What contributes to delays? The primary care determinants of immunisation timeliness in New Zealand

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ABSTRACT

INTRODUCTION: Delay in receipt of the first vaccine dose in the primary series is one of the strongest and most consistent predictors of subsequent incomplete immunisation.

AIM: To describe the on-time immunisation delivery of New Zealand infant scheduled vaccines by primary care practices and identify characteristics of practices, health professionals and patients associated with delays in receipt of infant immunisations.

METHODS: Timeliness of immunisation delivery and factors associated with timely immunisation were examined in 124 randomly selected primary care practices in two large regions of New Zealand.

RESULTS: A multiple regression model of demographic, practice, nurse, doctor and caregiver association explained 68% of the variance in immunisation timeliness between practices. Timeliness was higher in practices without staff shortages (ß-coefficient -0.0770, p= 0.01), where nurses believed parental apathy (ß-coefficient 0.0819, p=0.008) or physicians believed parental access (ß-coefficient 0.109, p=0.002) was a barrier, and lower in practices with Maori governance (ß-coefficient -0.0868, p=0.05), higher social deprivation (ß-coefficient -0.0643, <0.001) and where caregivers received immunisation-discouraging information (ß-coefficient -0.0643, p=0.04).

DISCUSSION: Interventions supporting practice teams and providers in primary care settings could produce significant improvements in immunisation timeliness.

KEYWORDS: Immunization; vaccination; immunization programs; primary health care; family practice

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Introduction

Delivering vaccinations at the ages recommended in the national immunisation schedule is important. Although achieving high coverage at two years of age is a valuable achievement, it fails to recognise several challenges: firstly the serious risks posed to young infants from diseases such as Haemophilus influenzae type b and pertussis,[1–5] secondly, the potential reservoir of disease in unvaccinated infants[6,7] and, thirdly, that delays in receipt of scheduled immunisations are significantly more likely to result in lower overall coverage.[8–10] Delayed immunisation significantly increases the infant risk for hospitalisation for pertussis and Haemophilus influenzae type b.[2,3,6]

Delay in receipt of the first vaccine dose in the primary series is one of the strongest and most consistent predictors of subsequent incomplete immunisation;[8,11,12] therefore, identifying factors that contribute to delays and addressing them can ultimately reduce the vaccine-preventable disease burden in a population.

The factors that determine immunisation timeliness are likely to have their effect from very

early in the child's life, or even before the child is born. There is a range of factors that contribute to vaccine uptake, including the knowledge and attitudes of caregivers,[13–16] attitudes of health professionals[17,18] and aspects of health care systems such as cost, recall and reminders, and cost to provider.[19] Little is known about the impact of these factors on immunisation in New Zealand, a country that has traditionally had a significant problem with low immunisation coverage[20] and relatively high rates of vaccine-preventable disease.[21]

Aim

The aims of our study were to describe the on-time immunisation delivery of the New Zealand infant scheduled vaccines by primary care practices and to identify the characteristics of the practices, the health professionals and the patients that are associated with delays in receipt of infant immunisations.

Methods

This study was part of a comprehensive project exploring the contributions of different health system factors to immunisation coverage and timeliness in New Zealand. These methods have been previously reported.[22–25]

The Ministry of Health definition of on-time immunisation was used, being receipt of the six-week immunisation within four weeks of due date and within six weeks of due date for the three-month, five-month and 15-month immunisations.[26] A delayed immunisation is, therefore, one that is delivered beyond this time window.

WHAT GAP THIS FILLS

What we already know: Many factors are known to affect immunisation rates—socioeconomic factors, health care system factors and family and child factors. The relative contribution of various factors is not well established and less is known about the factors that affect timeliness of delivery.

What this study adds: The key factors affecting timeliness of delivery of the childhood immunisation schedule in the primary care setting are demonstrated: the dominant environmental factors are social deprivation in the enrolled population, ethnicity and early enrolment of infants; significant practice systems factors are staffing stability and type of practice management system used. Provider issues are around confidence and engagement; and the major parental issue is having contact with discouraging material in the antenatal arena.

Study design and setting

A survey of primary care practices was conducted from 2005 to 2007 in the Auckland and Midland regions in New Zealand which care for approximately 50% of all New Zealand children aged 0–4 years. Ethical approval was obtained from the Ministry of Health Auckland Regional Ethics Committee.

