased odds of receiving encouraging vaccination information (OR = 0.66, 95%CI 0.46–0.94). Younger fathers (<20 years old) had increased odds of receiving encouraging vaccination information (OR = 2.19, 95%CI 1.24–3.81). Compared to employed fathers, unemployed fathers had decreased odds of receiving encouraging vaccination information (OR = 0.70, 95%CI 0.48–0.99) and student fathers had increased odds of receiving conflicting vaccination information (OR = 1.50, 95%CI 1.06–2.08). Compared to fathers living in the least deprived households (first quintile), fathers living in slightly (second quintile; OR = 1.56, 95%CI

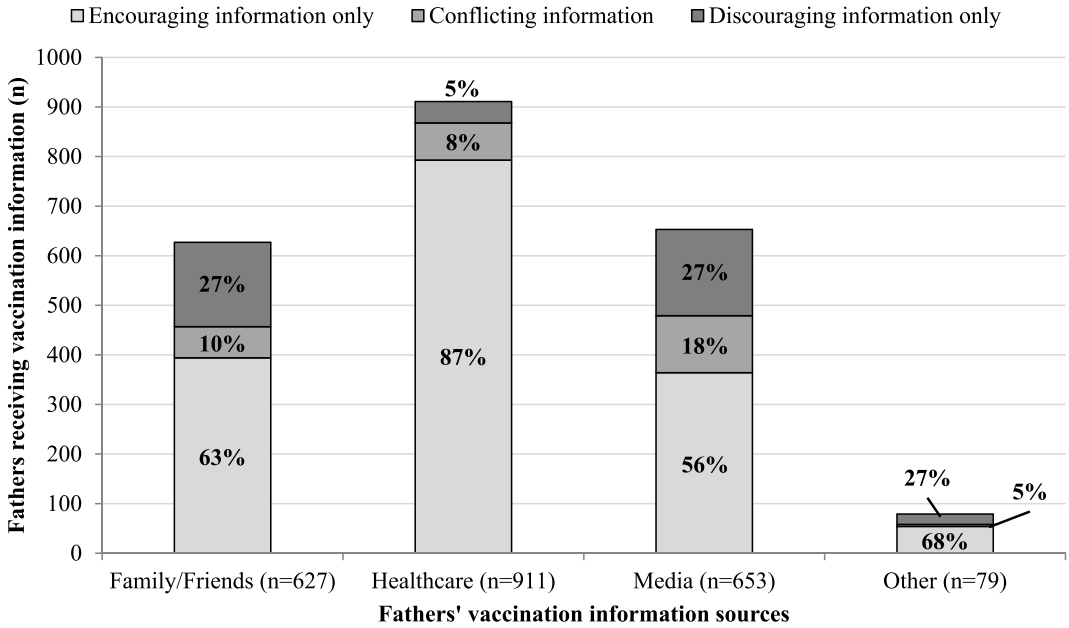

Figure 3. Sources of information that encouraged and/or discouraged fathers from vaccinating their infant.

Table 1. Fathers' sources of antenatal information encouraging or discouraging infant vaccination (n = 4017).

		Type of information received antenatally about infant vaccinations			
Source of Vaccination information	N (column %)	Encouraging information only n = 915 n (row %)	Conflicting Information* n=293 n (row %)	Discouraging information only n=222 n (row %)	P-value†
Family/Friends	**627**				**<0.001**
Family only	236 (38)	168 (71)	45 (19)	23 (10)	
Friends only	201 (32)	79 (39)	59 (29)	63 (31)	
Family and friends	190 (30)	89 (47)	82 (43)	19 (10)	
Healthcare providers	**911**				**<0.001**
Family doctor (General practitioner) only	186 (20)	146 (78)	33 (18)	<10	
Midwife only	287 (32)	224 (78)	51 (18)	12 (4)	
Obstetrician only	19 (2)	12 (63)	<10	0 (0)	
Dietician/nutritionist only	0 (0)	0 (0)	0 (0)	0 (0)	
Complimentary healthcare practitioner only	14 (2)	<10	<10	<10	
Antenatal class only	110 (12)	70 (64)	34 (31)	<10	
Two-or-more healthcare sources	295 (32)	211 (72)	82 (28)	<10	
Media	**653**				**0.003**
The internet only	48 (7)	21 (44)	15 (31)	12 (25)	
Radio only	37 (6)	19 (51)	<10	10 (27)	
Television only	191 (29)	101 (53)	46 (24)	44 (23)	
Books, magazines, newspaper only	119 (18)	73 (61)	29 (24)	17 (14)	
Two-or-more media sources	258 (40)	113 (44)	102 (40)	43 (17)	
Other	79 (100)	40 (51)	27 (34)	12 (15)	N/A

*Both encouraging and discouraging information.
†*P*-value derived from Chi square test or Fisher's exact test.

1.01–2.44) and moderately (third quintile; OR = 1.70, 95%CI 1.09–2.66) deprived households had increased odds of receiving discouraging vaccination information.

