Vaccine 37 (2019) 4525–4532

Contents lists available at ScienceDirect

Vaccine

journal homepage: www.elsevier.com/locate/vaccine

The privilege paradox: Geographic areas with highest socio-economic advantage have the lowest rates of vaccination

Gabrielle M. Bryden, Matthew Browne *, Matthew Rockloff, Carolyn Unsworth

School of Human, Health & Social Sciences, Central Queensland University, University Dr, Branyan, QLD 4670, Australia

ARTICLE INFO

Article history:
Received 7 December 2018
Received in revised form 4 June 2019
Accepted 18 June 2019
Available online 28 June 2019

Keywords:
Health psychology
Health promotion
Vaccine hesitancy
Vaccine refusal
Childhood immunisation
Childhood vaccination
2016 Australian Population and Household Census

ABSTRACT

The present study is the first to examine associations between area-level socio-demographic factors and uptake of vaccination among 5-year old children throughout Australia. A public-health focused ecological methodology was used that combined postcode-level socio-demographic variables from the 2016 Census with postcode-level vaccination data. Analyses included one-way analysis of variance and assessment of linear trends for each socio-demographic variable across five categories of vaccination rate; ranging from lowest ($\leq$90%) to highest (96.1–100%), as well as using vaccination rate as a continuous variable. Multiple regression analysis was also conducted using select indicators to predict vaccination rates in postcodes from major cities. The results of the univariate analyses showed that communities with lower rates of vaccination had relatively less disadvantage, and had relatively greater education and occupation status, as measured by SEIFA (ABS [4]). When we looked at the ASGS Remoteness Areas, we saw that the vaccination rates were lowest in postcodes from the major cities of Australia, and vaccination rates increased as communities became more remote. When the community is further refined to postcodes located in the major cities, and to the target group of parents/partners in a family with children aged 4–7, we found that postcodes with lower vaccination rates were characterised as having a relatively greater proportion of people with: a high education level (bachelor degree level or higher); having white-collar jobs as managers; having no religion, having people in the older age category (50–54); and conversely being unemployed.

1. Introduction

Immunisation programs rely on high uptake of vaccines [53] in order to be successful in reducing the prevalence and incidence of vaccine preventable disease (VPD), and an aspirational vaccination target rate of 95% in children has been set in Australia [18]). High uptake of vaccines, with threshold levels varying by disease, from 83 to 85% for diphtheria and rubella, and 92–94% for measles and pertussis [10], contributes to "herd immunity" [21,49], whereby indirect protection is provided to the whole community, including individuals who cannot be vaccinated for medical reasons [41]. The National Centre for Immunisation Research and Surveillance has shown that in the past decade Australia has improved the overall vaccination coverage for young children and adolescents [25]; using Government incentives to encourage vaccination, including the No Jab, No Pay policy [30,55] requiring children are vaccinated before parents receive Family Assistance Payments. However, despite these gains, there have been geographic clusters with lower than average vaccination rates, as well as clusters of recorded objection to vaccination in all States [10]. Logistical barriers to accessing vaccination, such as issues of poverty or geographic isolation, are important contributors to lower vaccination coverage [10] in Australia. However, some parents of infants and young children are either delaying or selectively vaccinating (vaccine hesitancy), or are otherwise refusing to vaccinate (vaccine refusal) for other non-access related reasons, and this is also contributing to reduced rates of childhood vaccination in areas of Australia, the USA, as well as other developed countries [11,19,20,35]. This vaccine hesitancy/refusal, in turn, is leading to a resurgence of previously controlled diseases such as pertussis (i.e., whooping cough) and measles in some local areas [9,12,29,40,44].

Recent literature is indicating that vaccine refusal and under-immunisation tend to cluster geographically [34,38], and VPD outbreaks also cluster geographically [7,44]. A study in Australia [26] mapped vaccination coverage, including specifically conscientious objectors, across geographic regions of the State of New South Wales (NSW), and found a number of areas with lower than optimal coverage across all age groups and all vaccines. The lowest

* Corresponding author.
E-mail address: m.brown@cqu.edu.au (M. Browne).

https://doi.org/10.1016/j.vaccine.2019.06.060
0264-410X/© 2019 Published by Elsevier Ltd.

coverage was found in the north coast area of NSW, and this area also had the highest proportion of conscientious objectors. A study in Australia of trends and patterns in vaccination objections [10] from 2002 to 2013, compared officially recorded objections to vaccination in the highest and lowest deciles of socio-economic status. The results showed that the proportion of officially recorded objections to vaccination was highest (1.9%) in the highest decile of socio-economic status, and lowest (1.1%) in the lowest decile. The proportion that were only partly vaccinated (for vaccines due at 2, 4 and 6 months of age), but not affected by a recorded objection, was however higher among those in the lowest decile, which the authors suggest indicates logistical difficulties, and problems of access to health services. The authors also mapped the distribution of recorded vaccination objection and this showed geographical clustering. Atwell and colleagues [7] investigated non-medical vaccine exemptions in California and rates of pertussis in the year 2010, and found evidence of temporal and spatial clustering of cases of pertussis with non-medical exemptions; suggesting that high rates of exemptions were related to increased rates of pertussis.

Studies of rates of vaccination are often conducted looking at the influence of individual level socio-economic factors on rates of vaccination, and these studies have shown contradictory results with regard to associations between deprivation or low socio-economic status and compliance with vaccination schedules [51]. In the field of public health, including cancer prevention, the investigation of area-based factors is commonplace, and many socio-demographic factors or indicators (e.g., poverty, ethnicity, and education) have been shown to influence health behaviours and health status. However, very few studies have investigated area-based or geographic clustering of socio-demographic factors and their relationship to vaccination rates. It is highly plausible that area-based factors are having an impact on vaccination rates; e.g., through the influence of social networks, cultural norms, language barriers in ethnic minority groups, perception of risk, education levels, geographic accessibility, and access to free health programs for those in poorer areas [24,52].