Study sample

A random sample of 124 practices was recruited with stratification by region. As immunisation coverage is lower among Maori[27] there was oversampling of practices with Maori governance (practices that provide services primarily for Maori and that have a Maori management structure). The characteristics of the sample practices are described in Figure 1.

Figure 1. Summary of study sample

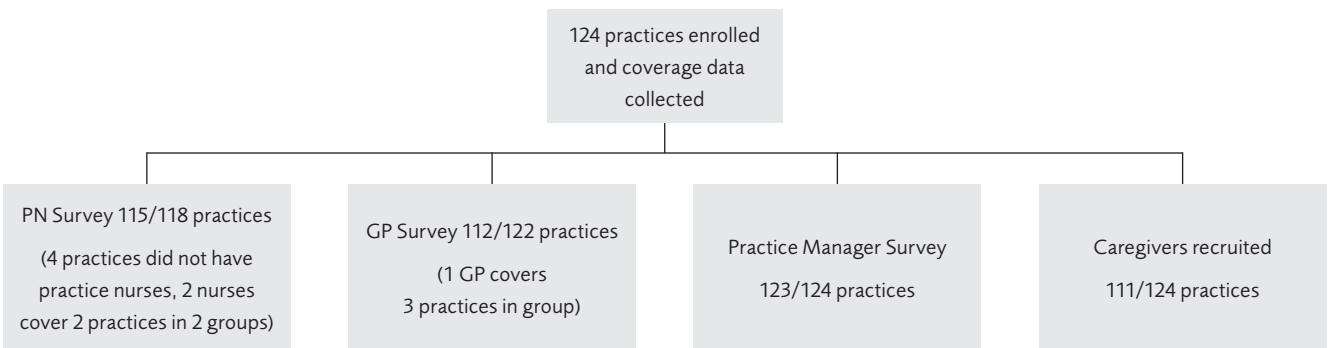


Table 1. New Zealand infant immunisation schedule at time of study

DTaP-IPV	Hib-HepB	HepB	DTaP/Hib	MMR
6 weeks	6 weeks			
3 months	3 months			
5 months		5 months		
			15 months	15 months

Data collection and measurements

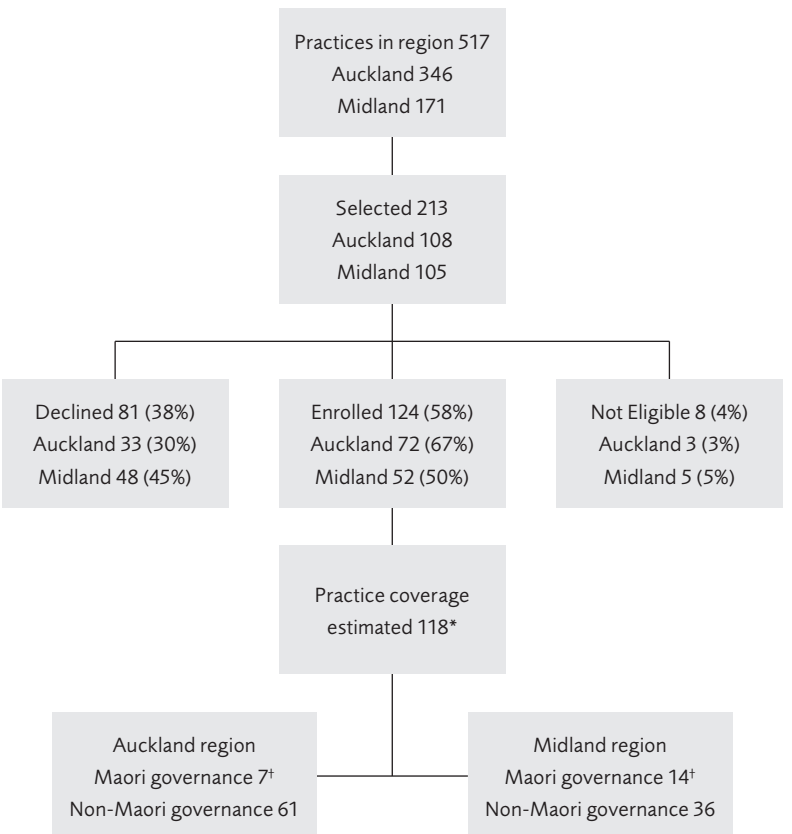
An audit was conducted of the recruited practice immunisation records of all children six weeks to 23 months. The immunisation schedule for children under two years of age at the time of this study is shown in Table 1.