Compared to fathers who were decided about vaccination, fathers who were undecided about vaccination had decreased odds of receiving encouraging vaccination information (OR = 0.58, 95%CI 0.47–0.71) and increased odds of receiving discouraging (OR = 1.39, 95%CI 1.02–1.88) or no (OR = 1.30, 95%CI 1.10–1.54) vaccination information. When mothers recalled receiving vaccination information, fathers had increased odds of receiving encouraging (OR = 1.88, 95%CI 1.61–2.19), conflicting (OR = 2.55, 95%CI 1.99–3.28) or discouraging vaccination information (OR = 1.42, 95%CI 1.08–1.87) and decreased odds of receiving no vaccination information (OR = 0.44, 95%CI 0.38–0.50). Statistically significant variables in Supplementary Table 1 were included in the multivariable logistic regression analyses as described below.

Paternal factors associated with timeliness of infant vaccinations

The infant vaccination series (given at ages six-weeks, three-months, and five-months old) was received by 3551/4017 (88%) infants, with 2900/4017 (72%) receiving all vaccinations on time (Supplementary Table 2). The six-week vaccinations were received on time by 3496/4017 (87%) infants. All infant vaccinations were delayed for 401/4017 (10%) infants.

Vaccination timeliness was independently associated with the father's ethnicity, education and vaccination decision-making, mother's receipt of vaccination information, and the type of vaccine information the father received during pregnancy (Table 3). Infants whose father was of Māori (OR = 0.56, 95%CI 0.44–0.71) or Pacific ethnicity (OR = 0.71, 95%CI 0.55–0.92), had decreased odds of receiving all vaccinations on time, compared to infants whose father was European. Infants whose father was of Asian ethnicity had increased odds of being vaccinated on time (OR = 1.88, 95%CI 1.45–2.48) (Table 3). Timely receipt of the six-week vaccinations and delayed receipt of all infant vaccinations were also associated with paternal ethnicity, with infants whose father was of Māori ethnicity having decreased odds of vaccination timeliness and increased odds of vaccination delay. Infants whose father's were of Pacific or Asian ethnicity had increased odds of receiving the six-week vaccinations on time and decreased odds of delay in receiving all of the infant vaccinations.

When fathers had only a primary school education, their infants had decreased odds of receiving their vaccinations on time (OR = 0.73, 95%CI 0.56–0.96) compared with fathers who had a tertiary education.

Compared to receiving no vaccination information, fathers' receipt of conflicting vaccination information was associated with decreased timeliness of all infant vaccinations (OR = 0.71, 95%CI 0.54–0.92) and the six-week vaccinations (OR = 0.57, 95%CI 0.42–0.78). If fathers received conflicting vaccination information the odds of vaccination delay were increased (OR = 2.00, 95%CI 1.41–2.79). Likewise, if fathers received discouraging vaccination information the odds of timely six-week vaccinations (OR = 0.45, 95%CI 0.33–0.63) and timely complete infant vaccination series (OR = 0.55, 95%CI 0.41–0.74) were decreased and the odds of vaccination delay were increased (OR = 2.36, 95%CI 1.64–3.34). Paternal receipt of encouraging vaccination information was not associated with infant vaccination timeliness.

When a father was undecided about vaccination, their infant was at decreased odds of being vaccinated on time (OR = 0.75, 95%CI 0.63–0.89). When the infant's mother recalled receiving vaccination information, the odds of timely six-week vaccinations were decreased (OR = 0.79, 95%CI 0.65–

Table 2. Association of father and household characteristics with antenatal receipt of information about infant vaccination (n = 4017).