A recent study in the USA [24] was the first to study the potential influence of area-based socio-economic factors on rates of Human papillomavirus (HPV) vaccination among boys. This study showed that boys living in high-poverty areas were *more* likely to have completed the series of HPV vaccinations (receipt of three doses to complete immunisation) than boys in low-poverty areas. The probability of completing the series of vaccinations was higher for Hispanic and African-American boys in high poverty areas, and also boys in general from areas with high population density. The authors surmise that greater access to HPV vaccines through a program providing free vaccines for children with little or no insurance may be positively influencing the uptake of HPV vaccination in these groups. In contrast, an ecological study in the United Kingdom [47] looking at area-level socio-economic deprivation and compliance with the booster immunisation schedule (by age five), found that lower immunisation coverage was associated with *higher* area-level deprivation. An ecological study in England [47] found a significant relationship between area-level socio-economic deprivation and coverage of vaccinations (including Tetanus, Diphtheria, Pertussis, Polio, and MMR) by age five, with those areas of greatest deprivation having lower vaccination coverage. Deprivation was also a factor in explaining lack of uptake of HPV vaccination for teenage girls across England [31]. Two other studies in England, of the combined measles, mumps, rubella (MMR) vaccination at age two [32] and the HPV vaccination for young women [22], found no association between deprivation and uptake of these specific vaccinations; however, barriers to services (road distance to services) and adequate housing (overcrowding and affordability) were strongly related to *reduced* vaccination levels. A systematic review and *meta*-analysis of social determinants of vaccine uptake in the elderly in Europe, also looked at area-level deprivation, finding a correlation between deprivation and lower uptake of vaccination in the elderly [28].

A USA study by Omer and colleagues (2008) investigated the relationship between non-medical exemptions and vaccination within schools in the state of Michigan, looking specifically at rates of pertussis cases by geographic area. This revealed exemption clusters characterised by a higher percentage of 5-year old children, a larger average family size, a higher population density, and a higher percentage of ethnic/racial minorities. The authors theorise that cultural and social aspects of particular communities are playing a role in non-medical exemptions to vaccination. A study in the USA by Lieu and colleagues [34] also investigated geographic clusters in vaccination rates in Northern California, using spatial scan statistics to identify clusters of under-immunisation and vaccine refusal. They found clustering by geographic areas of under-immunisation for the varicella vaccine, and the combined measles, mumps, rubella (MMR) vaccine, as well as for vaccine refusal. Analyses were adjusted for ethnicity/race and neighbourhood income, though these demographic characteristics were not considered major factors in clustering. A study in Ontario [43] looked at both individual-level and regional-level factors relating to refusal of the free-of-charge HPV vaccine, and found that at an individual-level both the lowest and the highest incomes were associated with refusing this vaccine. However, geographic areas of high social and material deprivation were associated with greater acceptance of the vaccine. It is possible that contradictory results in both individual and area-based studies as outlined above, are the result of for example, variations in types of vaccine studied; whether vaccine programs are free or self-paid; the country in which the study is undertaken; and the type of healthcare systems available [13].

The goal of this current study was to investigate the relationship between area-level socio-demographic indicators and compliance with the National Immunisation Program (NIP) Schedule[1] [8] for children in Australia. The aim was to identify postcode-level socio-demographic indicators that are associated with lower rates of vaccination for 5-year old children, including:

- SEIFA Index of Relative Disadvantage; and SEIFA Index of Education & Occupation.
- Socio-demographic indicators of parents/partners in families with children aged between 4 and 7 (i.e., education, employment, occupation, indigenous status, language spoken at home, religion, age, and personal income).
- The Australian Statistical Geography Standard (ASGS) [3] Remoteness Area classifications (i.e., major cities, inner regional, outer regional, remote, and very remote areas of Australia).

Based on findings of prior studies, we expected that socio-economic advantage within geographic regions might be related to vaccination rates in Australia. Given the contradictory findings in past studies, we maintained a non-directional hypothesis that socio-economic advantage would influence vaccination in some way (positive or negative). Moreover, the influence of other demographic factors on vaccine compliance were explored in this study as potential predictors.

[1] Note, throughout this document the terms immunisation and vaccination are considered interchangeable, but we have generally used the term vaccination. In particular, the Australian Government refers to child immunisation rates (as outlined in the My Healthy Communities website [6], but we will refer to the data in terms of vaccination rates.

2. Methods

2.1. Design

A public-health focused ecological methodology was used, which combined postcode area-level socio-demographic variables from the *2016 Census of Population and Housing* [2] with postcode area-level vaccination data made available by the Australian Institute of Health and Welfare [6]. An ecological study uses the population or community as the unit of observation, rather than analysis at the individual level [48].

2.2. Measures

2.2.1. Census of population and housing

The ABS regularly conduct a census of the Australian population [2]. In this study socio-demographic variables from the 2016 Census (the night of Tuesday, 9th of August) were analysed at the geographic level of postcode. De-identified and summary data from the 2016 Census are publicly available on the ABS website for analysis by interested parties [2]. However, in this study a request was made to the ABS for a data matrix of socio-demographic variables at the postcode level; restricted to a target population of *parents/partners in a family with at least one child aged between four and seven years of age*. This selective aggregation targeted most parents or caregivers who would be responsible for the vaccination of children aged five years; the age of vaccination that we are investigating as the outcome variable in this study. We note that several concerns were raised about the implementation of the 2016 Census, including the first time use of online forms, public issues regarding privacy, and four denial-of-service attacks on the Census website on the night of the Census leading to problems with filling out online forms. However, an Independent Assurance Panel [23] concluded that 2016 Census data could be used with confidence and was comparable in quality to previous censuses.

2.2.1.1. Socio-Economic indexes for areas (SEIFA). SEIFA have been developed by the ABS [4] using data from the 2016 Census to create indexes which rank areas in Australia according to four summary measures broadly relating to advantage and disadvantage. Note that the SEIFA in this study are computed for the whole Australian population rather than for the target population of parents/partners in a family with at least one child aged between 4 and 7 years of age. Two SEIFA were selected for this study: The Index of Relative Socio-economic Disadvantage (IRSD); and the Index of Education and Occupation (IEO). These indexes are assigned to geographic areas, rather than individuals, and are ordinal measures that can be used to rank local areas by these measures. The IRSD is a socio-economic index that summarises a range of information from the census. Low scores indicate in general that the local area has greater disadvantage in relation to other local areas. A high score indicates that the local area has a relative lack of disadvantage compared to other local areas. The IEO is an index that reflects the education and occupation level of local areas. Low scores in general indicate a relatively lower education and occupation status of the local community compared to other local areas in Australia. High scores indicate relatively higher education and occupation status of the local community compared to other local areas.

