Attitudes toward vaccinations are becoming more polarized in New Zealand: Findings from a longitudinal survey

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**ABSTRACT**

**Background:** Despite continuing vaccine controversies, little is known about the trajectory of change in vaccine confidence over time. The current study examined whether there are subpopulations among the New Zealand public with diverging trajectories of confidence in the safety of childhood vaccinations from 2013 to 2017. **Methods:** Using longitudinal survey data from the New Zealand Attitudes and Values Study, latent class growth models identified subpopulations with distinct rates and directions of change in vaccine confidence from 2013 to 2017 (N= 12,423; 11,912; 12,009; 10,254). The demographic profiles of these subpopulations were examined. **Findings:** Most New Zealanders’ (60%) maintained strong vaccine confidence throughout the years (i.e. vaccine believers), but 30% expressed decreasing confidence over time (i.e. vaccine skeptics). Around 10% were former skeptics who had low vaccine confidence in 2013 but showed increasing confidence thereafter. Men, Europeans/Others, those more educated and living in more affluent regions were more likely to be vaccine believers. Relative to former skeptics, women, older individuals and those with lower education were more likely to be vaccine skeptics. **Interpretation:** Attitudes toward the safety of childhood vaccinations are becoming increasingly polarized in New Zealand. Roughly 30% of the population are becoming more concerned about vaccine safety over time, 10% are becoming more confident, whereas 60% show consistent high vaccine confidence. It is vital to further investigate the key contributors to decreasing confidence among vaccine skeptics and implement target interventions. **Funding:** Templeton Religion Trust Grant (TRT0196) for data collection; Corresponding author supported by University of Auckland Doctoral Scholarship. © 2020 The Authors. Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license. (http://creativecommons.org/licenses/by-nc-nd/4.0/)

Childhood vaccinations are a crucial public health intervention that protects people against harmful infections [1,2]. However, vaccine hesitancy has been highlighted as a major threat to global health by the World Health Organization in 2019 [3]. The refusal or delay in vaccinations can be linked to a diverse range of factors, including limited healthcare access, distrust in health professionals, complacency and vaccine safety concerns [4,5]. Standard vaccinations undergo rigorous safety testing before approval and are constantly monitored thereafter [1]. Nonetheless, with the recent increase in anti-vaccination movements and dissemination of anti-vaccine information, public concern about vaccine safety seem to be on the rise [4,7]. Many express concerns that vaccines contain harmful substances and may cause various illnesses [1,4]. Specific fears about the Mumps, Measles and Rubella (MMR) vaccine can be traced back to Wakefield’s (1998) fraudulent study on the link between MMR and autism [4]. Despite the retraction of this study and multiple epidemiological studies disproving its proposed association, MMR-autism myths continue to circulate and cause fear among parents [1,4,7]. Such doubts about vaccine safety challenge vaccination uptake and have contributed to the resurgence of measles outbreaks in multiple countries [4], including New Zealand [8].

In New Zealand, the National Immunisation Schedule offers a series of free standard vaccinations for New Zealanders from six weeks to 65 years of age (see Appendix for full Immunisation Schedule) [1]. To achieve herd immunity and prevent disease transmission, it is important to ensure that 92-94% of the population have been immunised [1]. Yet, during the 12-month period ending 31st December 2019, children who were fully immunised for their age at the six milestone ages (6, 8, 12, 18, and 24 months, and 5 years) were 79%, 90%, 92%, 84%, 91% and 88% respectively [9]. The proportion of fully immunised children was particularly low among Māori; the indigenous peoples of New Zealand (63.3% to 87.8%), and children living in highly deprived areas (69.6% to 89.7%). At each of the milestone ages, 4.3 to 5.4% of parents declined any one vaccination during the year 2019 [9]. Although reasons for declines are complex and cannot be explained by a single factor, they are often linked to concern about vaccine safety [4,10].
Among parents who delayed or missed immunisations, concerns about the risk or side effects of vaccinations are frequently cited as one of the main reasons for incomplete immunisations [10,11]. Some parents hold misconceptions that vaccines can cause illnesses such as autism or cot death [1], while others undermine vaccine necessity or desire more vaccine information [10,11]. As for the general population, the 2013 New Zealand Attitudes and Values Study (NZAVS) found that 68-5% of New Zealanders expressed strong confidence in the safety of the New Zealand childhood immunisation schedule but 26% showed moderate and 5-5% showed low confidence [12]. Māori individuals, women, parents, those less educated and living in more deprived areas reported decreased levels of vaccine confidence [12]. Among Māori and those with high deprivation, increased healthcare barriers and negative experiences with health professionals [13,14] may be contributing to their low vaccine confidence. Given that belief in vaccine safety is an important determinant of vaccination uptake [15,18], it is essential to track changes in and constantly monitor public vaccine confidence. However, due to the scarcity of large-scale panel data, little is currently known about the trajectory of change in New Zealanders’ vaccine confidence over time.