	Type of information received antenatally about infant vaccinations							
	Encouraging only n=915		Conflicting n=293		Discouraging only n=222		No information	
Father and household characteristics	Adjusted Odds Ratio (95% CI)	Forest Plot	Odds Ratio (95% CI)	Forest Plot	Odds Ratio (95% CI)	Forest Plot	Odds Ratio (95% CI)	Forest Plot
Relationship with mother								
No relationship or dating	0.84 (0.41-1.62)		0.77 (0.18-2.33)		0.26 (0.01-1.31)		1.50 (0.83-2.82)	
Cohabitating	0.92 (0.76-1.11)		1.13 (0.84-1.50)		0.97 (0.70-1.33)		1.03 (0.87-1.21)	
Married or civil union	1.00		1.00		1.00		1.00	
Household Structure								
Parent alone or with non-kin	**0.66 (0.46-0.94)**		1.26 (0.73-2.08)		1.42 (0.75-2.48)		1.17 (0.87-1.59)	
Two parents	1.00		1.00		1.00		1.00	
Parent(s) and extended family	0.92 (0.75-1.13)		0.98 (0.68-1.40)		1.18 (0.77-1.75)		1.03 (0.85-1.24)	
Self-prioritized ethnicity[†]	***		***		***			
European	1.00		1.00		1.00		1.00	
Māori	**1.49 (1.13-1.96)**		**0.63 (0.38-0.99)**		0.78 (0.46-1.24)		0.92 (0.72-1.18)	
Pacific	**1.83 (1.39-2.40)**		**0.47 (0.27-0.78)**		**0.26 (0.11-0.52)**		0.95 (0.74-1.22)	
Asian	**2.53 (2.01-3.18)**		**0.39 (0.23-0.62)**		**0.17 (0.07-0.34)**		**0.74 (0.60-0.92)**	
Other	1.04 (0.70-1.50)		0.73 (0.40-1.26)		1.12 (0.63-1.87)		1.04 (0.76-1.43)	
Age group	*							
<20	**2.19 (1.24-3.81)**		0.52 (0.08-1.84)		0.60 (0.09-2.18)		0.62 (0.37-1.07)	
20-29	1.17 (0.97-1.40)		1.03 (0.76-1.39)		0.92 (0.65-1.29)		0.90 (0.77-1.06)	
30-39	1.00		1.00		1.00		1.00	
>40	0.90 (0.71-1.13)		1.04 (0.72-1.46)		1.04 (0.69-1.53)		1.07 (0.88-1.30)	
Education							**	
Primary	0.83 (0.59-1.15)		0.57 (0.29-1.02)		0.60 (0.27-1.15)		**1.49 (1.12-2.01)**	
Secondary	0.85 (0.70-1.04)		0.70 (0.49-0.97)		0.92 (0.63-1.32)		**1.27 (1.07-1.51)**	
Tertiary	1.00		1.00		1.00		1.00	
Employment								
Employed	1.00		1.00		1.00		1.00	
Unemployed	**0.70 (0.48-0.99)**		0.86 (0.41-1.63)		1.42 (0.71-2.60)		1.27 (0.93-1.75)	
Student	0.82 (0.64-1.05)		**1.50 (1.06-2.08)**		1.07 (0.69-1.59)		1.00 (0.81-1.22)	
Not in workforce	1.16 (0.68-1.94)		1.38 (0.52-3.08)		0.68 (0.11-2.25)		0.83 (0.51-1.36)	
Household deprivation[‡]								
1 to 2 (least deprived)	1.00		1.00		1.00		1.00	
3 to 4	0.89 (0.69-1.15)		0.80 (0.55-1.15)		**1.56 (1.01-2.44)**		1.06 (0.85-1.31)	
5 to 6	0.97 (0.75-1.26)		0.70 (0.47-1.04)		**1.70 (1.09-2.66)**		1.00 (0.80-1.25)	
7 to 8	1.02 (0.79-1.31)		0.93 (0.64-1.36)		1.35 (0.84-2.18)		0.94 (0.76-1.17)	
9 to 10 (most deprived)	1.03 (0.79-1.34)		0.88 (0.58-1.31)		1.38 (0.83-2.29)		0.94 (0.75-1.18)	
Infant vaccination[§]	***				*		**	
Decided	1.00		1.00		1.00		1.00	
Undecided	**0.58 (0.47-0.71)**		1.05 (0.79-1.40)		**1.39 (1.02-1.88)**		**1.30 (1.10-1.54)**	
Mother received vaccination information	***		***		*		***	
No	1.00		1.00		1.00		1.00	
Yes	**1.88 (1.61-2.19)**		**2.55 (1.99-3.28)**		**1.42 (1.08-1.87)**		**0.44 (0.38-0.50)**	
	0 1 2 3 4 Odds Ratio (95% CI)		0 1 2 3 4 Odds Ratio (95% CI)		0 1 2 3 4 Odds Ratio (95% CI)		0 1 2 3 4 Odds Ratio (95% CI)	

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; remaining findings were not statistically significant.
[†]Other includes Middle Eastern, Latin American, and African.
[‡]Area-level socioeconomic deprivation was measured using the NZ Index of Deprivation, Dep 1 to 2 = least deprived, Dep 9 to 10 = most deprived households.[27]
[§]Whether each father was decided about the vaccination of his expected child.[7]

0.96) and the odds of delayed vaccinations were increased (OR = 1.37, 95%CI 1.10–1.70). Household structure and household deprivation were not independently associated with vaccination timeliness.

Timeliness of vaccinations from family/friends, healthcare and media sources

We examined three information source types, family/friends, healthcare and media, separately to better understand their associations with vaccination timeliness (Tables 4–6).

The odds of receiving all vaccinations on time were decreased when fathers received conflicting information from family/friends (OR = 0.43, 95%CI 0.26–0.72), or received discouraging information from family/friends (OR = 0.41, 95%CI 0.30–0.56) or healthcare (OR = 0.40, 95%CI 0.21–0.73) (Tables 4–6).

The odds of receiving the six-week vaccinations on time were increased when fathers received encouraging information from family/friends (OR = 1.46, 95%CI 1.01–2.17) or healthcare (OR = 1.37, 95%CI 1.05–1.80). The odds of receiving the six-week vaccinations on time was decreased when fathers received conflicting information or discouraging information from any of the three sources (Tables 4–6).

