

The 2009 influenza pandemic: a review of the strengths and weaknesses of the health sector response in New Zealand

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Abstract

Introduction To inform future pandemic planning and disaster response, we aimed to review the literature on the health sector response to the influenza A (H1N1) 2009 pandemic in New Zealand in 2009.

Methods We searched PubMed and Google Scholar along with the websites of government agencies for the period 1 April 2009 to 20 May 2012.

Results In 2009, 18% of the New Zealand population had evidence of infection from the pandemic strain, 1122 people were hospitalised (with pandemic influenza as the primary diagnosis), 102 of those hospitalised were treated in intensive care units (ICU), and there were an estimated 49 pandemic-attributed deaths. At the severe end of the disease spectrum (ICU admissions and mortality), the health burden was significantly worse for Māori and Pacific peoples.

The available evidence (including various estimates of low case-fatality risk relative to other high income countries), is consistent with the overall response in the public health, primary care and hospital sectors being fairly successful. Nevertheless, a number of likely weaknesses were identified, including a relative lack of: (i) a detailed review of the epidemiology and health sector response; (ii) sophisticated analytic studies to identify risk factors (e.g., using case-control studies); (iii) studies on pandemic vaccine uptake and public acceptability; and (iv) evaluation of the health protection messages that were used in campaigns and in media releases from health authorities.

Conclusions There appear to have been both strengths and weakness in the New Zealand health sector's response to the 2009 influenza pandemic. Nevertheless, it is probably still worthwhile to address some of the omissions to inform future pandemic and natural disaster planning and preparations.

It is important to consider the lessons from the influenza A (H1N1) 2009 pandemic for New Zealand (NZ), given the likely occurrence of future such pandemics. These lessons may inform how this country could further upgrade its national and local pandemic plans and also develop its surveillance system for infectious diseases in general (for which there is significant scope for improvement¹).

Such lessons may also be relevant to other pandemic diseases such as a re-emergence of a more infectious form of SARS or even disease associated with bioweapons, albeit probably a very low risk for NZ.² Finally this pandemic, although involving a virus strain of relatively low virulence,³ can be considered a type of "natural disaster". As such it may provide lessons for dealing with other natural disasters and civil defence emergencies.

Some of these events are likely to become more prevalent with global climate change (e.g., severe storms and flooding events).

Three years following a new influenza pandemic is a good point to reflect on the health sector response at a country-level. This is a time when relevant local research has often been published. Some review work to date has included an official document that had reported and summarised selected aspects of the health burden of the 2009 pandemic for New Zealanders.⁴ But the scope of this work was largely limited to the mortality burden. Two other reviews have considered studies from the Southern Hemisphere, but these dealt with fairly selected aspects of the NZ data.^{5,6}

We therefore aimed to review the literature on the 2009 pandemic relating to NZ so as to: summarise its impact; to make comparisons with the 1918 pandemic; and to detail the strengths and weaknesses of the health sector responses (including public health, primary care and hospitals).

Methods

We searched PubMed and Google Scholar along with the websites of government agencies (Ministry of Health and ESR – a Crown Research Institute). The search period was from 1 April 2009 to 20 May 2012, and the search terms included “influenza” and “2009” and “Zealand”. We identified a total of 54 relevant PubMed-indexed articles and letters. We purposefully excluded from the above total the following: case reports (n=2); international studies/reviews that contained NZ data, but with this not being new data (n=6); research related to subsequent waves in 2010 (n=4); and research on certain highly specialised intensive care unit (ICU) issues (n=4).

We organised the findings by first summarising the health impact of the pandemic and to provide context, followed by a structured comparison of key parameters in 2009 along-side those relating to the 1918 pandemic. For organising the published literature we used the following headings: national epidemiology, local epidemiology, surveillance systems, key epidemiological parameters, risk factors, screening and self-diagnosis and response to influenza-like illness, behavioural responses and risk communication, laboratory diagnostics and virological studies, health services response and clinical management, and immunisation. From our interpretation of literature and the apparent gaps, we then attempted to extract the possible strengths and weaknesses of the health sector response.