Records describing immunisations received by each registered child and their age at registration were extracted from the Practice Management System (PMS). Interviews with practice managers or senior staff collected data about the characteristics of the practice, including funding, co-payments and immunisation recall and outreach methods used. Socioeconomic status was measured using the New Zealand Index of Social Deprivation.[28]

One randomly selected general practitioner and one nurse per practice were invited to complete a computer-assisted telephone interview (CATI) exploring their experiences, knowledge, attitudes, perceived barriers to immunisation, sources of information and perceptions of practice teamwork. The questionnaires were adapted from previously used tools from both the United Kingdom and New Zealand.[29–31]

Additionally, a random sample of caregivers of children registered at each practice was generated and the practice receptionist recruited to contact the caregivers of these children, aiming for a sample of 10 children per practice. Following informed consent, the caregivers completed a CATI exploring caregivers' education, antenatal primary care, and immunisation knowledge and attitudes. Their impression of the quality of primary care their child received was measured using the General Practice Assessment Survey.[32,33] Responses were aggregated by practice and expressed as the median or predominant response per practice.

Figure 2. Practice recruitment



* At one practice none of the immunised children were registered or enrolled

† Coverage for four Auckland and three Midland Maori governance practices were estimated as one practice.

Data analysis

The proportion of children registered at each practice who had received their scheduled immunisations on time was described. The proportion immunised was transformed to facilitate analysis using the arcsin of the square root of the variable. This transformation made the variance constant across the distribution of timeliness at each practice. Interaction with either region or practice governance for any of the variables associated with coverage was examined. The inverse of the number of enrolled children was used as a weight.

For the regression analyses a base model was created that included region (Auckland or Midland), practice governance (Maori or non-Maori),

socioeconomic deprivation, and the median age and median age at registration of the children as explanatory variables. Explanatory variables that described practice characteristics, doctors, nurses and caregivers were then examined after adjustment for the effect on immunisation timeliness of these base-model variables. Multiple regression analyses were performed for each of these four areas, and then a summary analysis that combined variables from all four areas.

Results

The study sample (Figure 1) and recruitment (Figure 2) have been described previously, and the sample has been demonstrated to be regionally and nationally representative.[22,23,34]

Practice immunisation timeliness

A median (25th, 75th centile) of 56% (40%, 64%) of registered children at each practice were immunised on time. There was a wide distribution of timeliness across practices. Significant delay existed even for the first dose of DTaP-IPV and Hib-HepB due at six weeks of age where a median of 22% of registered children had delayed immunisation. This increased with each successive vaccination event (Table 2).

Factors associated with delay in immunisation

Socioeconomic deprivation, practice funding and whether urban or rural

Immunisation timeliness varied with socioeconomic deprivation of the practice population (the greater the deprivation the less likely that immunisations were delivered on time) but not with type of practice funding, or rurality. Practices with a smaller proportion of registered patients from socioeconomically deprived households delivered immunisations on time to a larger proportion of children ($p<0.001$)—see Table 3.

Characteristics of the practice

Timeliness decreased as age of the children at registration increased ($p=0.03$) and as the child's age increased ($p=0.004$). Timeliness was higher at practices where the electronic practice management system MedTech (Medtech Limited, Auckland, NZ) was used rather than one of the three alternative electronic systems ($p=0.01$). Practice staff shortages were associated with less timely immunisation delivery ($p=0.04$)—see Table 4.

Health professional characteristics

Immunisation delivery was more timely in practices where nurses perceived parental apathy to be a barrier to immunisation ($p=0.008$) and where the doctors perceived parental apathy to be a barrier ($p=0.002$).

Caregiver characteristics

Practice coverage was more timely where the caregivers had not received discouraging information about immunisation during the antenatal period ($p=0.04$). Coverage was also higher at practices where more caregivers had a tertiary qualification ($p=0.06$).