The odds of all vaccinations being delayed were decreased when fathers received encouraging information from healthcare sources (OR = 0.72, 95%CI = 0.53–0.98). The odds of all

Table 3. Associations of father and household characteristics with infant vaccination timeliness when father received vaccination information from any source (n = 4017).

	Father received vaccination information from any source					
	Received all vaccinations on time (n=2900)		Received six-week vaccinations on time (n=3496)		All infant vaccinations delayed (n=401)	
Father and household characteristics	**Adjusted* Odds Ratio (95% CI)**	**Forest Plot**	**Adjusted* Odds Ratio (95% CI)**	**Forest Plot**	**Adjusted* Odds Ratio (95% CI)**	**Forest Plot**
Information type	***		***		***	
Encouraging only	0.97 (0.81-1.16)		1.24 (0.96-1.61)		0.86 (0.63-1.15)	
Conflicting‡	**0.71 (0.54-0.92)**		**0.57 (0.42-0.78)**		**2.00 (1.41-2.79)**	
Discouraging only	**0.55 (0.41-0.74)**		**0.45 (0.33-0.63)**		**2.36 (1.64-3.34)**	
No information	1.00		1.00		1.00	
Household Structure						
Parent alone or with non-kin	0.85 (0.64-1.15)		0.98 (0.66-1.49)		1.00 (0.62-1.54)	
Two parents	1.00		1.00		1.00	
Parent(s) and extended family	0.90 (0.75-1.09)		0.93 (0.72-1.21)		1.08 (0.80-1.43)	
Self-prioritized ethnicity	***		***		***	
European	1.00		1.00		1.00	
Māori	**0.56 (0.44-0.71)**		**0.66 (0.50-0.89)**		**1.66 (1.21-2.26)**	
Pacific	**0.71 (0.55-0.92)**		**1.87 (1.26-2.85)**		**0.49 (0.30-0.77)**	
Asian	**1.88 (1.45-2.48)**		**2.60 (1.72-4.06)**		**0.22 (0.11-0.38)**	
Other	0.96 (0.69-1.33)		0.86 (0.58-1.30)		1.22 (0.77-1.87)	
Education						
Primary	**0.73 (0.56-0.96)**		0.82 (0.58-1.19)		1.14 (0.75-1.69)	
Secondary	0.95 (0.79-1.14)		0.98 (0.77-1.25)		0.89 (0.67-1.17)	
Tertiary	1.00		1.00		1.00	
Household deprivation§						
1 to 2 (least deprived)	1.00		1.00		1.00	
3 to 4	0.86 (0.68-1.08)		0.90 (0.67-1.22)		1.06 (0.76-1.48)	
5 to 6	0.85 (0.67-1.07)		0.90 (0.66-1.22)		0.99 (0.70-1.40)	
7 to 8	1.07 (0.85-1.37)		0.98 (0.71-1.34)		0.91 (0.64-1.30)	
9 to 10 (most deprived)	0.80 (0.63-1.01)		0.82 (0.60-1.13)		1.20 (0.84-1.70)	
Infant vaccination‖	***		***		***	
Decided	1.00		1.00		1.00	
Undecided	**0.75 (0.63-0.89)**		**0.61 (0.50-0.76)**		**1.71 (1.36-2.15)**	
Mother received vaccination information			*		**	
No	1.00		1.00		1.00	
Yes	0.88 (0.76-1.02)		**0.79 (0.65-0.96)**		**1.37 (1.10-1.70)**	
		0 1 2 3 4 5 Odds Ratio (95% CI)		0 1 2 3 4 5 Odds Ratio (95% CI)		0 1 2 3 4 5 Odds Ratio (95% CI)

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; remaining findings were not statistically significant.
†Multivariable analysis adjusted for father ethnicity and education; household structure and deprivation; whether each father, when interviewed, was decided about their vaccination intentions for their child; and whether the child's mother received information about vaccination.
‡Both encouraging and discouraging information.
§Area-level socioeconomic deprivation was measured using the NZ Index of Deprivation, Dep 1 to 2 = least deprived, Dep 9 to 10 = most deprived households.[27]
‖Whether each father was decided about the vaccination of his expected child.[7]
CI – confidence interval.

vaccinations being delayed were increased when fathers received conflicting information or discouraging information from any of the three sources (Tables 4–6).

Discussion

Pregnancy and antenatal care offer an important opportunity to provide appropriate and accessible information to expectant parents and to support their decision-making about infant vaccinations. This is the first study to examine paternal determinants of vaccination timeliness and the relationship between the information fathers receive about infant vaccination during pregnancy.