2.2.1.2. Area-based Socio-demographic indicators from a target population. The following postcode-level socio-demographic variables or indicators were selected for inclusion in this study, with summary data across postcodes limited to the target population of parents/partners in a family with at least one child aged between 4 and 7 years of age:

- Highest Level of Education (Bachelor degree level or higher; and completed year 10, 11, or 12).
- Labour Force Status (Unemployed - as derived by the ABS [1] via the combination of four census questions - the standard ABS definition of Unemployed requires that the person not be working more than 1 h the previous week, that the person is actively looking for work, and available to start work).
- Occupation (Managers; Professionals; Technicians and Trade Workers; Clerical and Administrative Workers; Sales Workers; Machinery Operators and Drivers; and Labourers).
- Indigenous Status (Aboriginal).
- Language Spoken at Home (English; Mandarin).
- Religion (No Religion; Catholic; Anglican; Buddhism; Hinduism; and Islam).
- Age Categories (20–24, 25–29, 30–34, 35–39, 40–44, 45–49, 50–54).
- Weekly Personal Income (Low < $1000, $1000–2000, $2000–3000, Very High $3000 and over).

Note, only key indicators are included in analyses to avoid duplication, and to cover the most important variables. Some variables were excluded because of low prevalence rates. For example, the census also includes the religions of Uniting Church, Presbyterian, Baptist, and Greek Orthodox. Uniting Church was excluded as the religions of Catholic and Anglican were considered sufficient to cover Christian religions. The other religions were not included because they had on average less than 2% representation across Australia. Mandarin was selected as a language because it was the second most common language spoken at home. The languages Italian, Arabic, Cantonese, Greek, and Vietnamese were not included because they had on average less than 2% representation across the country.

2.2.2. AIHW vaccination data

The AIHW routinely analyses data from the Australian Immunisation Register (AIR) which is administered by the Australian Government Department of Human Services. This includes surveillance data on rates of vaccination for children and teenagers, by geographic area, including percentage of fully immunised or vaccinated 5-year old children. All people enrolled with Medicare are included in the AIR. Also, persons who are not enrolled with Medicare can be added to the AIR via a supplementary number, and if vaccinations are given overseas, this information can also be added if it can be verified. This data is publicly available and can be accessed through the AIHW website ‘‘My Healthy Communities” [6]. It should be noted that The National Centre for Immunisation Research and Surveillance [25] identifies that the ‘‘fully immunised” coverage figures are likely an underestimate for a range of reasons, including under-reporting. It should be noted that some overseas born children may be vaccinated overseas but not have this information recorded in the AIR. In this study vaccination rates of 5 year olds for the financial year 2015/16 were analysed at the geographic level of postcode. The data from both the ABS and the AIHW sources are only made available in summary statistical format (e.g., percentage of 5-year olds fully vaccinated for each postcode; percentage unemployed for each postcode) and no individuals can be identified. To further ensure confidentiality, data on location is not included in this report (only summary statistical information).

2.2.3. ASGS remoteness areas

The Australian Statistical Geography Standard (ASGS) Remoteness Areas, developed by the ABS [3] fall into five categories (i.e., major city, inner regional, outer regional, remote, and very remote areas of Australia) and are derived by road distance to urban areas and population density. In this study these classifications were applied to postcodes throughout Australia.

2.3. Data analysis

Data from the ABS and the AIHW were initially obtained in Microsoft Excel spreadsheets. Both databases were then sorted, matched and merged at the postcode level, in order for further analyses to be conducted with IBM SPSS Statistics for Windows, Version 24.0 [17]. Analyses included one-way analysis of variance (ANOVA) for each socio-demographic variable across five categories of vaccination rate. The five categories, ranging from lowest (≤90%) to highest (96.1–100%), were derived using the 20th percentile to categorise data into bins of roughly equal sizes. Linear trends were assessed using the contrast function in one-way ANOVA. Simple linear regression was conducted for each socio-demographic variable using vaccination rate as a continuous variable to obtain standardised beta weights. Multiple regression was also conducted, using all socio-demographic variables as predictors, but due to multicollinearity issues the model resulted in unstable beta weights. A smaller multiple regression was conducted using a subset of key indicators (to reduce the effects of multicollinearity) to predict vaccination rate of 5-year olds in the major cities (as defined by Remoteness Areas) of Australia (N = 897). Analysis was restricted to major cities to ensure adequate representation of low prevalence variables such as Buddhist religion (e.g., the proportion of Buddhists is less than 1 percent in all remoteness areas, except for major cities (3% Buddhists). The sub-group of major cities was also selected as they had the lowest vaccination rates, as revealed in the final analysis – an assessment of the impact of ASGS Remoteness Areas (five categories) using a one-way ANOVA with vaccination as a continuous dependent variable.

3. Results

Vaccination data were available for analysis from 1490 different postcodes. The mean rate of fully vaccinated 5-year olds across postcodes in 2016 was 92.5% (*Md* = 93.20%; *Mo* = 100%; *SD* = 4.35), with 70.4% of postcodes having vaccination rates less than or equal to Australia's national aspirational coverage target of 95% [18]; and 21.0% of postcodes having vaccination rates less than or equal to 90%. Table 1 displays the standardised beta weights for each socio-demographic variable using vaccination as a continuous variable; and the mean of each socio-demographic variable across vaccination levels (postcodes with the lowest through highest level of vaccination), linear trends, and effect sizes. The results show that there were significant linear trends for all variables, except the age category 35–39.

3.1. SEIFA: Disadvantage (IRSD); and education and occupation (IEO)

The IRSD was higher (relatively less disadvantaged) in those areas with the lowest vaccination rates and lower (more disadvantaged) in those areas with the highest vaccination rates. The IEO was also higher (relatively more education and occupation status) in those areas with the lowest vaccination rates and lower (relatively less education and occupation status) in those areas with the highest vaccination rates.