*Table 2. Percentage of the registered children at each of the practices not on time for each immunisation**

Scheduled vaccine	Median % of children delayed (5th, 95th centile)
6-week immunisations	
DTaP-IPV#1	22 (7, 67)
Hib-HepB #1	23 (8, 67)
3-month immunisations	
DTaP-IPV#2	27 (10, 67)
Hib-HepB #2	27 (11, 67)
5-month immunisations	
DTaP-IPV#3	30 (14, 73)
HepB 5M	30 (15, 77)
15-month immunisations	
DTaP-Hib	42 (19, 75)
MMR#1	44 (20, 75)

* An immunisation was defined as delayed (not on time) if not given within four weeks of the due date for vaccines scheduled at age six weeks, and within six weeks of the due date for vaccines scheduled at three months, five months and 15 months of age.

DTaP-IPV—diphtheria, tetanus, acellular pertussis, inactivated polio vaccine

Hib-HepB—Haemophilus influenzae type B, hepatitis B

MMR—measles, mumps and rubella

Multivariable model including practice, health professional and caregiver characteristics

The multivariable model explained 68% of the variance in immunisation timeliness between practices. In this multiple regression model of demographic, practice, nurse, doctor and caregiver associations with practice on-time immunisation, timeliness was higher in practices where there were no staff shortages (p=0.01), and that enrolled children at a younger age (p=0.02), where the nurse believed parental apathy to be a barrier (p=0.008), where the physician believed parental access was a barrier (p=0.002), and lower in practices with Maori governance (p=0.05), higher social deprivation (p<0.001) and where caregivers received information discouraging them from immunising (p=0.04)—see Table 5.

Discussion

There are many factors that contribute to timeliness of immunisation delivery. However, the relative contribution of each of these has not been explored previously. This study provides information on general practice characteristics and systems, health professional and caregiver factors and their relative contribution to the timeliness of immunisation delivery in children under two years in two major regions in New Zealand. It demonstrates the strong influence of social deprivation on practice immunisation delivery, but shows that independent of this effect there are practice, health professional and caregiver-specific issues that determine how well an individual practice delivers immunisations to its population.

The three major contributors to incomplete immunisation documented to date are socioeconomic factors, health care system factors and family and child factors.[35]

Immunisation timeliness has neither received as much focused attention nor been measured as intensely as absolute coverage. Additionally, most studies examining this issue in developed countries have been conducted in the United States.

Table 3. Practice immunisation timeliness by socioeconomic deprivation, practice funding and whether an urban or rural practice

Variable (number of practices)	Median % of children at each practice with immunisations on time (25th, 75th centile)				p value*
Region	Auckland		Midland		
Governance	Maori	Non-Maori	Maori	Non-Maori	
Number of practices	n=7	n=61	n=14	n=36	
Percentage of registered patients in most socioeconomically deprived quintile† (118)					
Less than 30% (86)	39 (30, 47)	60 (47, 68)	62 (9, 64)	59 (47, 63)	< 0.001‡
30% or more (32)	32 (23, 42)	50 (20, 61)	40 (25, 47)	61 (27, 64)	
Access funding§ (118)					
No (72)	||	60 (47, 68)	64 (64, 64)	59 (47, 63)	0.59¶
Yes (46)	32 (23, 47)	56 (33, 64)	40 (25, 47)	60 (47, 62)	
Urban or rural practice (110)**					
Urban (90)	37 (25, 45)	61 (46, 68)	36 (25, 62)	59 (50, 65)	
Rural (20)	23 (23, 23)	49 (47, 57)	46 (45, 47)	60 (27, 63)	0.43¶

* Analysis adjusted for region and governance

† Percentage in most socioeconomically deprived quintile included in model as a continuous variable

‡ Based on the NZDep2001 index of deprivation; a small area-based measure that combines nine variables from the 2001 census which reflect aspects of material and social deprivation[28]

§ A practice is eligible for access funding if 50% of enrolled patients are from high-deprivation communities or are of Maori or Pacific ethnicities

|| No practices in this category

¶ Adjusted for region, practice governance and socioeconomic deprivation of the registered population

** As defined by a national rural ranking scale[49]

Table 4. Practice immunisation timeliness by characteristics of registered children and of the practice