Most parents decide about infant vaccinations during pregnancy, including 78% of fathers in this study.[4–8] When fathers were undecided about vaccinations, their infant had reduced odds of timely vaccinations. This is also true in mothers, where vaccination delay is more likely for infants of mothers who are undecided about vaccination.[10] When mothers have a higher knowledge of vaccine-preventable diseases and vaccines, they are more likely to intend to get their infant vaccinated.[29] There is a positive association with vaccination timeliness when parents intend to fully vaccinate their infant.[7]

One-third of fathers received information about infant vaccinations during pregnancy, compared to 44% of pregnant women in the same cohort.[10] Two-thirds of these fathers received information encouraging infant vaccination but this was not associated with vaccination timeliness, similar to findings in mothers.[10] Infants of fathers who received conflicting or discouraging information had decreased odds of timely vaccinations, again consistent with our findings in mothers.[10] An earlier NZ study found that children were less likely to receive timely vaccinations in primary care practices where caregivers reported receiving information that discouraged vaccination.[30]

We found that healthcare was a source of conflicting vaccination information. Healthcare providers, especially doctors, midwives, and nurses, are a common and trusted source of vaccination information and they have a professional responsibility to convey impartial, honest, and accurate vaccination

Table 4. Associations of father and household characteristics with infant vaccination timeliness when father received vaccination information from family/friends (n = 4017).

	Father received vaccination information from family/friends					
	Received all vaccinations on time (n=2900)		Received six-week vaccinations on time (n=3496)		All infant vaccinations delayed (n=401)	
Father and household characteristics	Adjusted* Odds Ratio (95% CI)	Forest Plot	Adjusted* Odds Ratio (95% CI)	Forest Plot	Adjusted* Odds Ratio (95% CI)	Forest Plot
Information type	***		***		***	
Encouraging only	1.16 (0.90-1.50)		**1.46 (1.01-2.17)**		0.77 (0.49-1.15)	
Conflicting‡	**0.43 (0.26-0.72)**		**0.42 (0.24-0.76)**		**2.96 (1.59-5.27)**	
Discouraging only	**0.41 (0.30-0.56)**		**0.33 (0.23-0.47)**		**3.17 (2.19-4.54)**	
No information	1.00		1.00		1.00	
Household Structure						
Parent alone or with non-kin	0.84 (0.63-1.14)		0.93 (0.63-1.42)		1.04 (0.65-1.62)	
Two parents	1.00		1.00		1.00	
Parent(s) and extended family	0.90 (0.75-1.09)		0.93 (0.72-1.20)		1.08 (0.80-1.45)	
Self-prioritized ethnicity	***		***		***	
European	1.00		1.00		1.00	
Māori	**0.55 (0.44-0.70)**		**0.67 (0.50-0.89)**		**1.65 (1.20-2.25)**	
Pacific	**0.70 (0.55-0.90)**		**1.90 (1.28-2.89)**		**0.48 (0.29-0.76)**	
Asian	**1.86 (1.43-2.45)**		**2.67 (1.78-4.18)**		**0.21 (0.11-0.37)**	
Other	0.97 (0.70-1.35)		0.87 (0.59-1.32)		1.20 (0.76-1.84)	
Education						
Primary	**0.74 (0.56-0.97)**		0.84 (0.59-1.21)		1.11 (0.73-1.65)	
Secondary	0.96 (0.80-1.15)		1.00 (0.78-1.28)		0.87 (0.65-1.15)	
Tertiary	1.00		1.00		1.00	
Household deprivation§	*					
1 to 2 (least deprived)	1.00		1.00		1.00	
3 to 4	0.84 (0.67-1.06)		0.88 (0.65-1.19)		1.09 (0.78-1.52)	
5 to 6	0.83 (0.66-1.05)		0.89 (0.65-1.21)		1.00 (0.71-1.41)	
7 to 8	1.08 (0.85-1.37)		0.98 (0.72-1.35)		0.90 (0.63-1.29)	
9 to 10 (most deprived)	0.80 (0.62-1.01)		0.83 (0.60-1.14)		1.19 (0.83-1.69)	
Infant vaccinationǀ	**		***		***	
Decided	1.00		1.00		1.00	
Undecided	**0.77 (0.65-0.91)**		**0.62 (0.51-0.77)**		**1.68 (1.33-2.12)**	
Mother received vaccination information			*		**	
No	1.00		1.00		1.00	
Yes	0.88 (0.76-1.02)		**0.79 (0.65-0.96)**		**1.37 (1.10-1.70)**	
	0 1 2 3 4 5 6 Odds Ratio (95% CI)		0 1 2 3 4 5 6 Odds Ratio (95% CI)		0 1 2 3 4 5 6 Odds Ratio (95% CI)	

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; remaining findings were not statistically significant.
†Multivariable analysis adjusted for father ethnicity and education; household structure and deprivation; whether each father, when interviewed, was decided about their vaccination intentions for their child; and whether the child's mother received information about vaccination.
‡Both encouraging and discouraging information.
§Area-level socioeconomic deprivation was measured using the NZ Index of Deprivation, Dep 1 to 2 = least deprived, Dep 9 to 10 = most deprived households.[27]
ǀWhether each father was decided about the vaccination of his expected child.[7]
CI – confidence interval.