The present study addresses this gap in research by assessing New Zealanders’ perceptions of childhood vaccine safety over time. The study addresses this gap in research by using a large longitudinal sample of New Zealand adults to identify distinct subpopulations with diverging trajectories of vaccine confidence from 2013 to 2017. The demographic profiles of these distinct subpopulations are also examined.

### Implications of all the available evidence

Although the majority of New Zealanders consistently exhibit strong vaccine confidence, a considerable proportion continue to show decreasing confidence over time. It is imperative to develop tailored interventions for groups at higher risk of low vaccine confidence. This includes improving healthcare access for low socio-economic groups, and implementing educational campaigns on vaccine safety and interpreting vaccine information for those with low education. Health professionals also need to be sufficiently trained to effectively address vaccine safety concerns among diverse groups.
(1) Yes–fully, (2) No–partially, (3) No–none, (4) Don’t know. This item
was developed for the NZAVS and included in the Time 7, 8 and 9 sur-
vey. We only report vaccination status data from Time 9 as vaccine confidence is the focus of our study.

1.3.2. Demographics
Participants were asked to report their gender, date of birth, eth-
nicty, region of residence and education level. Ethnicity was mea-
sured using the standard New Zealand Census item, in which participants could indicate each ethnic group they identified with. Education was coded into an eleven-level ordinal variable (0 = No qualification, 1–level 1 Certificate [basic knowledge/skills for work] to 10 = doctoral degree) based on the ten tertiary qualification levels in New Zealand. Deprivation was measured using the 2013 New Zea-
land Deprivation Index, which uses census information to assign a
decile-rank index from 1 (least deprived) to 10 (most deprived) to
each meshblock unit (i.e. small geographical area) [19].

1.4. Analytic overview
Latent class growth models were conducted on Mplus version 8 to
identify distinct latent classes (i.e. subpopulations) with similar tra-
jectories of change in vaccine confidence over time. As some partici-
pants opted out while others opted in at different time points, we
were unable to follow the same group of individuals throughout
2013 to 2017. Thus, we used a linked model that allowed for missing
data and identified links between respondent’s responses over the
four survey years. Those who were constant responders contributed
more to the model. This was the most appropriate method of analysis
given the algorithm of the model and provides novel insight into lon-
gitudinal changes in vaccine confidence at a population level.
Guided by Asparuhov and Muthen’s three-step approach to mix-
ture modelling [20], we identified (1) the number of subpopulations
based on the growth curve of vaccine confidence, (2) then particip-
ants were assigned to the subpopulation they most likely belonged
to and (3) the demographic covariates characterizing the subpopula-
tions were examined. Gender, age, ethnicity (European/Other as ref-
ence category), education and deprivation level were included as
covariates. Participants’ reported education and deprivation level at
Time 5 was prioritized and if missing, was overridden by that
reported in Time 7, 8, and 9 consecutively (prioritizing Time 9 made
trivial difference).
Osborne and Sibley [21] note several model criteria including the
Akaike information criterion (AIC), Bayesian Information Criteri-
a (BIC), sample-sized adjusted BIC (aBIC), entropy and class proportion. These criteria assess the suitability of a model with k profiles relative to k-1 profiles. Good fitting models have lower AIC, BIC and aBIC values, and
higher entropy and likelihood of correct class membership [21]. An
entropy of 0.8 or above is generally regarded as a good fitting model.
According to Kim [22] and Tofghi and Enders [23], aBIC is the most
recommended fit criteria for growth mixture models. The sample-
size adjusted consistent AIC (ADCAIC) also performed quite well [22].
BIC, aBIC, ADCAIC and entropy values were used to determine our
best fitting model. As a good model should be parsimonious (i.e. con-
tain fewer classes as possible) and avoid extremely small class pro-
portions, model parsimony and class proportions were also taken
into account.

1.5. STROBE Checklist
This manuscript adheres to the STROBE checklist where applicable.

Table 1
Model indices and class proportions for solutions ranging from one to six classes.

| No. of Classes | BIC      | aBIC     | ADCAIC  | Entropy | Class proportions |
|---------------|----------|----------|---------|---------|-------------------|
| 1             | 138955   | 138927   | 138895  | 1       | 0.00              |
| 2             | 133194   | 133159   | 133120  | 0.57    | 0.57, 0.43        |
| 3             | 131001   | 130954   | 130901  | 0.73    | 0.60, 0.30, 0.10  |
| 4             | 129185   | 129124   | 129057  | 0.77    | 0.60, 0.26, 0.07, 0.06 |
| 5             | 128266   | 128192   | 128111  | 0.80    | 0.60, 0.22, 0.11, 0.06, 0.01 |
| 6             | 127374   | 127289   | 127193  | 0.80    | 0.56, 0.19, 0.10, 0.10, 0.03, 0.01 |