Variable (number of practices)	Median % of children at each practice with no delayed immunisations (25th, 75th centile)				p value*
Region	Auckland		Midland		
Governance	Maori	Non-Maori	Maori	Non-Maori	
Number of practices	n=7	n=61	n=14	n=36	
Characteristics of the registered children <2 years old					
Median age of children (118)					
Less than 13 months (48)	38 (30, 46)	62 (56, 66)	49 (44, 57)	62 (57, 64)	0.004
13 months or older (70)	32 (23, 42)	49 (38, 67)	31 (25, 47)	55 (42, 61)	
Median age of children at registration† (118)					
Less than 3 months (72)	–‡	61 (45, 68)	25 (13, 52)	59 (47, 63)	0.03
3 months or older (46)	32 (23, 46)	55 (44, 62)	43 (31, 47)	58 (47, 63)	
Number of registered children† (118)					
Less than 150 (71)	31 (27, 39)	61 (45, 68)	42 (25, 50)	59 (46, 65)	0.64
150 or more (47)	42 (17, 47)	57 (44, 65)	47 (31, 62)	59 (50, 62)	
Characteristics of the practice					p value§
Medtech is patient management system used (117)					
Yes (89)	36 (23, 46)	62 (50, 67)	44 (31, 52)	59 (50, 63)	0.01
No (28)	32 (32, 32)	45 (33, 61)	19 (11, 46)	47 (42, 63)	
Practice charges for appointments for registered children (117)					
No (86)	32 (23, 46)	55 (40, 67)	40 (25, 47)	58 (46, 65)	0.24
Yes (31)	–‡	62 (59, 68)	64 (64, 64)	60 (57, 62)	
>15% of registered patients at the practice owed money† (116)					
Yes (43)	37 (30 46)	49 (43, 64)	42 (30, 62)	53 (39, 64)	0.18
No (73)	23 (23 23)	62 (49, 70)	36 (17, 50)	60 (49, 63)	
Practice has specific immunisation clinics or appointments (119)					
Yes (41)	30 (23, 46)	60 (46, 67)	40 (31, 62)	55 (47, 63)	0.43
No (78)	37 (25, 45)	55 (44, 67)	43 (25, 52)	59 (47, 63)	
Practice has staff shortages (117)					
Yes (76)	36 (23, 46)	57 (44, 66)	40 (25, 47)	58 (47, 63)	0.04
No (41)	32 (32, 32)	61 (46, 67)	62 (9, 64)	61 (57, 65)	

* Adjusted for region, practice governance and socioeconomic deprivation of the registered population

† Entered into model as continuous variable

‡ No practices in this category

§ Adjusted for region, practice governance and socioeconomic deprivation of the registered population, age and registration age of children <2 years old

With the potential to eradicate or better control diseases such as Haemophilus influenzae type B and pertussis it is necessary to shift the goal posts from coverage to timely coverage. Immunisation Registers make the regular monitoring and reporting of immunisation timeliness along with coverage more feasible. In order to be able to make use of this data to improve practice immunisation delivery it is necessary to determine what the features are of practices that achieve timelier immunisation delivery.

After adjustment for region, Maori governance, social deprivation and age of the child we found several other important determinants. Within the practice, staff shortages and the type of

practice management system influenced coverage. Maintaining stable practice staff and, to a lesser extent, the type of management system that facilitates the systematic management of immunisation data and recalls appear to result in more timely immunisation delivery. Practices which registered their population of child patients at a younger age achieved more timely immunisation. While this appears intuitive, it is an important issue in New Zealand where the majority of antenatal primary care is provided by midwives, and it is necessary for the mother of a newborn child to then identify a family practice for Well Child care. Prompt transition between these two components of the primary care system is clearly necessary to achieve a good start to the immunisation components of this Well Child care.

Both the practice nurse and physician perception of caregiver barriers was associated with more timely immunisation delivery by the practice. This could be an indirect measure of a type of health professional who is more interested and engaged with immunisation issues at their practice and also more aware of the issues facing the populations they serve. It has been previously shown that confident, engaged providers support improved immunisation coverage.[12,36]

Anti-immunisation material from various sources discouraging caregivers from immunising their children has frequently been shown to affect coverage.[37–39] Of all caregiver variables measured in this study, receipt of discouraging information in the antenatal period was the only one to remain significant after controlling for all likely confounders. This emphasises the importance of the antenatal period as a time when promotion of immunisation must occur as well as limiting the exposure to anti-immunisation material.[40]

Relationship to international literature

Most studies reporting timeliness have been conducted in the US[41–44] as well as surveys of

Table 5. Combined analysis of practice, child, health professional and caregiver associations with practice immunisation timeliness