3.2. Area-based socio-demographic variables for the target population

Those postcodes with relatively lower vaccination rates were characterised as having, on average, more of the target population:

- with a Bachelor degree level or higher as their highest level of education;
- being unemployed;
- having an occupation as a Manager;
- having an occupation as a Professional;
- speaking Mandarin at home;
- having no religion, so described;
- with the religion Buddhism;
- with the religion Hinduism;
- with the religion Islam;
- in the older age categories (40–44, 45–49, 50–54);
- with a weekly income of $2000–3000;
- with a very high personal weekly income ($3000 and over).

Those postcodes with relatively higher vaccination rates were characterised as having, on average, more of the target population:

- having only completed year 10, 11, or 12 as their highest level of education;
- with an occupation as Technicians and Trade Workers;
- with an occupation as Community and Personal Service Workers;
- with an occupation as Clerical and Administrative Workers;
- with an occupation as Sales Workers;
- with an occupation as Machinery Operators and Drivers;
- with an occupation as Labourers;
- being Aboriginal;
- speaking English at home;
- with the religion Catholic;
- with the religion Anglican;
- in the younger age categories (20–24; 25–29; 30–34);
- with a lower personal weekly income (<$1000; and $1000–2000).

Table 2 displays the results of a multiple linear regression analysis conducted on a sub-set of data restricted to postcodes from major cities of Australia (N = 897) as defined by the ASGS Remoteness areas [3]. The dependent variable in this multiple regression was vaccination rate among 5-year olds in postcodes from major cities of Australia. The predictors were a subset of key indicators from each variable grouping (e.g., Highest Level of Education) including: Bachelor Degree level or Higher; Being Unemployed; Occupation of Manager; Being Aboriginal; Speaking Mandarin at home; having No Religion; Religions - Catholic, Buddhism, Hinduism, and Islam; $2000–3000, and $3000 and over weekly personal income, and Ages 40–44, 45–49, and 50–54. The results of the multiple regression indicated the 15 predictors explained 30.0% of the variance (R^2 = 0.30, F(15,896) = 24.66, p < .001). Variables that significantly predicted a *lower* vaccination rate included having a bachelor degree level or higher; being unemployed; having an occupation as Manager; having no religion; and being aged 50–54. Variables that significantly predicted a *higher* vaccination rate included being Aboriginal, having the religion Catholic, and having a weekly personal income $2000–3000.

3.3. ASGS remoteness areas

The mean vaccination rate decreased proportionately as postcodes became more urban, as defined by ASGS Remoteness Areas: Very Remote: ***M* = 95.43**; *SD* = 2.74; *N* = 19; Remote: ***M* = 94.94**; *SD* = 3.70; *N* = 27; Outer Regional: ***M* = 93.73**; *SD* = 4.24; *N* = 171; Inner Regional: ***M* = 93.09**; *SD* = 4.68; *N* = 334; and Major Cities: ***M* = 91.98**; *SD* = 3.91; *N* = 897. A one-way ANOVA revealed a significant effect of Remoteness Area on vaccination rates (F(4,1443) = 17.61, p < .001). There was a significant linear trend (R^2 = 0.04, F(1,1443) = 17.61, p < .001) indicating that vaccination rates

Table 1
Standardized beta weights, means for each socio-demographic indicator across vaccination levels (postcodes with lowest through highest vaccination levels), linear trends, and effect size for each socio-demographic variable.

Socio-Demographic Variables	*Standardised Beta Weights*	Vaccination Rate: Lowest (≤90%) *M* (*N* = 305)	(90.1–92%) *M* (*N* = 245)	*(92.1–94%) M* (*N* = 326)	(94.1–96%) *M* (*N* = 315	Highest (96.1–100%) *M* (*N* = 257)	Linear Trend: *F(1,1443)*	*p*	Effect Size: R^2
Socio Economic Indexes for Areas (SEIFA):									
IRSD (Disadvantage)	−**0.11**	6.25	6.27	6.07	5.73	5.21	21.88	<.001	**0.02**
IEO (Education & Occupation)	−**0.25**	6.75	6.26	5.98	5.24	4.5	96.44	<.001	**0.06**
Highest Level of Education									
Bachelor Degree or higher	−**0.29**	41.17	38.51	36.1	30.07	24.25	144.11	<.001	**0.09**
Year 10, 11, and 12	**0.24**	21.96	23.13	23.81	26.28	28.17	91.96	<.001	**0.06**
Labour Force Status									
Unemployed	−**0.1**	4.3	3.95	3.83	3.77	3.64	17.76	<.001	**0.01**
Occupation									
Managers	−**0.16**	17.79	16.01	16.17	15.06	15.43	24.16	<.001	**0.02**
Professionals	−**0.27**	30.3	28.53	27.22	24.12	20.71	118.82	<.001	**0.08**
Technicians/Trade Workers	**0.23**	12.47	13.78	13.89	15.19	16.09	73	<.001	**0.05**
Community/Personal Service Workers	**0.15**	8.91	9.11	9.22	9.94	10.73	36.46	<.001	**0.03**
Clerical/Administrative Workers	**0.21**	11.75	12.85	13.35	13.72	13.36	54.36	<.001	**0.06**
Sales Workers	**0.09**	5.76	6.15	6.12	6.51	6.23	11.05	<.01	**0.01**
Machinery Operators/Drivers	**0.22**	4.78	5.51	5.79	6.35	7.53	54.24	<.001	**0.04**
Labourers	**0.12**	6.81	6.67	6.94	7.59	8.42	23.13	<.001	**0.02**
Indigenous Status									
Aboriginal	**0.14**	2.3	1.58	2.61	4	5.65	39.54	<.001	**0.03**
Language Spoken at Home									
English	**0.18**	74.8	71.8	74.53	80.8	86.77	68.65	<.001	**0.06**
Mandarin	−**0.22**	3.05	2.93	2.43	1.67	0.61	65.3	<.001	**0.05**
Religion									
No religion	−**0.18**	37.46	34.06	33.5	33.9	31.5	33.5	<.001	**0.03**
Catholic	**0.27**	20.88	21.94	23.17	24.72	26.22	117.66	<.001	**0.08**
Anglican	**0.26**	11.03	10.75	11.74	13.71	17.16	146.51	<.001	**0.11**
Buddhism	−**0.21**	2.67	2.95	2.5	1.84	1.14	60.66	<.001	**0.05**
Hinduism	−**0.16**	2.87	3.11	2.4	1.89	1.11	38.54	<.001	**0.03**
Islam	−**0.07**	3.46	4.92	4.08	2.35	1.5	9.59	<.001	**0.03**
Age Categories									
20–24	**0.16**	1.12	1.08	1.27	1.58	1.9	45.11	<.001	**0.03**
25–29	**0.23**	6.3	6.43	7.09	8.55	9.66	84.77	<.001	**0.06**
30–34	**0.25**	18.19	19.38	19.56	21.38	21.36	98.22	<.001	**0.07**
35–39	−**0.01**	30.14	31.32	30.82	30.6	30.17	0.67	.41	**0.01**
40–44	−**0.23**	27.17	26.53	25.97	24.17	21.96	93.9	<.001	**0.07**
45–49	−**0.29**	11.91	10.86	10.82	9.55	8.55	131.5	<.001	**0.09**
50–54	−**0.27**	3.11	2.7	2.66	2.37	2.29	78.66	<.001	**0.06**
Weekly Personal Income									
Low (<$1000)	**0.08**	45.74	46.28	45.68	46.92	48.13	10.34	<.01	**0.01**
$1000–2000	**0.18**	27.44	29.38	29.62	30.31	30.08	32.58	<.001	**0.03**
$2000–3000	−**0.06**	8.92	9.49	9.32	8.85	8.05	6.32	<.05	**0.01**
Very High ($3000 and over)	−**0.22**	9.05	7.22	7.12	4.91	4.04	74.11	<.001	**0.05**