2. Results

2.1. Main Analyses

A total of 12,826 participants were included in our final analysis.
The number of responses included from Time 5, 7, 8 and 9 were
12,423, 11,912, 12,009 and 10,254, respectively. We assessed the
growth curve of vaccine confidence using one to six latent class solu-
tions. Each model was estimated using 500 initial stage starts, 40 ini-
tial stage iterations and 80 final stage optimizations to ensure we
obtained a global solution. As seen in Table 1, model fit indices sub-
stantially improved after adding a second latent class to the single
class model. The BIC, aBIC and ADCAIC showed a sharp decrease but
the entropy value was still slightly low (0.57). Adding a third class
further improved model fit, with the aBIC and ADCAIC decreasing by
2205 and 2220, respectively. The entropy value increased to 0.73,
indicating a reasonably good model fit.
Due to the complexity of the model (i.e. latent class model with ran-
dom effect on intercepts but not slopes), the model criteria contin-
ued to improve the more classes we added. However, considering
model parsimony and class proportions, having more classes does not
necessarily indicate a better model. In the four-class model, the fourth
group was created by simply splitting the existing classes a little more
and the class proportion of two groups were fairly small (6% and 7%;
See Supplementary Material). The fifth and sixth-class model also
extracted extremely small classes, with one class representing only 1% of
the sample. Caution needs to be applied when interpreting such small
classes as they are based on a minor proportion of the sample.
Overall, the three-class model had a reasonably good model fit and rel-
atively large class sizes. The three-class model was judged to be the
most parsimonious model and thus chosen as our final model.

2.2. Subpopulations

Three subpopulations with distinct rates and directions of change
in vaccine confidence were identified. These groups were labelled
‘vaccine (safety) believers’, ‘vaccine (safety) skeptics’ and ‘former
(safety) skeptics’. The term ‘safety’ has been omitted from group labels
hereafter for simplicity. Table 2 clarifies the definitions of key terms
and groups labels used in this study. Table 3 reports the intercept
(indicating group level of vaccine confidence in 2013) and slope
(indicating the trend in confidence over time) for each group.

2.2.1. Vaccine believers

The largest subpopulation (N = 7784, 60.7% of sample) was charac-
terised by a high intercept (unstandardized mean intercept=-6.52,
p < 0.001) and small positive slope (unstandardized mean slope=0.02,
p < 0.001). This subpopulation represents ‘vaccine believers’ who
exhibited consistently high and subtly increasing belief in vaccine
safety over time.

2.2.2. Vaccine skeptics

The second subpopulation contained 29.6% of the sample
(N = 3792) and was characterised by a moderate intercept

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This manuscript adheres to the STROBE checklist where applicable.
2.3. Differences between subpopulations

Vaccine believers persistently showed the highest level of vaccine confidence (see Figure 1). Former skeptics showed the steepest slope, with a particularly sharp increase in confidence between 2013 and 2015. Vaccine skeptics exhibited higher confidence than former skeptics in 2013, but their positions reversed across the years. In 2015, these two groups showed similar levels of confidence but in 2017, former skeptics showed notably higher confidence than vaccine skeptics (5.88 vs 4.29). With increasing confidence among former skeptics and decreasing confidence among vaccine skeptics, our findings indicate that vaccination attitudes are becoming increasingly polarized in New Zealand.

2.4. Demographic profiles of subpopulations

To identify key demographic differences between subpopulations, gender (reference category: women), age, ethnicity (reference category: European/Other), education (0=no qualification to 10= doctoral degree) and deprivation (1=lowest to 10=highest deprivation) level were included as auxiliary covariates to predict subpopulation membership. Each subpopulation was consecutively treated as the reference category and compared to the other two subpopulations. Tables in the Appendix present the 95% confidence intervals of odds ratios and the demographic breakdown of subpopulations based on most likely group membership (Note: caution needs to be taken when interpreting demographic breakdown as our analyses were based on probability of classification).
2.4.1. Vaccine believers

Compared to vaccine believers, former skeptics were more likely to be female relative to male (OR = 0.83), of Māori (OR = 1.70) or Pacific (OR = 1.97) compared to European ethnicity, live in more deprived as opposed to affluent regions (OR=1.05) and have lower education (OR=0.93). Similarly, vaccine skeptics were more likely to be women (OR = 0.66), of Māori (OR = 1.99), Pacific (OR = 1.58) or Asian (OR = 1.41) ethnicity, live in more deprived regions (OR = 1.06) and have lower education (OR = 0.89).

2.4.2. Vaccine skeptics

Compared to vaccine skeptics, former skeptics were more likely to be male relative to female (OR = 1.25), younger (OR = 0.99; age range: 18–94) and have higher education (OR = 1.95). Vaccine believers were less likely to be of Māori (OR = 0.50), Pacific (OR = 0.63) or Asian (OR = 0.71) compared to European ethnicity, and more likely to be men (OR = 1.51), live in more affluent regions (OR = 0.95) and have higher education (OR = 1.13).