Variable*	Direction of effect on timeliness	ß-coefficient	p value
Demographics			
Governance	More timely in non-Maori than Maori governance practices	-0.0868	0.05
Socioeconomic deprivation	Less timely with increased socioeconomic deprivation	-0.0025	< 0.001
Practice			
Age of children at registration	Less timely with increasing age at registration	-0.0009	0.02
Staff shortages	More timely in practices that did not have staff shortages	-0.0770	0.01
Nurse			
Nurse perceives parental apathy as barrier to immunisation	More timely in practices where nurse had this perception	0.0819	0.008
Doctor			
Doctor perceives parental access difficulties as a barrier	More timely in practices where doctor had this perception	0.1090	0.002
Caregiver			
Received discouraging information about immunisation antenatally	Lower at practices where caregivers received discouraging information	-0.0643	0.04

* Other variables in model for which associations with coverage were not significant:

- region (p=0.96)
- age of registered child (p=0.30)
- patient management system used (p=0.12)
- nurse to child ratio (p=0.73)
- doctor perceives parental apathy as a barrier (p=0.18)
- caregiver has a tertiary qualification (p=0.06)

Australian clinical records using national register data[45] and well-baby records in Sweden.[46] A comparison of international studies reported a range in delay in infant programmes from 6% (US)[43] to 75% (Australia).[45] There is a range of factors associated with timeliness reported in these studies.

Delay in commencing immunisation is associated with delay for later doses and incomplete immunisation.[36] We found that the increasing age of child at enrolment was inversely associated with coverage. Delay in enrolment at the general practice could lead to delay in uptake of the first vaccination.

Ethnicity, area of residence[16,47,48] and, in Sweden, negative media coverage was associated with delay in MMR vaccination.[46] Consistent with these findings, we specifically determined that region and social deprivation were important factors in determining coverage. Also, coverage was lower at practices where caregivers had received discouraging information.

Strengths and limitations

A strength of this study is that it involved a large population of 26 000 children under two years of age in a regionally representative sample of practices including urban and rural, serving a wide socioeconomic and ethnic spectrum. Immunisation data was obtained by an electronic audit of individual child immunisation data and so is, to the best of our knowledge, the most accurate measure of practice immunisation available. A comprehensive range of factors likely to impact upon practice immunisation delivery was measured, allowing the description of a complete picture of practice immunisation delivery.

Limitations include a practice decline rate of 38%. However, the sample is both regionally and nationally representative. We were limited to interviewing one GP and one nurse from each practice whose responses may not have been representative of all GPs and nurses at the practice. Seeking to interview multiple GPs and nurses would have been an unacceptably high respondent burden and would likely have resulted in a higher decline rate.

Implications and recommendations

A variety of factors at the primary care and health professional level contribute significantly to immunisation timeliness and, unlike most caregiver characteristics, are under greater control by the practice. This study has identified those practice characteristics that contribute most significantly to timely immunisation uptake.

Interventions that promote early enrolment of infants at a primary health care practice, sufficient stable staffing, committed and confident providers and a practice management system capable of managing immunisation information could facilitate improvements in the timeliness of immunisation uptake. Monitoring and managing anti-immunisation activity in the antenatal period could also mitigate the effects of discouraging information affecting immunisation uptake. Our study suggests that significant improvements in immunisation timeliness can be made within the primary care setting.

References

1. Somerville RL, Grant CC, Scragg RK, Thomas MG. Hospitalisations due to pertussis in New Zealand in the pre-immunisation and mass immunisation eras. J Paediatr Child Health. 2007;43(3):147–53.
2. Grant CC, Roberts M, Scragg R, et al. Delayed immunisation and risk of pertussis in infants: unmatched case-control study. BMJ. 2003 April 19, 2003;326(7394):852–3.
3. Kolos V, Menzies R, McIntyre P. Higher pertussis hospitalization rates in indigenous Australian infants, and delayed vaccination. Vaccine. 2007;25(4):588–90.
4. Greenberg DP, Doemland M, Bettinger JA, et al. Epidemiology of pertussis and Haemophilus influenzae type b disease in Canada with exclusive use of a diphtheria-tetanus-acellular pertussis-inactivated poliovirus-Haemophilus influenzae type b pediatric combination vaccine and an adolescent-adult tetanus-diphtheria-acellular pertussis vaccine: implications for disease prevention in the United States. Pediatr Infect Dis J. 2009;28(6):521-8 10.1097/INF.0b013e318199d2fc.
5. Crowcroft NS, Pebody RG. Recent developments in pertussis. Lancet. 2006 Jun 10;367(9526):1926–36.
6. Singleton R, Bulkow LR, Levine OS, Butler JC, Hennessy TW, Parkinson A. Experience with the prevention of invasive Haemophilus influenzae type b disease by vaccination in Alaska: the impact of persistent oropharyngeal carriage. J Pediatr. 2000;137(3):313–20.
7. Anonymous. The measles epidemic. The problems, barriers, and recommendations. The National Vaccine Advisory Committee. JAMA. 1991 Sep 18;266(11):1547–52.
8. Guyer B, Hughart N, Holt E, et al. Immunization coverage and its relationship to preventive health care visits among inner-city children in Baltimore. Pediatr. 1994;94(1):53-8.
9. Farizo KM, Stehr Green PA, Markowitz LE, Patriarca PA. Vaccination levels and missed opportunities for measles vaccination: a record audit in a public pediatric clinic. Pediatr. 1992;89(4 Pt 1):589–92.