Results

Summary of the health impact—New Zealand was one of the first countries to experience the 2009 pandemic,⁷ which was characterised by a short and abrupt “epidemic curve” with evidence of moderate infectivity.⁸ Relative to past influenza pandemics to reach NZ,^{9, 10} this one involved a pandemic strain of relatively low virulence and case-fatality risk. It was much less severe than what had been anticipated and planned for in pandemic preparations which were relatively advanced in the NZ setting.¹¹ The key epidemiological features of the 2009 pandemic are summarised in Table 1 and compared to the much more severe 1918 pandemic (which was also the last H1N1 pandemic to affect NZ, the 1957 pandemic being H2N2, and 1968 being H3N2). Most striking was the much lower cumulative proportion dying in the 2009 pandemic.

For the 2009 pandemic, a national serosurvey estimated that 18.3% of New Zealanders were infected with the pandemic virus during the first wave (when adjusting for baseline immunity from testing of stored sera from before the pandemic and with age and ethnicity standardisation to the NZ population) (Table 1).¹²

Table 1. Key epidemiological parameters and features of the 2009 influenza pandemic in New Zealand (Wave 1) and comparison with those for the 1918 pandemic

Key parameter/feature	2009 pandemic – wave 1 (95% CI)	1918 pandemic	Comment and sources
Reproduction number	1.25 (1.07–1.47)	1.3–3.1 in a military setting; 1.2–1.8 in community settings	For the 2009 pandemic: based on work by Roberts and Nishiura, ¹⁵ (see Table 2 for other studies). For the 1918 pandemic: estimates in military ¹⁶ and community settings. ¹⁷ The reproduction number estimates for NZ in 1918 fit within worldwide estimates of between 1.1–5.4. ^{18–21}
Generation time (days)	2.38 (mean result)	Estimated between 2–4 days	For the 2009 pandemic there was variation in the modelled results: “generation time is biased downwards during the beginning of the epidemic”. ¹⁵ For the 1918 pandemic, ¹⁷ this was based on previous generation time modelling. ^{22,23}
Cumulative infection	18.3% (serological evidence)	Unknown for NZ	For the 2009 pandemic. ¹² For the 1918 pandemic: worldwide estimates suggest between 25–50% cumulative infection. ^{24,25}
Cumulative proportion with symptomatic illness	12.2%	Estimated: 33%–50%	The estimate for the 2009 pandemic was for the total population (with another 6.1% having asymptomatic illness). ⁸ For the 1918 pandemic this was for the total NZ population. ⁹
Cumulative proportion hospitalised	26 per 100,000	Unknown for NZ	For the 2009 pandemic ⁸ and with 10.6% of these hospitalised cases being admitted to ICUs. ⁴
Cumulative proportion dying	1.38 per 100,000	550 per 100,000 (European) 4230 per 100,000 (Māori)	For the 2009 pandemic. ⁴ For the 1918 pandemic, ⁹ but excluding deaths of New Zealanders overseas. The case-fatality risk was: around 0.005% of infected cases, ⁸ 0.01% of symptomatic cases, ⁸ and 0.5% (16/3179) of laboratory-confirmed cases. ²⁷
Ethnic gradient for hospitalisation and mortality	Elevated for Māori and Pacific peoples	7.3 (times higher burden for Māori ⁹)	Māori and Pacific peoples had higher rates of ICU admissions than the NZ European population ⁴ and similarly for both populations for age-standardised mortality (e.g., for Māori vs Others (non-Māori and non-Pacific, mainly European) the rate ratio was 2.6, (95%CI: 1.3–5.3). ¹⁴
Socioeconomic gradient (mortality)	Suggestive evidence	Suggestive evidence	For the 2009 pandemic there appeared to be a deprivation gradient for mortality (39% of the cases in the 2 most deprived deciles) – but this was not adjusted for age, sex or ethnicity. ⁴ For the 1918 pandemic in Auckland, the mortality rate in “poor” suburbs was higher than “well-to-do” suburbs (RR=1.42; 95%CI: 1.10–1.82, p=0.004**) but there was no age, sex or ethnicity adjustment.

Notes: * Insufficient data were generally available for similar comparisons with the other influenza pandemics of the 20th century that reached New Zealand (though some ethnicity comparisons for the 1957 pandemic have been performed¹⁴).

** Risk ratio calculated from tabulated data in a thesis (p169).²⁶ Other work by Rice⁹ indicates some variation in mortality rates by occupational group (Table 10.2, p226), but it is difficult to interpret these results e.g., there was no age/sex-standardisation and some denominators may have been influenced by differential involvement by occupation in the overseas war effort (e.g., many of the country’s health professionals were overseas). The socioeconomic analysis by Rice (Table 10.4, p233) was also constrained (e.g., no rate calculations).