2.4.3. Former skeptics

Compared to former skeptics, vaccine skeptics were more likely to be female relative to male (OR = 0.80), older (OR = 1.01) and have lower education (OR = 0.96). Vaccine believers were less likely to be of Māori (OR = 0.59) or Pacific (OR = 0.51) compared to European ethnicity, and more likely to live in more affluent regions (OR = 0.95) and have higher education (OR = 1.08).

2.5. Vaccination status in Time 9

We only report data on vaccination status from Time 9 (most recent Time point) to reduce the density of our results and maintain our focus on vaccine confidence. As shown in Table 4, most participants reported that their children were ‘fully vaccinated’ (87.6%), followed by ‘partially vaccinated’ (6.1%) and ‘unvaccinated’ (2.9%). Asian peoples reported the highest percentage of fully vaccinated children (92.2%), whereas Pacific (6.9%) and Europeans (6.9%) reported the highest percentage of partially and Māori reported the highest percentage of unvaccinated children (4.0%).

Among those with ‘no qualification to Level 2 certificate’, 83.1% were fully vaccinated (see Table 5). This increased to 87.1%, 88.7%, and 89.3% for each higher education category respectively. The proportion of unvaccinated children slightly decreased as education level increased (3.5%, 3.3%, 2.7%, and 2.3% respectively). The rate of partially vaccinated children was similar across all education groups (5.9-6.4%). Compared to those with higher education, those with ‘no qualification to Level 2 certificate’ (2.9%) reported a higher rate of ‘don’t know’ (1.3%, 0.5%, 0.6%, respectively).

3. Discussion

Our results indicate that confidence in the safety of childhood vaccinations are becoming increasingly polarized in New Zealand. Around 30% of the population show decreasing confidence over time (i.e. vaccine skeptics), 10% are becoming more confident (i.e. former skeptics) and the remaining 60% show consistent high vaccine confidence (i.e. vaccine believers). A wide range of factors are likely contributing to the maintenance of strong vaccine confidence among vaccine believers. Based on previous studies [24–26], vaccine believers may be those who have satisfactory access to vaccine information and strong trust in health professionals. Similar to Australian mothers with strong confidence [24], vaccine believers in New Zealand may also have better knowledge regarding the risk of vaccine-preventable diseases as well as the benefits and social responsibility associated with vaccinating. Oppositely, vaccine skeptics may represent those who lack access to adequate healthcare, have inaccurate or insufficient vaccine knowledge or negative perceptions of health professionals [24,25,27]. Due to limited access to trusted sources of vaccine information, their doubts about vaccine safety may not have been sufficiently addressed by health professionals and further exacerbated by exposure to anti-vaccine sentiments.

As health professionals have important influence on one’s vaccination attitudes and uptake [4,24,27,28], they may have had a pivotal

| Table 4 | Response to item: “If you have children under 18, are their vaccinations up-to-date, as per the recommendations of your doctor/GP?” across ethnic groups in Time 9. |
|---------|-------------------------------------------------------------------------------------------------|
|         | European (N = 3232) | Māori (N = 705) | Pacific (N = 274) | Asian (N = 599) | Total (N = 4909) |
|         | % | N | % | N | % | N | % | N | % | N |
| Yes-Fully | 87.3 | 2823 | 85.5 | 603 | 86.9 | 239 | 92.2 | 552 | 87.6 | 4302 |
| No-partially | 6.9 | 222 | 5.8 | 41 | 6.9 | 19 | 2.4 | 15 | 6.1 | 299 |
| No-none | 2.9 | 94 | 4.0 | 28 | 0.9 | 3 | 1.8 | 10 | 2.9 | 142 |
| Don’t know | 1.2 | 37 | 2.0 | 14 | 0 | 0 | 0.5 | 3 | 1.1 | 55 |
| Unreported | 1.8 | 57 | 2.7 | 19 | 5.2 | 14 | 3.2 | 19 | 2.3 | 111 |

Note: Ethnic groups determined based on prioritized ethnicity (in order: Māori, Pacific, Asian, European). Sample weighting on gender, ethnicity and region of residence applied. Note the small cell sizes for Pacific and Asian peoples due to their low response rate.

| Table 5 | Response to item: “If you have children under 18, are their vaccinations up-to-date, as per the recommendations of your doctor/GP?” across education level groups in Time 9. |
|---------|-------------------------------------------------------------------------------------------------|
|         | No qualification to Level 2 Cert (N = 712) | Level 3 to 5 Cert (N = 1185) | Graduate cert/Bachelor degree (N = 1690) | Post-graduate degree (N = 1239) |
|         | % | N | % | N | % | N | % | N |
| Yes-Fully | 83.1 | 591 | 87.1 | 1032 | 88.7 | 1500 | 89.3 | 1107 |
| No-partially | 6.4 | 46 | 6.3 | 75 | 5.9 | 100 | 6.1 | 75 |
| No-none | 3.5 | 25 | 3.3 | 39 | 2.7 | 46 | 2.3 | 29 |
| Don’t know | 2.9 | 20 | 1.3 | 15 | 0.5 | 8 | 0.6 | 7 |
| Unreported | 4.1 | 29 | 1.9 | 23 | 2.2 | 37 | 1.7 | 21 |

Note: Education was coded based on the ten tertiary qualification levels in New Zealand (e.g. Level 1 Cert: basic knowledge/skills for work, Level 2 Cert: introductory knowledge/skills for field of work).