decreased proportionately, from the *highest* rates in postcodes from Very Remote locations, to the *lowest* rates in postcodes from Major Cities.

4. Discussion

The WHO has highlighted the importance of both individual-level and regional-level factors in the analysis of vaccine hesitancy and refusal [33], including those factors of an environmental and socio-cultural nature. However, most studies have focused on individual-level variables, rather than area-based factors. This current study is the first of its kind in Australia to research area-based indicators associated with lower vaccination rates for children throughout the country. It is evident that, except for the unemployed indicator, postcodes with lower vaccination rates were characterised by indicators of high socio-economic status (e.g., high levels of education, and white-collar occupations); as well as higher levels of the older age groups (50–54); and lower levels of indicators of disadvantage (e.g., SEIFA Index of Relative Disadvantage, and being Aboriginal). Not identifying with formal religions (i.e., no religion, so described) was associated with postcodes having lower rates of vaccination. Levels of vaccination were also clearly related to Remoteness Areas, with the mean vaccination rate decreasing proportionately as communities become more urban, with Major Cities having the lowest vaccination rates.

Area-level deprivation has long been associated with negative health behaviours and health outcomes [37,46], so it is counter-intuitive to expect indicators of high socio-economic status to be associated with vaccine hesitancy and refusal. However some studies have shown that indicators of high socio-economic status are associated with lower rates of vaccination [24,28,50]. A study in California [36] clearly showed that affluence was associated with a greater prevalence of personal belief exemptions (PBEs) to immunisation requirements for private kindergartens. The study also showed that those private kindergartens with higher fees had a greater proportion of students admitted without being fully vaccinated. Another California study of PBEs from mandatory

Table 2
Summary of multiple regression analysis for select indicators predicting rate of vaccination in major cities (n = 897) of Australia.

	B	*SE B*	*β*	*p*
Constant	97.109	1.537		<.001
Highest Level of Education				
Bachelor degree or Higher	−0.068	0.019	−0.339	<.001
Labour Force Status				
Unemployed	−0.62	0.094	−0.263	<.001
Occupation				
Managers	−0.151	0.044	−0.241	<.01
Indigenous Status				
Aboriginal	0.272	0.098	0.107	<.01
Language Spoken at Home				
Mandarin	−0.004	0.032	−0.005	ns
Religion				
No Religion	−0.053	0.021	−0.149	<.05
Catholic	0.067	0.026	0.109	<.01
Buddhism	−0.023	0.043	−0.019	ns
Hinduism	−0.047	0.038	−0.058	ns
Islam	0.025	0.021	0.056	ns
Age Categories				
40–44	0.077	0.04	0.141	ns
45–49	−0.052	0.065	−0.054	ns
50–54	−0.571	0.13	−0.166	<.001
Weekly Personal Income				
$2000–3000	0.252	0.046	0.307	<.001
Very High ($3000 and over)	0.01	0.032	0.022	ns

Note: R^2 = 0.30; *B* = unstandardized beta; *SE B = standard error of unstandardized beta; β = standardized beta.*

vaccination, using regional models, showed that exemptions were more common in areas with a higher percentage of higher median household income, private school type, and white race; but no effect was found for educational attainment [54]. A qualitative analysis [42] showed a close relationship between PBEs and the concept of "privilege" at a socio-economic level; identifying issues of choice against vaccination in relation to class, gender, and social responsibility. Interviews with 25 mothers who were vaccine refusers by choice, rather than because of issues of access, identified narratives relating to intensive mothering practices (e.g., around feeding, natural living, and nutrition - which they perceive incorrectly as a superior form of support for immunity and disease prevention than vaccination), drawing on access to resources and privilege, to employ choice. They often rejected the notion that their choices against vaccination adversely affected the health of children in the general community. Reich's study highlights underlying themes of natural living which relate to those found with the use of complementary and alternative medicine (CAM). Indeed, our previous research found a close relationship between the use of CAM and anti-vaccination attitudes [16,45], tied together via an underlying worldview which embraced magical health beliefs, and to a lesser extent holistic health beliefs.