information.[31–34] The ambiguity created by receiving both encouraging and discouraging information, particularly from a trusted source, may contribute to vaccine hesitancy among parents and poor vaccination outcomes for children.[35]

In NZ, childhood vaccinations are publicly funded for all infants,[36] however inequities exist in vaccination uptake and timeliness, particularly for Māori children and children from deprived households.[37–40] We found no association between household deprivation and vaccination timeliness. However, the father's ethnicity was strongly associated with vaccination timeliness. While Māori or Pacific fathers had increased odds of receiving information encouraging vaccination and decreased odds of receiving conflicting information compared to European fathers, their infants had decreased odds of timely vaccinations. Healthcare providers need to ensure that expectant fathers receive accurate information that encourages infant vaccination and emphasizes the importance of timely vaccinations for disease prevention in their infant(s).

There is a strong association between receiving the first infant vaccination on time and receiving subsequent vaccinations on time.[24] Promisingly, infants of Pacific fathers had increased odds of receiving their first vaccinations on time (at age six weeks) and decreased odds of delayed vaccinations. Unfortunately this was not the case for the infants of Māori fathers, who had decreased odds of receiving their six-week vaccinations on time and increased odds of delayed vaccinations.[24]

Current figures reveal that Māori continue to experience inequity in infant vaccination delivery, with 63% of Māori infants fully vaccinated at six months old compared to coverage for European (84%), Pacific (76%) and Asian (91%) infants in 2019.[41] In 2020, Māori and Pacific infants experienced vaccination inequity as a result of Covid-19 disruptions to vaccination delivery in NZ, with −2.8% and −1.4% coverage, respectively, compared to 2019.[42] Covid-19-related effects were negligible for European infants (−0.1%) and there was a slight improvement for Asian infants (+0.4%).[42]

Table 5. Associations of father and household characteristics with infant vaccination timeliness when father received vaccination information from healthcare (n = 4017).

	Father received vaccination information from healthcare sources					
	Received all vaccinations on time (n=2900)		Received six-week vaccinations on time (n=3496)		All infant vaccinations delayed (n=401)	
Father and household characteristics	Adjusted* Odds Ratio (95% CI)	Forest Plot	Adjusted* Odds Ratio (95% CI)	Forest Plot	Adjusted* Odds Ratio (95% CI)	Forest Plot
Information type	*		***		***	
Encouraging only	0.97 (0.81-1.17)		**1.37 (1.05-1.80)**		**0.72 (0.53-0.98)**	
Conflicting‡	0.95 (0.57-1.62)		**0.52 (0.30-0.94)**		**2.19 (1.17-3.89)**	
Discouraging only	**0.40 (0.21-0.73)**		**0.25 (0.13-0.47)**		**4.32 (2.22-8.17)**	
No information	1.00		1.00		1.00	
Household Structure						
Parent alone or with non-kin	0.84 (0.63-1.13)		0.94 (0.64-1.42)		1.05 (0.65-1.62)	
Two parents	1.00		1.00		1.00	
Parent(s) and extended family	0.90 (0.75-1.09)		0.92 (0.72-1.20)		1.08 (0.81-1.45)	
Self-prioritized ethnicity	***		***		***	
European	1.00		1.00		1.00	
Māori	**0.57 (0.45-0.72)**		**0.68 (0.51-0.91)**		**1.62 (1.18-2.21)**	
Pacific	**0.74 (0.58-0.95)**		**2.00 (1.35-3.05)**		**0.45 (0.28-0.72)**	
Asian	**1.96 (1.51-2.58)**		**2.75 (1.83-4.30)**		**0.20 (0.10-0.36)**	
Other	0.95 (0.69-1.33)		0.86 (0.58-1.30)		1.22 (0.77-1.86)	
Education						
Primary	**0.74 (0.56-0.97)**		0.85 (0.60-1.24)		1.08 (0.71-1.61)	
Secondary	0.96 (0.80-1.15)		1.00 (0.79-1.28)		0.87 (0.65-1.14)	
Tertiary	1.00		1.00		1.00	
Household deprivation§						
1 to 2 (least deprived)	1.00		1.00		1.00	
3 to 4	0.86 (0.68-1.08)		0.89 (0.66-1.20)		1.07 (0.77-1.50)	
5 to 6	0.84 (0.67-1.07)		0.89 (0.66-1.21)		1.00 (0.71-1.41)	
7 to 8	1.07 (0.84-1.36)		0.96 (0.70-1.32)		0.93 (0.65-1.32)	
9 to 10 (most deprived)	0.80 (0.63-1.02)		0.82 (0.60-1.13)		1.20 (0.85-1.71)	
Infant vaccination[I]	***		***		***	
Decided	1.00		1.00		1.00	
Undecided	**0.74 (0.63-0.88)**		**0.60 (0.49-0.75)**		**1.73 (1.37-2.18)**	
Mother received vaccination information	*		**		**	
No	1.00		1.00		1.00	
Yes	0.86 (0.75-1.00)		**0.76 (0.62-0.92)**		**1.44 (1.16-1.79)**	
		0 2 4 6 8 10 Odds Ratio (95% CI)		0 2 4 6 8 10 Odds Ratio (95% CI)		0 2 4 6 8 10 Odds Ratio (95% CI)