Group categorization: ‘No qualification to Level 2 Cert’ (No qualification, Level 1 and 2 Certificate), ‘Level 3 to 5 Cert’ (Level 3 to 5 diploma/Certificate), ‘Graduate Cert/Bachelor degree’ (Level 6 diploma/Certificate to Bachelor degree), ‘Post-graduate degree’ (Postgraduate diploma/Honours, Masters and Doctorate degree). Sample weighting on gender, ethnicity and region of residence applied.
role in persuading and providing reassurance for former skeptics. Given their initially low confidence, parents who were former skeptics are more likely to have previously delayed or declined vaccinations. Among American parents who had previously declined the HPV vaccine, receiving higher quality recommendations from healthcare providers and greater satisfaction with provider communication were associated with greater secondary vaccine acceptance [15]. Likewise, satisfactory follow-up vaccine conversations with doctors may have led former skeptics in New Zealand to reconsider and gradually change their views of vaccine safety. The 2014 measles outbreak [8] may have been a key event that encouraged these individuals to seek further vaccine information and consult health professionals. In contrast, vaccine skeptics may have limited knowledge about the risk of measles and lack the opportunities or capability to reassess their vaccine beliefs. Such discrepancies can be linked back to potential differences in healthcare access and trust in health professionals between subpopulations.

Disparities in healthcare access, perceptions of health professionals or vaccine knowledge are closely tied to one’s demographic characteristics. Thus, examining demographic differences between the three subpopulations not only allowed us to identify those more likely to be vaccine skeptics but provided important insight into the reasons why certain groups may be exhibiting strong or decreasing vaccine confidence. Our results revealed similar differences between vaccine believers and those who were either vaccine skeptics or former skeptics. Men, those of European/Other ethnicity, with lower deprivation and higher education were more likely to be vaccine believers. Conversely, women, Maori and Pacific peoples, those living in more deprived regions and with lower education were more likely to have previously held or continue to show increasing vaccine safety concerns. Relative to vaccine believers, Asian peoples were more likely to be vaccine skeptics but not any more likely to be former skeptics than European/Others.

For those of Maori or Pacific ethnicity and from highly deprived regions, low healthcare access may be a key contributing factor to their higher likelihood of being a vaccine skeptic or former skeptic. These groups typically experience greater financial or transport related barriers to healthcare and difficulty communicating with health providers due to language or cultural differences [13,29–31]. They are thus less likely to have sufficient access to vaccine information, feel well-informed or have high-quality vaccine conversations with doctors. Among these groups, those who were able to have their initial vaccine concerns addressed by culturally competent health professionals may be showing increasing confidence, while those who lacked this opportunity or do not trust their health professional persistently express growing concern. As for Asian peoples, contrary to decreasing confidence among vaccine believers, older adults may exhibit growing distrust in vaccine safety amidst persistent vaccine controversies.

Many pregnant women and parents receive or seek information about childhood vaccinations through various sources such as health professionals, family and the internet [28,32,33]. With the abundance of anti-vaccine information online and on social media [4], this increases the chances they are exposed to anti-vaccine sentiments. As women typically make all decisions regarding their child’s vaccination [11], they are more inclined to do additional vaccine research and feel anxious about making the right decision for their child. Consistent with findings from an American sample [28], perhaps New Zealand women are also more likely to trust non-professional sources of vaccine information than men. Given that health professionals are important sources of vaccine information that influence vaccination attitudes [10,26,27], they may have had a central role in alleviating safety concerns among women who are former skeptics. On the contrary, women who remain skeptical may be those that are swayed by anti-vaccine information and unsatisfied with their providers’ ability to address their concerns. To effectively convince these women, health professionals need to go beyond simply providing pro-vaccine information [32,34]. They need to take the time to understand the specific concerns and sources of misinformation among skeptical women, and use easily-understood language to communicate evidence-based data to correct any misconceptions they hold [34].