It is important to note that logistical and access barriers are still playing a significant role in the ability of parents to vaccinate their children. A longitudinal study of Australian children [39] found that the majority of mothers of children who were incompletely immunised, did not disagree with vaccination, but rather had difficulty overcoming a range of access barriers. Our data showed that postcodes with higher percentages of unemployed parents had significantly lower levels of vaccination, thus providing some evidence that access issues are still important. Australians who live in rural and remote areas of the country have poorer health outcomes, including lower life expectancy, higher rates of injury and disease, and reduced access to the range of health services available to residents in cities [5]. However, our study has shown that rates of vaccination among children were lower in the major cities than in the rural and remote areas of Australia. It is likely that this finding is a result of non-access related issues, such as the promulgation of anti-vaccination attitudes via social and parenting networks, cultural norms, and language and other barriers among ethnic minorities who often live in the cities [24,52]. Finally, local areas with a larger proportion of the community having no religion (as categorised in the 2016 Census) had relatively lower rates of vaccination. It is possible that personal worldviews that are underpinned by beliefs in spirituality, rather than formal religion, may be key to these results. Our previous research has shown that people who do not identify with major religions, may have a belief in spiritual and metaphysical ideas which lie outside formal religions [14]; and we have shown [15] that psychosocial factors including endorsement of spirituality as a source of knowledge predict negative attitudes to vaccination.

The results of this current study provide important evidence to inform public health interventions to increase participation in the Australian National Immunisation Program in local areas with lower rates of vaccination. The disproportionate under-vaccination of children from affluent and well educated families in the major cities of Australia has significant implications in terms of increased clusters of unvaccinated children; reduced herd immunity; the spread of vaccine hesitancy/refusal [27]; the spread of VPDs and the undermining of public health policy. These findings highlight a concern that *less* privileged Australians are shouldering a disproportionate burden of responsibility for reducing VPDs at the population or public health level. This issue is of such a complex nature that multiple intervention strategies will be required to increase vaccination coverage. Australia links immunisation status with eligibility for welfare and benefits to 'encourage' full vaccination of children [55]. However, these types of financial incentives or punishments have minimal impact on the more affluent members of society who do not receive these types of benefits, and who have greater resources available to justify (from their perspective) the opting out from vaccination programs (e.g., access to private health care; better nutrition; access to CAM). Legislation has its place in increasing rates of vaccination, but it is important to develop a far greater understanding of the motivations and reasoning behind vaccine hesitancy and refusal, particularly among the more urban and privileged groups of Australians, as well as those with more alternative worldviews regarding the place of science in healthcare. Public health interventions that rely on persuasive messaging targeting specific groups and their worldviews would be a useful adjunct to existing legislative approaches.

5. Limitations

The main limitation of this study is the ecological nature of the methodology, which means characteristics of individuals cannot be directly linked to their vaccination behaviours (as would be the case in survey data). Therefore, any inferences arising from the results must be applied to groups of people at the postcode level, rather than individuals. Inferences applied to individuals is referred to as 'the ecological fallacy' [48]. It is also noted that the census data is collected in August 2016, which is just outside the collection time period for vaccination data (the 2015/16 financial year). However, given that the target group includes parents/partners with children of the age range from 4 to 7, we feel that the data adequately captures the necessary groups and timeframes.

6. Future research

Future research would benefit from more detailed study into the characteristics of local communities identified as having lower vaccination levels, particularly those more affluent postcodes in the major cities of Australia. These studies could include in-depth qualitative interviews with parents who refuse or are hesitant about letting their children receive the recommended vaccinations. Further research is also required to clarify the results regarding groups who do not identify with formal religion (no religion), and the unemployed, to ascertain possible reasons for lower rates of vaccination in postcodes with significant proportions of these people.

7. Conclusion

This study identified characteristics of communities, at the postcode level, that were associated with lower rates of vaccination. These communities had relatively less disadvantage, and had greater education and occupation status, as measured by two SEIFA's [4] – IRSD and IEO. When we looked at the ASGS Remoteness Areas, we saw that the vaccination rates were lowest in postcodes from the major cities of Australia, and vaccination rates increased as communities became more remote. When the community is further refined to postcodes located in the major cities, and to the target group of parents/partners in a family with children aged 4–7, we found that postcodes with lower vaccination rates were characterised as having a relatively greater proportion of people with: a high education level (bachelor degree level or higher); having white-collar jobs as managers; having no religion, having people in the older age category (50–54); and conversely being unemployed.

Acknowledgement

This study was supported under the Australian Commonwealth Government's Research Training Program/Research Training Scheme for a Research Higher Degree candidate. We gratefully acknowledge the financial support provided by the Australian Government.

Declaration of Competing Interest

The authors declared that there is no conflict of interest.

Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.vaccine.2019.06.060.