Children and adolescents (aged 5–19 years) had the highest total seroprevalence (46.7% – not adjusted for pre-pandemic immunity). Prevalence was also relatively high for Pacific peoples (49.5%) and for Māori (36.3%), compared to the “Other” (mainly European) ethnic group (25.9%).

For the year 2009 there were an estimated 1508 hospitalisations for influenza, a four-fold increase on the number in the preceding year.⁴ Most of these people (n=1122) were admitted to hospital with a primary diagnosis of “pandemic influenza A (H1N1) 2009”. Of these admissions, 102 occurred to ICUs. These ICU admissions were significantly higher for both Māori and Pacific peoples compared to European New Zealanders.⁴ Other risk factors identified for ICU admission included: pregnancy, body mass index >35, and having pre-existing asthma or another chronic pulmonary disease.¹³

An official Mortality Review Group reported that there were 49 deaths due to H1N1 infection in 2009.⁴ Significantly elevated age-standardised mortality rates for both Māori and Pacific peoples were apparent.¹⁴ There was also some evidence of a socioeconomic gradient with 39% of those dying having an area deprivation score of either 9 or 10 (the most deprived two deciles), compared with the expected 20% of the population. Of those dying, 86% had at least one comorbid or associated condition e.g., obesity (74%), morbid obesity (56%) and respiratory disease (49%).

In addition to the above summarised data, many additional aspects of the pandemic and the health sector response have been considered in other studies (Table 2).

Table 2. Published work on to the 2009 pandemic in New Zealand (to 20 May 2012)*

Topic area	Aspects covered
National epidemiology	A detailed initial description of the epidemiology in NZ was published in August 2009 ²⁷ (with this information subsequently compared to that of other Southern Hemisphere countries ⁷).
Local epidemiology	These studies included one for South Auckland using a capture-recapture method, ²⁸ and studies of hospitalisations at Hutt Hospital ²⁹ and for the Wellington region. ³⁰
Surveillance systems	The surveillance systems used in NZ for the pandemic were described in 2009 ^{27 31} along with the potential for more innovative approaches (e.g., “Google flu trends” ³²) and summarised as part of a wider surveillance review. ¹
Key epidemiological parameters	The reproduction number of the new pandemic was calculated in several analyses ^{33 15 34-36} with additional commentaries. ^{37 38} The NZ data has also been used to suggest the utility of a forecasting system that could be used in real time at the early stages of a pandemic. ³⁹ Specific data on transmission risk came from an airline setting ⁴⁰ and a tour group study. ⁴¹ Other epidemiological studies (see above) provided further information e.g., on estimating the community burden and the case-fatality risk. An international study included a focus on age distribution data from NZ. ⁴²
Risk factors	Several of the epidemiological and ICU studies detailed elsewhere in this Table included risk factor data (i.e., relating to age, ethnicity, obesity and chronic conditions). In addition, two other studies considered pregnancy as a risk factor (including the increased risk for Māori and Pacific women who were pregnant). ^{43 44}
Screening and self-diagnosis and response to influenza-like illness	A study of screening at the border (Auckland airport), suggested a very low sensitivity of this intervention at 5.8% (95%CI: 2.3%–14.0%). ⁴⁵ However the screening system used was a relatively passive one that relied on self-identification of symptoms by the in-coming travellers. Another study investigated self-diagnosis behaviour and found that those who thought they had been infected with H1N1 in 2009 were no more likely to be seropositive than those who did not. ⁴⁶

Topic area	Aspects covered
Behavioural responses and risk communication	A study in mid-2010 involved eight focus groups (including Māori, Pacific peoples, parents of children, and vulnerable people with chronic conditions). ⁴⁷ This work identified a range of issues around risk perception, risk communication, response to pandemic-specific health messages, and community-level approaches. One conclusion was “the problem with a ‘one size fits all’ pandemic warning strategy that risks antagonising and distancing communities and thereby reducing trust in agencies and the likelihood that advice will be followed.” Hand hygiene behaviours of the public were studied in a hospital entrance setting, ⁴⁸⁻⁵⁰ along with respiratory hygiene behaviours in a range of public places (with low use of the recommended behaviours). ⁵¹
Laboratory diagnostics and virological studies	Diagnostic methods were studied ⁵²⁻⁵⁴ along with studies around the sensitivity of the pandemic strain to oseltamivir. ^{55 56}
Health services response and clinical management	Health professional bodies provided guidelines, ⁵⁷ opinion leaders provided advice, ^{58 59} and a review on pandemic-related psychological issues was published. ⁶⁰ A study described how “a range of Canterbury agencies worked together in a coordinated health-led response” and how the response meant that “health care services were not overwhelmed”. ⁶¹ The key lesson was “the importance of preparing and working together across the sector”. Other work reported on the response of nurses in a community mental health residential facility ⁶² and how a hospital managed diagnosis and care of healthcare workers at risk of H1N1 infection. ⁶³ The experience for ICUs and data on admissions was particularly well studied, often in combination with Australian ICU data. ^{13 64-67} Even the paediatric ICU ⁶⁸ was covered. Some work focused on the use of extracorporeal membrane oxygenation in treatment. ⁶⁹⁻⁷¹
Immunisation	The effectiveness of the 2009 seasonal influenza vaccine against the pandemic strain was studied. ⁷² Adverse events following use of the trivalent influenza vaccine in children have also been investigated. ⁷³