Our findings suggest that low education is an important contributor to decreasing confidence among vaccine skeptics. Despite somewhat mixed findings [6], numerous studies suggest that low education is associated with poor vaccine knowledge, decreased access to vaccine information and lower trust in health professionals [25,35,36]. Due to their reduced cognitive capability and increased feeling of powerlessness, people with low education are also more receptive to conspiracy theories [37]. Hence, vaccine skeptics, who tend to have lower education, may be more likely to endorse anti-vaccine conspiracy theories but lack access to trusted sources of vaccine information that can correct their misconceptions. On the other hand, higher education may be a key factor helping maintain strong vaccine confidence among vaccine believers. Through better education, these individuals may possess the cognitive ability to accurately interpret vaccination information and differentiate between false and evidence-based studies on vaccinations. Those more educated may also be better able to understand and communicate with their doctor, and thus more likely to trust in health professionals and the safety of vaccinations they recommended. Parents with higher education were found more likely to have fully vaccinated children (see Table 4), further highlighting that parental education is a crucial contributor to both vaccine confidence and uptake among New Zealanders.

In contrast to studies that assess vaccination attitudes at one given (static) point in time, our analyses provide novel information forecasting how New Zealanders’ perceptions of vaccine safety are changing over time, and how they are forecast to continue to change in the near future. Although the majority of New Zealanders consistently exhibit strong vaccine confidence, a considerable proportion show steadily decreasing confidence over time. Unless appropriate interventions are implemented in a timely manner, vaccine confidence among vaccine skeptics are likely to continue to decrease and lead to declines in vaccination uptake. It is imperative to develop tailored interventions for groups at higher risk of low vaccine confidence. This includes improving healthcare access for low socio-economic
groups, and implementing educational campaigns on vaccine safety and interpreting vaccine information for those with low education. Moreover, health professionals need to be sufficiently trained to develop trusting relationships with and adequately address vaccine concerns among diverse groups, especially young mothers and ethnic minorities. To better identify specific strategies to effectively persuade vaccine skeptics, it is vital to further investigate the key facilitators of attitude change among former skeptics.

As there were limitations in the number and types of predictors we could include in our model, we were unable to assess how various other NZAVS items (e.g. satisfaction with healthcare access or family doctor, subjective health, personality traits) may influence subpopulation membership. We were also unable to assess non-linear trends or potential fluctuations in vaccine confidence among different subpopulations. Our study used a single 7-point likert item asking about safety perceptions of the New Zealand immunisation schedule to measure vaccine confidence. Although this item lends insight into general perceptions of childhood vaccine safety among the public, it could not accurately discern New Zealanders’ specific vaccine concerns or the main contributors to the differential trends of the three subpopulations. Future studies should employ more comprehensive measures of vaccine confidence that tap into people’s beliefs about vaccine harm and benefits, and trust in healthcare professionals or the government (see scale used by Gilkey et al. [16]). The influence of disparate access to healthcare and vaccine information, and susceptibility to anti-vaccine conspiracy theories should also be investigated. Subsequent studies should use risk ratios for more readily interpretable results and examine the clinical significance of demographic differences in vaccine confidence.

The present study did not examine the number of participants who had immunisation-age children nor potential differences in vaccination confidence between parents with different age groups of children. There may have been important differences in the way with those with young (<3 years) or school-aged children interpreted the vaccination item and viewed the safety of specific vaccinations (e.g. MMR or Human papillomavirus vaccine). Nevertheless, the aim of this study was to assess population level changes in general perceptions of vaccine safety in New Zealand and our findings still provide a valuable framework for future research on the key determinants of New Zealanders’ vaccine confidence. Examining the relationship between vaccine confidence and actual vaccination uptake is another important direction for future research. As the Time 7 to 9 NZAVS surveys ask about child vaccination status, our data will enable us to investigate the degree to which vaccine confidence and characteristics associated with the three subpopulations may influence vaccination uptake across time.

Survey response rates have been declining over the years. Telephone survey response rates at the Pew Research Centre have decreased from 36% to 15% between 1997 to 2009, and stabilized at 9% in 2012 [38]. Similarly, the NZAVS obtained a relatively low initial response rate of 16.6% in 2009 and the average response rate for booster samples remains at 9% (excluding Time 3 booster; See Appendix). As participants opted in and out of our study throughout the years, we were unable to follow the same group of individuals consistently over time. However, collecting booster samples helped us increase the national representativeness of our sample and maintain a large sample. Given that certain groups are more likely to respond to our surveys [39], booster samples purposely oversampled specific areas (e.g. areas with high deprivation, greater ethnically diversity) to compensate for this [17]. After applying sample weighting on gender, ethnicity and region, the NZAVS was able to accurately track changes in New Zealanders’ political attitudes over time [40]. Although this weighting procedure could not be used in our main analysis, our sample is still a reasonable reflection of the New Zealand adult population and provides scarce longitudinal data on population level changes in vaccine confidence.