10. Wood D, Pereyra M, Halfon N, Hamlin J, Grabowsky M. Vaccination levels in Los Angeles public health centers: The contribution of missed opportunities to vaccinate and other factors. Am J Pub Health. 1995;85(6):850.
11. Bobo JK, Gale JL, Thapa PB, Wassilak SG. Risk factors for delayed immunization in a random sample of 1163 children from Oregon and Washington. Pediatrics. 1993;91(2):308–14.
12. Williams IT, Milton JD, Farrell JB, Graham NM. Interaction of socioeconomic status and provider practices as predictors of immunization coverage in Virginia children. Pediatr. 1995;96(3 Pt 1):439–46.
13. Samad L, Butler N, Peckham C, Bedford H. Incomplete immunisation uptake in infancy: maternal reasons. Vaccine. 2006;24(47-48):6823–9.
14. Fields V, Sumpter C, Seagraves L, Laney A, Lott A, McBride K. Determining factors affecting parental non-compliance with vaccination schedules of children ages 6 months to 2 years. LaGrange College GA 30240, USA; 2007.
15. Tickner S, Leman PJ, Woodcock A. Factors underlying suboptimal childhood immunisation. Vaccine. 2006;24(49–50):7030–6.
16. Trauth JM, Zimmarman RK, Musa D, Mainzer H, Nutini JF. Do beliefs of inner-city parents about disease and vaccine risks affect immunization? J Nat Med Assoc. 2002;94(9):820–32.
17. Pattison H, Pareek M. Health professionals' attitudes to MMR vaccine. Advice in primary care affects parents' decision to take up MMR vaccination. BMJ. 2001;322(7294):1121.
18. Petousis-Harris H, Goodyear-Smith F, Turner N, Soe B. Family practice nurse views on barriers to immunising children. Vaccine. 2005;23(21):2725–30.
19. Briss PA, Rodewald LE, Hinman AR, et al. Reviews of evidence regarding interventions to improve vaccination coverage in children, adolescents, and adults. The Task Force on Community Preventive Services. AM J Prev Med. 2000;18(1 Suppl):97–140.
20. Ministry of Health. The National Childhood Immunisation Coverage Survey 2005. Wellington: Ministry of Health; 2007.
21. Ministry of Health. Immunisation Handbook 2006. Wellington: Ministry of Health; 2006.
22. Goodyear-Smith F, Grant C, Petousis-Harris H, Turner N. Immunization champions: characteristics of general practitioners associated with better immunization delivery. Hum Vaccines. 2009;5(6):403–11.
23. Goodyear-Smith F, Grant C, York D, et al. Determining immunisation coverage rates in primary health care practices: a simple goal but a complex task. Int J Med Inform. 2008;77:477–85.
24. Goodyear-Smith F, York D, Petousis-Harris H, et al. Recruitment of practices in primary care research: the long and the short of it. Fam Pract. 2009 April 1, 2009;26(2):128–36.
25. Turner N, Grant C, Goodyear-Smith F, Petousis-Harris H. Seize the moments: missed opportunities to immunize at the family practice level. Fam Pract. 2009 May 28, 2009:cmp028.
26. Ministry of Health. The National Childhood Immunisation Coverage Survey 2005. Wellington; 2007.
27. New Zealand Ministry of Health. Immunisation Coverage National and DHB Data. [Cited 2009 June 10]. Available from: http://www.moh.govt.nz/moh.nsf/indexmh/immunisation-coverage-data.
28. Crampton P, Davis P. Measuring deprivation and socioeconomic status: why and how? NZ Pub Health Report. 1998;5(11/12):81–4.
29. Petousis-Harris H, Goodyear-Smith F, Turner N, Soe B. Family physician perspectives on barriers to childhood immunisation. Vaccine. 2004;22(17-18):2340–4.