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; remaining findings were not statistically significant.
†Multivariable analysis adjusted for father ethnicity and education; household structure and deprivation; whether each father, when interviewed, was decided about their vaccination intentions for their child; and whether the child's mother received information about vaccination.
‡Both encouraging and discouraging information.
§Area-level socioeconomic deprivation was measured using the NZ Index of Deprivation, Dep 1 to 2 = least deprived, Dep 9 to 10 = most deprived households.[27]
[I]Whether each father was decided about the vaccination of his expected child.[7]
CI – confidence interval.

The World Health Organization characterizes vaccine hesitancy as a combination of a lack of confidence in the vaccine or healthcare provider; complacency toward the disease or the vaccine; and convenience of vaccine access.[43] Māori have lower levels of vaccine confidence than European, Pacific, and Asian New Zealanders.[44] Vaccinations are free in NZ[45] but structural, economic, and cultural barriers impede vaccination delivery.[46] Māori are more likely than non-Māori to have unmet need for primary care or after hours medical services due to cost, lack of childcare or lack of transport.[47] Culturally inappropriate or ineffective medical treatment from Pākehā (European) doctors leads to disparities in healthcare for Māori.[48] Cultural barriers to access, whereby vaccination is not promoted in line with Māori models of health, also contribute to hesitancy.[49] Grandparents are important role models for Māori mothers when deciding about infant vaccinations.[50]

Lead Maternity Carers (LMCs), predominantly midwives, provide antenatal care in NZ.[17,51] Lead maternity carers are expected to *'provide Ministry of Health information on vaccination and the National Vaccination Register (NIR)'* during the third trimester of pregnancy.[52] However, only 38% of pregnant women[10] and 15% of fathers in our study recalled receiving information encouraging vaccination from their LMC or general practitioner (GP). This may indicate poor delivery of vaccination information to fathers by LMCs/GPs, fathers forgetting they have received vaccination information, completing the *GUiNZ* antenatal interview prior to receiving vaccination information from their LMC/GP, or not attending antenatal care appointments.

One-on-one conversations during pregnancy about vaccination are associated with improved vaccination uptake, reduced vaccine hesitancy, and timely vaccination.[53–56] Antenatal appointments provide an ideal opportunity for both parents to receive accurate vaccination information from a trustworthy source. Midwives consider engaging fathers during perinatal care an important part of their role.[57] When fathers are actively involved in pregnancy and birth, maternal

Table 6. Associations of father and household characteristics with infant vaccination timeliness when father received vaccination information from media (n = 4017).

	Father received vaccination information from media sources					
	Received all vaccinations on time (n=2900)		Received six-week vaccinations on time (n=3496)		All infant vaccinations delayed (n=401)	
Father and household characteristics	Adjusted* Odds Ratio (95% CI)	Forest Plot	Adjusted* Odds Ratio (95% CI)	Forest Plot	Adjusted* Odds Ratio (95% CI)	Forest Plot
Information type			***		***	
Encouraging only	0.87 (0.68-1.11)		0.76 (0.56-1.05)		1.33 (0.92-1.88)	
Conflicting‡	0.70 (0.47-1.06)		**0.50 (0.32-0.81)**		**2.23 (1.34-3.56)**	
Discouraging only	0.74 (0.54-1.04)		**0.53 (0.36-0.78)**		**2.05 (1.35-3.05)**	
No information	1.00		1.00		1.00	
Household Structure						
Parent alone or with non-kin	0.84 (0.63-1.14)		0.95 (0.64-1.44)		1.03 (0.64-1.59)	
Two parents	1.00		1.00		1.00	
Parent(s) and extended family	0.89 (0.74-1.08)		0.92 (0.71-1.19)		1.10 (0.82-1.46)	
Self-prioritized ethnicity	***		***		***	
European	1.00		1.00		1.00	
Māori	**0.56 (0.45-0.71)**		**0.67 (0.51-0.90)**		**1.64 (1.19-2.24)**	
Pacific	**0.73 (0.57-0.94)**		**1.98 (1.34-3.01)**		**0.46 (0.28-0.73)**	
Asian	**1.94 (1.49-2.55)**		**2.81 (1.87-4.39)**		**0.20 (0.10-0.36)**	
Other	0.95 (0.69-1.33)		0.85 (0.58-1.30)		1.22 (0.77-1.87)	
Education						
Primary	**0.74 (0.56-0.97)**		0.83 (0.58-1.20)		1.12 (0.74-1.66)	
Secondary	0.95 (0.79-1.14)		0.97 (0.77-1.25)		0.89 (0.67-1.18)	
Tertiary	1.00		1.00		1.00	
Household deprivation§	*					
1 to 2 (least deprived)	1.00		1.00		1.00	
3 to 4	0.86 (0.68-1.08)		0.89 (0.66-1.21)		1.07 (0.77-1.49)	
5 to 6	0.83 (0.66-1.05)		0.87 (0.64-1.19)		1.03 (0.73-1.45)	
7 to 8	1.07 (0.84-1.35)		0.97 (0.71-1.33)		0.92 (0.64-1.31)	
9 to 10 (most deprived)	0.79 (0.62-1.00)		0.82 (0.59-1.12)		1.21 (0.85-1.72)	
Infant vaccination¶	***		***		***	
Decided	1.00		1.00		1.00	
Undecided	**0.74 (0.63-0.88)**		**0.59 (0.48-0.73)**		**1.77 (1.41-2.22)**	
Mother received vaccination information			*		**	
No	1.00		1.00		1.00	
Yes	0.87 (0.75-1.01)		**0.79 (0.65-0.96)**		**1.38 (1.11-1.71)**	
	0 1 2 3 4 5 Odds Ratio (95% CI)		0 1 2 3 4 5 Odds Ratio (95% CI)		0 1 2 3 4 5 Odds Ratio (95% CI)	