In summary, our findings indicate that 30% of the New Zealand population are becoming more concerned about vaccine safety over time, 10% are becoming more confident, while the remaining 60% show consistent high vaccine confidence. Men, those of European/Other ethnicity, those living in more affluent regions and more educated were more likely to be vaccine believers. Compared to former skeptics, women, older individuals and those with lower education were more likely to be vaccine skeptics. Better healthcare access, stronger trust in health professionals and higher education may be key factors that help maintain high vaccine confidence among vaccine believers. Health professionals are likely to have had a pivotal role in alleviating vaccine safety concerns and boosting confidence among former skeptics. In contrast, vaccine skeptics may be those who lack access to trusted sources of vaccine information and are more susceptible to anti-vaccine theories. It is essential to further investigate the specific concerns and reasons for declining confidence among vaccine skeptics and implement target interventions accordingly.

Author Contributions

CHJL was the primary author of the manuscript who did the literature search, writing and data interpretation. CGS supervised the project and led the data analysis. CGS provided feedback on the draft report and both authors approved the final version.

Declaration of Competing Interest

CHJL and CGS report a grant from Templeton Religion Trust.

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Link to study website: www.nzavs.auckland.ac.nz

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.eclinm.2020.100387.
Appendix

Tables A1, A2, A3, A4, A5.

**Table A1**
New Zealand Immunisation Schedule (applied from 1 July 2019). Retrieved from Ministry of Health Website [9].

| Age            | Diseases covered and vaccines                                                                 |
|----------------|---------------------------------------------------------------------------------------------|
| Pregnant women | Influenza 1 Injection annually, at any stage of pregnancy                                     |
|                | Tetanus/Diphtheria/Pertussis (whooping cough)                                                |
| 6 weeks        | Rotavirus (start first dose before 15 weeks)                                                 |
|                | 1 oral vaccine                                                                             |
|                | Diphtheria/Tetanus/Pertussis (whooping cough)                                              |
|                | 1 injection                                                                                 |
|                | Pneumococcal                                                                               |
|                | 1 injection                                                                                 |
| 3 months       | Rotavirus (second dose must be given before 25 weeks)                                       |
|                | 1 oral vaccine                                                                             |
|                | Diphtheria/Tetanus/Pertussis (whooping cough)                                              |
|                | 1 injection                                                                                 |
|                | Pneumococcal                                                                               |
|                | 1 injection                                                                                 |
| 5 months       | Rotavirus (second dose must be given before 25 weeks)                                       |
|                | 1 oral vaccine                                                                             |
|                | Diphtheria/Tetanus/Pertussis (whooping cough)                                              |
|                | 1 injection                                                                                 |
|                | Pneumococcal                                                                               |
|                | 1 injection                                                                                 |
| 15 months      | Haemophilus influenzae type b                                                               |
|                | 1 injection                                                                                 |
|                | Measles/Mumps/Rubella                                                                      |
|                | 1 injection                                                                                 |
|                | Pneumococcal                                                                               |
|                | 1 injection                                                                                 |
| 4 years        | Diphtheria/Tetanus/Pertussis (whooping cough)                                              |
|                | 1 injection                                                                                 |
|                | Measles/Mumps/Rubella                                                                      |
|                | 1 injection                                                                                 |
| 11 or 12 years | Tetanus/Diphtheria/Pertussis (whooping cough)                                              |
|                | 1 injection                                                                                 |
|                | Human Papillomavirus (HPV)                                                                  |
|                | 2 injections given at least 6 months apart for those aged 14 and under                      |
|                | 3 injections given over 6 months for those aged 15 and older                                |
| 45 years       | Diphtheria/Tetanus                                                                          |
|                | 1 injection                                                                                 |
| 65 years       | Diphtheria/Tetanus                                                                          |
|                | 1 injection                                                                                 |

Note: Response rates for Time 2, 3, 6, 7 and 9 are not reported as these time points did not include booster samples (these samples included participants from previous time points and occasional opt-ins). Time 3 included a non-random booster recruited from unrelated online newspaper website. Time 4 included one weighted deprivation booster and four electoral boosters (one random and the other three oversampling based on region of residence or ethnicity). Time 5 included a random electoral and Māori electoral booster. Time 8 included a random electoral booster. Around 400-450 Pacific participants were recruited informally via Pacific networks in Time 3.5.
Table A3
Odds ratios for multinomial logistic regression with vaccine believers, vaccine skeptics and former skeptics as reference groups respectively.