Discussion

Probable strengths of the health sector response

The NZ health sector appeared to invest considerable effort on initial containment measures with case identification, isolation, contact tracing and the provision of antivirals. There is no strong evidence that such measures may have slowed the initial spread. Nevertheless, one argument was that “the considerable interval without reported cases during May (before the epidemic accelerated in June) provides some suggestive evidence for the success of the containment measures”.²⁷ However, it is possible that this apparent lack of cases simply reflected the difficulty detecting spread of the pandemic virus during the early establishment stages, as was observed in parts of Australia.⁷⁴

Further work could compare the time scales for NZ with other OECD countries and in the context of the relatively low reproduction number of this pandemic strain.¹⁵ Nevertheless, the vigorous public health response was probably justified on precautionary grounds given that little was known about the new pandemic strain at the time. In addition, the relatively intensive response provided valuable experience in demonstrating that such a response is highly demanding in terms of human resources and requirements for antivirals.

Health agencies such as the Ministry of Health appeared to be extremely active in providing information to the public, sometimes with multiple media releases per day and having detailed website information. Regional health agencies were also active with their own campaigns and website information.⁶¹

The impact of the public health messages and information is not clear, but these could have facilitated the generally helpful response (from a public health perspective) of ongoing media coverage of the pandemic. There was also some evidence that New Zealanders responded to infection control messages with primary care consultations being reportedly down for other illnesses during the pandemic in Canterbury.⁶¹ There was also some limited evidence that hand hygiene practices improved during the pandemic period,⁵⁰ even though observed respiratory hygiene was fairly poor during the pandemic.⁵¹

The Mortality Review Group noted the “considerable logistical challenge for laboratories and primary and secondary health services.”⁴ Yet despite this limitation, there are various indications that the health sector performed fairly well, at least relatively to other countries:

- Firstly, the overall extremely low case-fatality risk (CFR) at 0.005% for all infected cases in NZ,⁸ was less than the 0.01% estimated in a systematic review for high-income countries.⁷⁵
- Secondly, the CFR for symptomatic cases in NZ was lowest for both groups of 0-17 year olds and 18-64 year olds) or second lowest (0-17 year olds) in a six study comparison (including Denmark, Netherlands, UK and USA [n=2 studies]; albeit with some overlapping confidence intervals).⁷⁶
- Thirdly, the CFR for laboratory-confirmed cases was only 0.5% (Table 1), which compares to that of 1.1% (95% CI: 0.0-3.0%) from a systematic review (using 33 reports from high-income countries).⁷⁵ This NZ result was also second lowest in a review of studies in Southern Hemisphere countries.⁵
- Fourthly, the CFR for those admitted to hospital and to ICUs was relatively low and also (for ICU admissions), the same as in Australia i.e., 16% (16/101) compared to 16% (105/643) for Australia (Personal communication, Lisa Higgins, Australian and New Zealand Intensive Care [ANZIC] Research Centre, Australia). These proportions were both lower than those for California at 25%.⁷⁷

There were also signs of effective management in the NZ setting whereby hospital work loads were re-organised to ensure capacity was maintained (e.g., postponing elective surgery). Indeed, this was seen with Australasian-wide reductions in admissions to ICUs associated with elective surgery during 2009.⁶⁶ Clinicians also actively explored intensive treatment options e.g. in the use of extracorporeal membrane oxygenation (Table 2).