References

[1] ABS (2016, August 23). 2901.0 - Census of Population and Housing: Census Dictionary; 2016. Retrieved November 5, 2018, from http://www.abs.gov.au/ausstats/abs@.nsf/mf/2901.0.
[2] ABS. Australian Bureau of Statistics, Census. Retrieved May 11, 2018; 2017 from http://www.abs.gov.au/websitedbs/D3310114.nsf/Home/Census/.
[3] ABS. Australian Statistical Geography Standard (ASGS) Volume 4 – Significant Urban Areas, Urban Centres and Localities, Section of State; 2017, October 9. Retrieved from http://www.abs.gov.au/ausstats/abs@.nsf/mf/1270.0.55.005.
[4] ABS. Socio-Economic Indexes for Areas (SEIFA) 2016; 2018, March 27. Retrieved October 18, 2022, from http://www.abs.gov.au/ausstats/abs@.nsf/mf/2033.0.55.001
[5] AIHW. Australia's Health 2016: Rural and Remote Health; 2017, May 17. Retrieved December 18, 2018, from https://www.aihw.gov.au/reports/rural-health/rural-remote-health/contents/rural-health
[6] AIHW. Australia Institute of Health and Welfare: My Healthy Communities; 2018. Retrieved April 17, 2018, from https://www.myhealthycommunities.gov.au/interactive/immunisation.
[7] Atwell JE, Van Otterloo J, Zipprich J, Winter K, Harriman K, Salmon DA, et al. Nonmedical vaccine exemptions and pertussis in California, 2010. Pediatrics 2013;132(4):624–30. https://doi.org/10.1542/peds.2013-0878.
[8] Australian Government, Department of Health. National Immunisation Program Schedule; 2018, March 9. Retrieved November 18, 2017, from https://beta.health.gov.au/health-topics/immunisation/immunisation-throughout-life/national-immunisation-program-schedule.
[9] Bass PF, III. Pertussis makes a nasty comeback; 2015. Retrieved from http://contemporarypediatrics.modernmedicine.com/contemporary-pediatrics/news/pertussis-makes-nasty-comeback?page=full.
[10] Beard FH, Hull BP, Leask J, Dey A, McIntyre PB. Trends and patterns in vaccination objection, Australia, 2002–2013 Retrieved from. Med J Australia 2016;204(7):275. https://onlinelibrary.wiley.com/doi/abs/10.5694/mja15.01226.
[11] Bedford H, Attwell K, Danchin M, Marshall H, Corben P, Leask J. Vaccine hesitancy, refusal and access barriers: the need for clarity in terminology. Vaccine 2018;36(44):6556–8. https://doi.org/10.1016/j.vaccine.2017.08.004.
[12] Bird C. Measles outbreaks threaten those averse to vaccine. CMAJ: Canadian Med Assoc J = Journal de l'Association Medicale Canadienne 2013;185(9):E393–4. https://doi.org/10.1503/cmaj.109-4480.
[13] Brewer NT, Fazekas KI. Predictors of HPV vaccine acceptability: a theory-informed, systematic review. Prev Med 2007;45(2–3):107–14. https://doi.org/10.1016/j.ypmed.2007.05.013.
[14] Browne M, Pennycook G, Goodwin B, McHenry M. Reflective minds and open hearts: cognitive style and personality predict religiosity and spiritual thinking in a community sample. Eur J Social Psychol 2014;44(7):736–42. https://doi.org/10.1002/ejsp.2059.
[15] Browne M, Thomson P, Rockloff MJ, Pennycook G. Going against the Herd: psychological and cultural factors underlying the "vaccination confidence gap". PLoS ONE 2015;10(9):e0132562. https://doi.org/10.1371/journal.pone.0132562.
[16] Bryden GM, Browne M, Rockloff M, Unsworth C. Anti-vaccination and pro-CAM attitudes both reflect magical beliefs about health. Vaccine 2018;36(9):1227–34. https://doi.org/10.1016/j.vaccine.2017.12.068.
[17] Corp IBM. IBM SPSS statistics for windows, version 25.0. Armonk, NY: IBM Corp.; 2017.
[18] Department of Health. Childhood immunisation coverage: What is our target?; 2018, October 18. Retrieved December 18, 2003, from https://beta.health.gov.au/health-topics/immunisation/childhood-immunisation-coverage.
[19] Dubé E, Laberge C, Guay M, Bramadat P, Roy R, Bettinger J. Vaccine hesitancy: an overview. Human Vacc Immunotherap 2013;9(8):1763–73. https://doi.org/10.4161/hv.24657.
[20] Dubé E, Vivion M, MacDonald NE. Vaccine hesitancy, vaccine refusal and the anti-vaccine movement: influence, impact and implications. Exp Rev Vacc 2015;14(1):99–117. https://doi.org/10.1586/14760584.2015.964212.
[21] Fine P, Eames K, Heymann DL. "Herd immunity": a rough guide. Clinical Infectious Diseases: An Official Publication of the Infectious Diseases Society of America; 2011. Retrieved from https://academic.oup.com/cid/article-abstract/52/7/911/299077.
[22] Fisher H, Audrey S, Mytton JA, Hickman M, Trotter C. Examining inequalities in the uptake of the school-based HPV vaccination programme in England: a retrospective cohort study. J Public Health 2014;36(1):36–45. https://doi.org/10.1093/pubmed/fdt042.
[23] Harding S, Jackson Pulver L, McDonald P, Morrison P, Trewin D, Voss A. Report on the quality of 2016 Census data; 2017. Retrieved from https://researchdirect.westernsydney.edu.au/islandora/object/uws:42389/.
[24] Henry KA, Swiecki-Sikora AL, Stroup AM, Warner EL, Kepka D. Area-based socioeconomic factors and Human Papillomavirus (HPV) vaccination among teen boys in the United States. BMC Public Health 2017;18(1):19. https://doi.org/10.1186/s12889-017-4567-2.
[25] Hull B, Hendry A, Dey A, Brotherton J, Macartney K, Beard F. Annual Immunisation Coverage Report 2017; 2018.
[26] Hull B, McIntyre P. Mapping immunisation coverage and conscientious objectors to immunisation in NSW. New South Wales Public Health Bull 2003;14(1–2):8–12. https://doi.org/10.1071/nb03003.