30. Petousis-Harris H, Goodyear-Smith F, Soe B, Turner N. Family practice nurses perspectives on barriers to childhood immunisation. Vaccine. 2005;23:2725–30.
31. Peckham C, Bedford H, Senturia Y, Ades A. The Peckham report—national immunisation study: factors influencing immunisation uptake in childhood. London: Institute of Child Health, April 1989. 46 p.
32. Ramsay J, Campbell JL, Schroter S, Green J, Roland M. The General Practice Assessment Survey (GPAS): tests of data quality and measurement properties. Fam Pract. 2000;17(5):372–9.
33. Campbell JL, Ramsay J, Green J. Age, gender, socioeconomic, and ethnic differences in patients' assessments of primary health care. Qual Health Care. 2001;10(2):90–5.
34. Grant CC, Turner NM, York DG, Goodyear-Smith F, Petousis-Harris HA. Factors associated with immunisation coverage and timeliness in New Zealand. Br J Gen Pract. 2010;60(572):180–6.
35. National Vaccine Advisory Committee. Strategies to sustain success in childhood immunizations. JAMA. 1999;282(4):363–70.
36. Strine TW, Luman ET, Okoro CA, McCauley MM, Barker LE. Predictors of age-appropriate receipt of DTaP dose 4. Am J Prev Med. 2003;25(1):45–9.
37. Gangarosa E, Galazka A, Wolfe C, et al. Impact of anti-vaccine movements on pertussis control: the untold story. Lancet. 1998;351:356–60.
38. Begg N. Media dents confidence in MMR vaccine. BMJ. 1998 14 February 1998;316(No. 7130):1–3.
39. Smith MJ, Ellenberg SS, Bell LM, Rubin DM. Media coverage of the measles-mumps-rubella vaccine and autism controversy and its relationship to MMR immunization rates in the United States. Pediatr. 2008 Apr;121(4):e836–43.
40. Leask J, Chapman S, Hawe P, et al. What maintains parental support for vaccination when challenged by anti-vaccination messages? A qualitative study. Vaccine. 2006 Nov 30;24(49–50):7238–45.
41. Luman ET, Barker LE, Shaw KM, McCauley MM, Buehler JW, Pickering LK. Timeliness of childhood vaccinations in the United States: days undervaccinated and number of vaccines delayed. JAMA. 2005 March 9, 2005;293(10):1204–11.
42. Luman ET, McCauley MM, Stokley S, Chu SY, Pickering LK. Timeliness of childhood immunizations. Pediatr. 2002 November 1, 2002;110(5):935–9.
43. Cotter JJ, Bramble JD, Bovbjerg VE, et al. Timeliness of immunizations of children in a medicaid primary care case management managed care program. J Nat Med Assoc. 2002;94(9):833–40.
44. de Nuncio MLZ, Nader PR, Sawyer MH, De Guire M, Prislin R, Elder JP. A prenatal intervention study to improve timeliness of immunization initiation in Latino infants. J Comm Health. 2003;28(2):151–65.
45. Hull BP, McIntyre PB. Timeliness of childhood immunisation in Australia. Vaccine. 2006;24(20):4403–8.
46. Dannetun E, Tegnell A, Hermansson G, Torner A, Giesecke J. Timeliness of MMR vaccination—influence on vaccination coverage. Vaccine. 2004;22(31–32):4228–32.
47. Dombkowski KJ, Lantz PM, Freed GL. The need for surveillance of delay in age-appropriate immunization. Am J Prevent Med. 2002;23(1):36–42.
48. Ehresmann KR, White KE, Hedberg CW, et al. A statewide survey of immunization rates in Minnesota school age children: implications for targeted assessment and prevention strategies. Pediatri Infect Dis J. 1998;17(8):711–6.
49. Health Funding Authority. Variation of Advice Notice Pursuant to Section 51 of the Health and Disability Services Act 1993. New Zealand, 1999.

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COMPETING INTERESTS
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