The health sector also appeared to work successfully to ensure that appropriate vaccines were made available prior to winter 2010. Initially a monovalent vaccine to provide protection against pandemic A (H1N1) 2009 was supplied, though this had low uptake,⁷⁸ and shortly became redundant with the availability of trivalent vaccines.⁷⁹ The latter provided additional protection against seasonal influenza A (H3N2) and influenza B in addition to pandemic A (H1N1) 2009.

These vaccines appear to have reasonable public acceptability and their introduction attracted little adverse media publicity in NZ. This situation is noteworthy for several reasons. Firstly, the pandemic strain had relatively low virulence. Secondly, the

vaccination programme had some remarkable features, including administration to pregnant women and children (with targeting based on ethnicity and residence in deprived areas). Use of one of these trivalent vaccines (Fluvax) was also associated with highly publicised adverse events in Australia (an increase in reported febrile convulsions in Western Australia).⁸⁰

Subsequent research in NZ indicated a significantly higher frequency of fever following administration of Fluvax(® CSL Biotherapies) compared with Vaxigrip(® Sanofi Pasteur).⁷³

Probable weaknesses in the responses

No overall review of the response—As of June 2012, there had been no detailed review of the epidemiology and health sector response to the 2009 pandemic in NZ. Any internal documents on the Ministry of Health’s review of its pandemic performance have not been made available on its website and the national response has not been considered in the light of review work by WHO on the international response.³

All this information would collectively assist with pandemic plan revisions and re-assessing the value of previous pandemic planning exercises (e.g., “Exercise Cruickshank”⁸¹). Ideally this work might also have been supplemented with more extensive research on risk factors and containment measures (see below), and relating to populations suffering the highest burden such as Māori and Pacific peoples (i.e., expanding on the one qualitative study⁴⁷). There could also have been a review by the relevant parts of the Parliament such as the Health Select Committee and/or the Māori Affairs Select Committee.

Some examples of additional issues (not discussed further below) for which some information should ideally have been reported nationally, include: the impacts on cancelling of elective surgery, the impacts on pharmaceutical use (antivirals and antimicrobials), and the impacts on laboratory and hospital staff workloads.

Limited analysis of the effectiveness of border control and containment measures—Probably the most distinctive element of NZ’s pandemic plan is a major focus on border control and containment (“*Keep it out, Stamp it out*”). These measures consumed a great deal of resources during the planning phase and the pandemic itself (up until the switch to the mitigation phase on 22 June 2009, eight weeks after H1N1 was first detected on 25 April). However, there has been just one study on border control issues,⁴⁵ and the impact of containment was limited to the study of a tour group.⁴¹ Yet NZ was relatively well positioned for more detailed studies given the extensive PCR testing of potential cases in the early stages of pandemic spread. This applied research could potentially have informed the use of in-the-field isolation measures and anti-viral prophylaxis.

No sophisticated analytic studies on risk factors for poor outcomes—Such work in the form of a case-control study of hospitalised cases could have substantially improved on the risk factor data from descriptive studies. Such work was conducted elsewhere for this pandemic e.g., in Canada^{82 83} and Australia.⁸⁴ Furthermore, national research funding agencies appeared to be relatively slow in making funds available for pandemic-related research (though the Health Research Council of New Zealand

did make useful funding available in a special funding round late in 2009, the *Influenza A (H1N1) Rapid Response Research Initiative*).⁸⁵

Lack of studies on pandemic vaccine uptake and acceptability—We could only identify one qualitative study that touched on vaccination in the pandemic context.⁴⁷ Yet information on public (and health professional) vaccine uptake and acceptability could help inform future decision-making around the provision of vaccination against pandemic influenza. One barrier to research on influenza vaccine in NZ is that administering this vaccine is not currently recorded on the National Immunisation Register. This appears to be an important information system deficit (albeit one that is in the process of being amended as of early 2012).

No evaluation of the public health messages—The hygiene and other messages used in mass media campaigns by the health sector were not formally evaluated, and information is limited to the modest amount of data from one qualitative study.⁴⁷ While some behavioural data around hygiene practices were collected,⁴⁸⁻⁵¹ this work was not specifically designed for campaign evaluation. Yet to appropriately inform future health sector investment in such messages and campaigns, evaluation of effectiveness and cost-effectiveness seems critical. Similarly, there was no research on how the media responded and yet such work can potentially inform how the health sector engages the media as was done for SARS in NZ.⁸⁶