*$P < 0.05$; **$P < 0.01$; ***$P < 0.001$; remaining findings were not statistically significant.
†Multivariable analysis adjusted for father ethnicity and education; household structure and deprivation; whether each father, when interviewed, was decided about their vaccination intentions for their child; and whether the child's mother received information about vaccination.
‡Both encouraging and discouraging information.
§Area-level socioeconomic deprivation was measured using the NZ Index of Deprivation, Dep 1 to 2 = least deprived, Dep 9 to 10 = most deprived households.[27]
¶Whether each father was decided about the vaccination of his expected child.[7]
CI – confidence interval.

engagement with antenatal care and breastfeeding rates improve, and maternal smoking and alcohol intake reduce, improving health outcomes for mother and child.[11–13,58]

Māori comprised 16.5% of the NZ population in 2018,[59] yet only 6% of midwives identify Māori as their primary ethnicity and 9% cite Māori as one of their ethnicities.[60] This under-representation of Māori in pregnancy, birth and infant healthcare delivery may compromise the cultural appropriateness of care, including vaccination education. Systemic changes are necessary to improve Māori participation in perinatal care. Addressing present and historic distrust of the health system and creating an environment where immunization fits into a Māori model of health may improve vaccination rates for Māori. Recognizing the importance of whānau (extended family) for Māori in decision making is essential to support vaccination uptake and timeliness for Māori parents. Including fathers and whānau in antenatal care and decision-making will improve outcomes for mothers and their children. An antenatal appointment that includes mothers, fathers and whānau could provide parents and whānau with accurate vaccination information, help address their concerns and guide decision-making, potentially improving infant vaccination uptake and timeliness.

The antenatal enrollment, participant number, and face-to-face interviewing of fathers independently from mothers are strengths of the *GUiNZ* study.[14] The prospective inclusion of fathers before birth is unique to *GUiNZ*. The cohort is ethnically and socioeconomically diverse, and broadly representative of all NZ births from 2007–2010.[14,15] Vaccination was one of a wide range of research domains considered and linkage to the NIR provided a robust measure of vaccination timeliness.

There are several limitations to this study. Recruitment of fathers was dependent on the mother providing contact details, with the father cohort representing 65% of the cohort of pregnant women. Thus, study results may not be generalizable to all expectant fathers within the cohort or to fathers of all NZ infants. The broad study scope limited our ability to investigate information sources in detail. This observational study cannot establish a causal link between fathers receiving discouraging information and infant vaccination timeliness. Furthermore, there is evidence that when making decisions on an issue, such as infant vaccination, people will selectively seek information that confirms their preexisting attitudes and beliefs, and avoid information that challenges them.[61] Thus, individuals with a negative view of vaccination are likely to avoid

encouraging information and to seek information that discourages vaccination, and vice versa for individuals who have a positive view of vaccination. This confirmation bias may have influenced our estimates of the proportion of fathers receiving encouraging or discouraging vaccination information.

During pregnancy, approximately one-third of fathers received information about infant vaccinations. Paternal determinants of vaccination timeliness were the father receiving discouraging or conflicting information about vaccination, father's ethnicity, father's vaccination hesitancy, and whether the mother received vaccination information. Māori infants are at particular risk of incomplete and delayed vaccinations. To address this inequity, we recommend an LMC-led vaccination conversation with expectant mothers, fathers and whānau be included in routine antenatal care to inform parents about vaccination, support decision-making, and provide an opportunity to address their concerns. Vaccination education should address present and historic distrust of the health system. Framing vaccination within a Māori model of health and including fathers and whānau in decision-making will address vaccination inequities in New Zealand.

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Disclosure of potential conflicts of interest

No potential conflicts of interest were disclosed.

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