[27] Ingraham C. California's epidemic of vaccine denial, mapped. Washington Post; 2015. Retrieved from https://www.washingtonpost.com/news/wonk/wp/2015/01/27/californias-epidemic-of-vaccine-denial-mapped/?noredirect=on&utm_term=.3b6b6da5d71d.
[28] Jain A, van Hoek AJ, Boccia D, Thomas SL. Lower vaccine uptake amongst older individuals living alone: a systematic review and meta-analysis of social determinants of vaccine uptake. Vaccine 2017;35(18):2315–28. https://doi.org/10.1016/j.vaccine.2017.03.013.
[29] Jansen VAA, Stollenwerk N, Jensen HJ, Ramsay ME, Edmunds WJ, Rhodes CJ. Measles outbreaks in a population with declining vaccine uptake. Science 2003;301(5634):804. https://doi.org/10.1126/science.1086726.
[30] Kirby T. No jab, no play: Australia and compulsory vaccination. Lancet Infect Dis 2017;17(9):903. https://doi.org/10.1016/S1473-3099(17)30459-0.
[31] Kumar VM, Whynes DK. Explaining variation in the uptake of HPV vaccination in England. BMC Public Health 2011;11:172. https://doi.org/10.1186/1471-2458-11-172.
[32] Lamden KH, Gemmell I. General practice factors and MMR vaccine uptake: structure, process and demography. J Public Health 2008;30(3):251–7. https://doi.org/10.1093/pubmed/fdn036.
[33] Larson HJ, Jarrett C, Eckersberger E, Smith DMD, Paterson P. Understanding vaccine hesitancy around vaccines and vaccination from a global perspective: a systematic review of published literature, 2007–2012. Vaccine 2014;32(19):2150–9. https://doi.org/10.1016/j.vaccine.2014.01.081.
[34] Lieu TA, Ray GT, Klein NP, Chung C, Kulldorff M. Geographic clusters in underimmunization and vaccine refusal. Pediatrics 2015;135(2):280–9. https://doi.org/10.1542/peds.2014-2715.
[35] McIntosh EDG, Janda J, Ehrich JHH, Pettoello-Mantovani M, Somekh E. Vaccine Hesitancy and Refusal. J Pediatrics 2016;175:248–249.e1. https://doi.org/10.1016/j.jpeds.2016.06.006.
[36] McNutt L-A, Desemone C, DeNicola E, El Chebib H, Nadeau JA, Bednarczyk RA, et al. Affluence as a predictor of vaccine refusal and underimmunization in California private kindergartens. Vaccine 2016;34(14):1733–8. https://doi.org/10.1016/j.vaccine.2015.11.063.
[37] Mulholland E, Smith L, Carneiro I, Becher H, Lehmann D. Equity and child-survival strategies Retrieved from. Bull World Health Organ 2008;86(5):399–407. https://www.ncbi.nlm.nih.gov/pubmed/18545743.
[38] Onnela J-P, Landon BE, Kahn A-L, Ahmed D, Verma H, O'Malley AJ, et al. Polio vaccine hesitancy in the networks and neighborhoods of Malegaon, India. Soc Sci Med 2016;153:99–106. https://doi.org/10.1016/j.socscimed.2016.01.024.
[39] Pearce A, Marshall H, Bedford H, Lynch J. Barriers to childhood immunisation: findings from the Longitudinal Study of Australian Children. Vaccine 2015;33(29):3377–83. https://doi.org/10.1016/j.vaccine.2015.04.089.
[40] Phadke VK, Bednarczyk RA, Salmon DA, Omer SB. Association between vaccine refusal and vaccine-preventable diseases in the United States: A review of measles and pertussis. JAMA: J Am Med Assoc 2016;315(11):1149–58. https://doi.org/10.1001/jama.2016.1353.
[41] Rashid H, Khandaker G, Booy R. Vaccination and herd immunity: what more do we know? Curr Opin Infect Dis 2012;25(3):243–9. https://doi.org/10.1097/QCO.0b013e328352f727.
[42] Reich JA. Neoliberal mothering and vaccine refusal: imagined gated communities and the privilege of choice. Gender Soc: Off Publ Sociol Women Soc 2014;28(5):679–704. https://doi.org/10.1177/0891243214532711.
[43] Remes O, Smith LM, Alvarado-Llano BE, Colley L, Lévesque LE. Individual- and regional-level determinants of human papillomavirus (HPV) vaccine refusal: the Ontario Grade 8 HPV vaccine cohort study. BMC Public Health 2014;14:1047. https://doi.org/10.1186/1471-2458-14-1047.
[44] Roggendorf H, Santibanez S, Mankertz A, van Treeck U, Roggendorf M. Two consecutive measles outbreaks with genotypes D8 and D4 in two mainly unvaccinated communities in Germany. Med Microbiol Immunol 2012;201(3):349–55. https://doi.org/10.1007/s00430-012-0240-7.
[45] Rose L, Browne M, Bryden G. Scepticism towards vaccination is associated with anti-scientific attitudes and related cultural factors. Focus on Alternative and Complementary Therapies: FACT/Dept. of Complementary Medicine, Postgraduate Medical School, University of Exeter, 2016;21(1): 58–9. https://doi.org/10.1111/fct.12234.
[46] Sánchez-Santos MT, Mesa-Frias M, Choi M, Nüesch E, Asunsolo-Del Barco A, Amuzu A, et al. Area-level deprivation and overall and cause-specific mortality: 12 years' observation on British women and systematic review of prospective studies. PLoS ONE 2013;8(9):e72656. https://doi.org/10.1371/journal.pone.0072656.
[47] Sandford H, Tata LJ, Browne I, Pritchard C. Is there an association between the coverage of immunisation boosters by the age of 5 and deprivation? An ecological study. Vaccine 2015;33(9):1218–22. https://doi.org/10.1016/j.vaccine.2014.12.006.
[48] Sedgwick P. Understanding the ecological fallacy. BMJ 2015. https://doi.org/10.1136/bmj.h4773.
[49] Sheerin D, Openshaw PJ, Pollard AJ. Issues in vaccinology: present challenges and future directions. Eur J Immunol 2017;47(12):2017–25. https://doi.org/10.1002/eji.201746942.
[50] Smith PJ, Chu SY, Barker LE. Children who have received no vaccines: who are they and where do they live? Pediatrics 2004;114(1):187–95. https://doi.org/10.1542/peds.114.1.187.
[51] Tiley KS, White JM, Andrews N, Ramsay M, Edelstein M. Inequalities in childhood vaccination timing and completion in London. Vaccine 2018;36(45):6726–35. https://doi.org/10.1016/j.vaccine.2018.09.032.
[52] Warner EL, Ding Q, Pappas LM, Henry K, Kepka D. White, affluent, educated parents are least likely to choose HPV vaccination for their children: a cross-sectional study of the National Immunization Study–teen Retrieved from. BMC Pediatrics 2017;17(1):200. https://bmcpediatr.biomedcentral.com/articles/10.1186/s12887-017-0953-2.
[53] World Health Organization. Global Vaccine Action Plan 2011–2020 Retrieved from. World Health Organization; 2013. https://www.cabdirect.org/cabdirect/abstract/20133287402.
[54] Yang YT, Delamater PL, Leslie TF, Mello MM. Sociodemographic predictors of vaccination exemptions on the basis of personal belief in California. Am J Public Health 2016;106(1):172–7. https://doi.org/10.2105/AJPH.2015.302926.
[55] Yang YT, Studdert DM. Linking immunization status and eligibility for welfare and benefits payments: the Australian "No Jab, No Pay" legislation. JAMA: J Am Med Assoc 2017;317(8):803–4. https://doi.org/10.1001/jama.2017.0123.