No economic impact assessment—Studying the economic impacts on the health sector, education sector and economy (tourism impacts, absenteeism from school and work) would help inform future decision-making around pandemic control. The cost of unused monovalent pandemic vaccine and expired stockpiled antivirals could also be documented. Some work identified the relatively high ICU costs for Australasia, but this work did not separate out NZ data.⁸⁷ NZ work, outside of the review period of this study, has also started to consider hospital costs associated with the pandemic.⁸⁸

Conclusions

The available evidence (including the low case-fatality risk relative to other countries), is consistent with a successful overall response to the 2009 influenza pandemic by the public health, primary care and hospital sectors. Nevertheless, we suggest there were a range of “weaknesses”, albeit mainly omissions in the post-pandemic period. It could be argued that some of these “weaknesses” might be justified in terms of limited resources and may reflect NZ having a relatively poor record of funding research (compared to some other OECD countries).

The pandemic was “predominantly of seasonal intensity”,⁸⁹ and so could be seen as providing a relatively weak test of NZ’s pandemic response capacity. Given the huge potential impact of more virulent pandemics in the future, we need to learn as much as possible from this recent experience. It is probably still worthwhile to address some of the omissions identified in this review and consider more the lessons detailed in the international literature.^{3 90} Such knowledge is important for informing future pandemic and natural disaster planning and preparations.

Competing interests: Although we do not consider it a competing interest, for the sake of full transparency we note that two of the authors (NW, MB) have done episodic contract work for the Ministry of Health on pandemic influenza in 2009 and as part of pandemic planning prior to this.

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References:

1. Baker MG, Easter S, Wilson N. A surveillance sector review applied to infectious diseases at a country level. *BMC Public Health* 2010;10:332.
2. Wilson N, Lush D. Bioterrorism in the Northern Hemisphere and potential impact on New Zealand. *N Z Med J* 2002;115:247-51.
3. World Health Organization. Report of the Review Committee on the Functioning of the International Health Regulations 2005 and on Pandemic Influenza A (H1N1) 2009, (WHA ref A64/10). Geneva: World Health Organization, 2011. http://apps.who.int/gb/ebwha/pdf_files/WHA64/A64_10-en.pdf
4. Pandemic Influenza Mortality and Morbidity Review Group. Report for the Minister of Health from the Pandemic Influenza Mortality and Morbidity Review Group. Wellington: Ministry of Health, 2010.
5. Falagas ME, Koletsi PK, Baskouta E, et al. Pandemic A(H1N1) 2009 influenza: review of the Southern Hemisphere experience. *Epidemiol Infect* 2011;139:27-40.
6. Van Kerkhove MD, Mounts AW, Mall S, et al. Epidemiologic and virologic assessment of the 2009 influenza A (H1N1) pandemic on selected temperate countries in the Southern Hemisphere: Argentina, Australia, Chile, New Zealand and South Africa. *Influenza Other Respi Viruses* 2011;5:e487-98.
7. Baker M, Kelly H, Wilson N. Pandemic H1N1 influenza lessons from the southern hemisphere. *Euro Surveill* 2009;14:pii=19370.
8. Baker M, Huang Q, Bandaranayake D, et al. The influenza A(H1N1) pandemic in New Zealand during 2009 [Poster presentation 217]. 2010 International Conference on Emerging Infectious Diseases. Atlanta, Georgia 11-14 July. 2010.
9. Rice G. Black November: The 1918 influenza pandemic in New Zealand. Christchurch: Canterbury University Press, 2005.
10. Davis L. Report on the 1957 pandemic of influenza (to the World Health Organization, Geneva). Wellington: Division of Public Hygiene, Department of Health, 1958.
11. Wilson N, Baker MG. Comparison of the content of the New Zealand influenza pandemic plan with European pandemic plans. *N Z Med J* 2009;122:36-46.
12. Bandaranayake D, Huang QS, Bissielo A, et al. Risk factors and immunity in a nationally representative population following the 2009 influenza A(H1N1) pandemic. *PLoS One* 2010;5:e13211.
13. Webb SA, Pettila V, Seppelt I, et al. Critical care services and 2009 H1N1 influenza in Australia and New Zealand. *N Engl J Med* 2009;361:1925-34.
14. Wilson N, Telfar Barnard L, Summers J, et al. Differential mortality by ethnicity in 3 influenza pandemics over a century, New Zealand. *Emerg Infect Dis* 2012;18:71-77.
15. Roberts MG, Nishiura H. Early Estimation of the Reproduction Number in the Presence of Imported Cases: Pandemic Influenza H1N1-2009 in New Zealand. *PLoS One* 2011;6:e17835.
16. Sertsoy G, Wilson N, Baker M, et al. Key transmission parameters of an institutional outbreak during the 1918 influenza pandemic estimated by mathematical modelling. *Theor Biol Med Model* 2006;3:38.