| Reference Category: Vaccine believers | OR  | Lower CI | Upper CI | SE  | P-value |
|--------------------------------------|-----|----------|----------|-----|---------|
| Gender                              | 0.827** | 0.704 | 0.972 | 0.068 | 0.011 |
| Māori                               | 1.699** | 1.372 | 2.104 | 0.185 | <0.001 |
| Pacific                             | 1.968** | 1.386 | 2.795 | 0.352 | 0.006 |
| Asian                               | 1.066** | 0.724 | 1.569 | 0.210 | 0.753 |
| Age                                 | 0.996** | 0.991 | 1.002 | 0.003 | 0.195 |
| Deprivation                         | 1.054** | 1.025 | 1.083 | 0.015 | <0.001 |
| Education                           | 0.929** | 0.904 | 0.956 | 0.013 | <0.001 |

| Reference Category: Vaccine skeptics | OR  | Lower CI | Upper CI | SE  | P-value |
|-------------------------------------|-----|----------|----------|-----|---------|
| Gender                              | 1.514** | 1.355 | 1.692 | 0.086 | <0.001 |
| Māori                               | 0.503** | 0.432 | 0.586 | 0.039 | <0.001 |
| Pacific                             | 0.634** | 0.476 | 0.845 | 0.093 | <0.001 |
| Asian                               | 0.711** | 0.551 | 0.918 | 0.093 | 0.002 |
| Age                                 | 0.997** | 0.993 | 1.001 | 0.002 | 0.114 |
| Deprivation                         | 0.947** | 0.929 | 0.966 | 0.009 | <0.001 |
| Education                           | 1.127** | 1.106 | 1.148 | 0.011 | <0.001 |

| Reference Category: Former skeptics | OR  | Lower CI | Upper CI | SE  | P-value |
|------------------------------------|-----|----------|----------|-----|---------|
| Gender                             | 0.799** | 0.663 | 0.963 | 0.076 | 0.008 |
| Māori                              | 1.170** | 0.929 | 1.473 | 0.138 | 0.216 |
| Pacific                            | 0.801** | 0.549 | 1.168 | 0.154 | 0.197 |
| Asian                              | 1.318** | 0.857 | 2.029 | 0.290 | 0.272 |
| Age                                | 1.007** | 1.001 | 1.013 | 0.003 | 0.032 |
| Deprivation                        | 1.002** | 0.971 | 1.034 | 0.016 | 0.902 |
| Education                          | 0.955** | 0.925 | 0.986 | 0.016 | 0.004 |

| Reference Category: Vaccine believers | OR  | Lower CI | Upper CI | SE  | P-value |
|--------------------------------------|-----|----------|----------|-----|---------|
| Gender                              | 1.210* | 1.029 | 1.421 | 0.100 | 0.035 |
| Māori                               | 0.589** | 0.475 | 0.729 | 0.064 | <0.001 |
| Pacific                             | 0.508** | 0.358 | 0.722 | 0.091 | <0.001 |
| Asian                               | 0.938** | 0.637 | 1.381 | 0.185 | 0.737 |
| Age                                 | 1.004** | 0.998 | 1.009 | 0.003 | 0.197 |
| Deprivation                         | 0.949** | 0.923 | 0.976 | 0.014 | <0.001 |
| Education                           | 1.076** | 1.046 | 1.107 | 0.016 | <0.001 |

Note: *p < 0.05, **p < 0.01, numbers in tables are rounded to 3 decimal points for greater accuracy.
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Table A4
Average latent class probabilities for most likely latent class membership (row) by latent class (column).

|       | 1   | 2   | 3   |
|-------|-----|-----|-----|
| 1. Former skeptics          | 0.843 | 0.101 | 0.056 |
| 2. Vaccine skeptics         | 0.057 | 0.878 | 0.065 |
| 3. Vaccine believers         | 0.014 | 0.065 | 0.901 |

Table A5
Demographic characteristics of subpopulations based on most likely group membership.

| Gender | Ethnicity | Age (Time 5) | Deprivation | Education |
|--------|-----------|--------------|-------------|-----------|
| Female (%) | Male (%) | Maori (%) | Pacific (%) | Asian (%) | Age range | Mean age (SD) | Mean level (SD) | Mean level (SD) |
| Vaccine believers (N = 12826) | 60.81 | 39.19 | 10.55 | 2.69 | 4.30 | 17–94 | 49.72 (14.30) | 4.45 (2.70) | 5.36 (2.78) |
| Vaccine skeptics (N = 3388) | 67.89 | 32.11 | 19.45 | 4.90 | 4.78 | 18–94 | 50.03 (12.09) | 5.02 (2.78) | 4.53 (2.73) |
| Former skeptics (N = 1117) | 64.87 | 35.13 | 17.46 | 5.55 | 4.48 | 18–82 | 48.90 (13.66) | 4.96 (2.80) | 4.83 (2.82) |

Note: The current study initially aimed to make inferences about and look at population level trends in vaccine attitudes rather than identify the specific demographic breakdown of subpopulations. This is because out analyses were based on the probability of classification (not simple categorization) and thus, we need to be cautious about categorizing people into groups. Nevertheless, this data may inform the development of target vaccination interventions by helping identify groups of individuals most likely to fall into each subpopulation.

Ethnicity is not mutually exclusive (participants indicated all ethnic groups they identified with at each time point); Proportion for European is not included as it was used as reference category in the regression analysis that was used to obtain most likely class membership. Scale for deprivation (1=lowest, 10=highest) and education level (0=no qualification, 10=doctoral degree).
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