17. Nishiura H, Wilson N. Transmission dynamics of the 1918 influenza pandemic in New Zealand: analyses of national and city data. *N Z Med J* 2009;122:81-86.
18. Andreasen V, Viboud C, Simonsen L. Epidemiologic characterization of the 1918 influenza pandemic summer wave in Copenhagen: implications for pandemic control strategies. *J Infect Dis* 2008;197:270-8.
19. Mills CE, Robins JM, Lipsitch M. Transmissibility of 1918 pandemic influenza. *Nature* 2004;432:904-6.
20. Chowell G, Ammon CE, Hengartner NW, Hyman JM. Transmission dynamics of the great influenza pandemic of 1918 in Geneva, Switzerland: Assessing the effects of hypothetical interventions. *J Theor Biol* 2006;241:193-204.
21. Ferguson NM, Cummings DA, Fraser C, et al. Strategies for mitigating an influenza pandemic. *Nature* 2006;442:448-52.
22. Nishiura H, Wilson N, Baker M. Quarantine for pandemic influenza control at the borders of small island nations. *BMC Infect Dis* 2009;9.
23. Carrat F, Vergu E, Ferguson NM, et al. Time Lines of Infection and Disease in Human Influenza: A Review of Volunteer Challenge Studies. *Am J Epidemiol* 2008;167:775-785.
24. Frost W. Statistics of influenza morbidity. *Public Health Rep* 1920;35:584-597.
25. Crosby AW. *Epidemic and Peace: 1918*. Westford: Greenwood Press, 1976.
26. Bryder L. *The 1918 Influenza Epidemic in Auckland* [Unpublished MA Thesis, University of Auckland], 1980.
27. Baker MG, Wilson N, Huang QS, et al. Pandemic influenza A(H1N1)v in New Zealand: the experience from April to August 2009. *Euro Surveill* 2009;14:ArticleId=19319.
28. Jackson G, Thornley S. Burden of novel influenza A virus (H1N1) in Auckland and Counties Manukau District Health Boards (July 2009): a capture-recapture analysis. *N Z Med J* 2009;122(1301):66-9.
29. Dee S, Jayathissa S. Clinical and epidemiological characteristics of the hospitalised patients due to pandemic H1N1 2009 viral infection: experience at Hutt Hospital, New Zealand. *N Z Med J* 2010;123:45-53.
30. Verrall A, Norton K, Rooker S, et al. Hospitalizations for pandemic (H1N1) 2009 among Maori and Pacific Islanders, New Zealand. *Emerg Infect Dis* 2010;16:100-2.
31. CDC. Surveillance for the 2009 pandemic influenza A (H1N1) virus and seasonal influenza viruses – New Zealand, 2009. *MMWR* 2009;58:918-21.
32. Wilson N, Mason K, Tobias M, et al. Interpreting Google flu trends data for pandemic H1N1 influenza: the New Zealand experience. *Euro Surveill* 2009;14:pii=19386.
33. Nishiura H, Wilson N, Baker MG. Estimating the reproduction number of the novel influenza A virus (H1N1) in a Southern Hemisphere setting: preliminary estimate in New Zealand. *N Z Med J* 2009;122(1299):73-7.
34. Paine S, Mercer GN, Kelly PM, et al. Transmissibility of 2009 pandemic influenza A(H1N1) in New Zealand: effective reproduction number and influence of age, ethnicity and importations. *Euro Surveill* 2010;15:pii=19591.
35. Opatowski L, Fraser C, Griffin J, et al. Transmission Characteristics of the 2009 H1N1 Influenza Pandemic: Comparison of 8 Southern Hemisphere Countries. *PLoS Pathog* 7:e1002225.
36. Hsieh YH. Pandemic influenza A (H1N1) during winter influenza season in the southern hemisphere. *Influenza Other Respi Viruses* 4:187-97.
37. Nishiura H, Roberts MG. Estimation of the reproduction number for 2009 pandemic influenza A(H1N1) in the presence of imported cases. *Euro Surveill* 2010;15:pii=19622.
38. Kelly P, Mercer G, Glass K, Paine S. Author's reply: Estimation of the reproduction number for 2009 pandemic influenza A(H1N1) in the presence of imported cases. *Euro Surveill* 2010;15:pii=19623.
39. Roberts MG. Epidemic models with uncertainty in the reproduction number. *J Math Biol* 2012;[e-Publication 5 May].

40. Baker MG, Thornley CN, Mills C, et al. Transmission of pandemic A/H1N1 2009 influenza on passenger aircraft: retrospective cohort study. *BMJ* 2010;340:c2424.
41. Mardani J, Calder L, Laurie K, et al. Limited novel influenza A (H1N1) 09 infection in travelling high-school tour group. *Influenza Other Respi Viruses* 2011;5:47-51.
42. Karageorgopoulos DE, Vouloumanou EK, Korbila IP, et al. Age distribution of cases of 2009 (H1N1) pandemic influenza in comparison with seasonal influenza. *PLoS One* 2011;6:e21690.
43. ANZIC Influenza Investigators and Australasian Maternity Outcomes Surveillance System. Critical illness due to 2009 A/H1N1 influenza in pregnant and postpartum women: population based cohort study. *BMJ* 2010;340:c1279.
44. Knight M, Pierce M, Seppelt I, et al. Critical illness with AH1N1v influenza in pregnancy: a comparison of two population-based cohorts. *BJOG* 2011;118:232-9.
45. Hale MJ, Hoskins RS, Baker MG. Screening for Influenza A(H1N1)pdm09, Auckland International Airport, New Zealand. *Emerg Infect Dis* 2012;18:866-8.
46. Jutel A, Baker M, Stanley J, et al. Self-diagnosis of influenza during a pandemic: a cross-sectional survey. *BMJ Open* 2011;1:e000234.
47. Gray L, MacDonald C, Mackie B, et al. Community responses to communication campaigns for influenza A (H1N1): a focus group study. *BMC Public Health* 2012;12:205.
48. Murray R, Chandler C, Clarkson Y, et al. Sub-optimal hand sanitiser usage in a hospital entrance during an influenza pandemic, New Zealand, August 2009. *Euro Surveill* 2009;14:pii=19331.
49. Manning S, Barry T, Wilson N, Baker M. Update: follow-up study showing post-pandemic decline in hand sanitiser use, New Zealand, December 2009. *Euro Surveill* 2010;15:pii=19466.
50. Manning S, Barry T, Baker M, Wilson N. Hand hygiene practices at a hospital entrance after the 2009 influenza pandemic: observational study over one year. *N Z Med J* 2011;124(1334):111-114.
51. Barry T, Manning S, Lee MS, et al. Respiratory hygiene practices by the public during the 2009 influenza pandemic: an observational study. *Influenza Other Respi Viruses* 2011;5:317-20.
52. Peacey M, Hall RJ, Bocacao J, Huang QS. Diagnostic assay recommended by the world health organization for swine origin influenza a (h1n1) virus cross-reacts with H5N1 influenza virus. *J Clin Microbiol* 2009;47:3789-90.
53. Hall RJ, Peacey M, Huang QS, Carter PE. Rapid method to support diagnosis of swine origin influenza virus infection by sequencing of real-time PCR amplicons from diagnostic assays. *J Clin Microbiol* 2009;47:3053-4.
54. Ducatez MF, Sonnberg S, Hall RJ, et al. Genotyping assay for the identification of 2009-2010 pandemic and seasonal H1N1 influenza virus reassortants. *J Virol Methods* 2010;168:78-81.
55. Hall RJ, Peacey MP, Ralston JC, et al. Pandemic influenza A(H1N1)v viruses currently circulating in New Zealand are sensitive to oseltamivir. *Euro Surveill* 2009;14:pii=19282.
56. Peacey M, Hall RJ, Sonnberg S, et al. Pandemic (H1N1) 2009 and seasonal influenza A (H1N1) co-infection, New Zealand, 2009. *Emerg Infect Disease* 2010;16:1618-20.
57. Cheng AC, Dwyer DE, Kotsimbos AT, et al. Summary of the Australasian Society for Infectious Diseases and the Thoracic Society of Australia and New Zealand guidelines: treatment and prevention of H1N1 influenza 09 (human swine influenza) with antiviral agents. *Med J Aust* 2009;191:142-5.
58. Jennings LC. Influenza A(H1N1)09: another public health risk to New Zealand. *N Z Med J* 2009;122(1298):11-6.
59. Thompson C, Rolls S. Keeping alert to changes during the pandemic. *Nurs N Z* 2009;15:30.
60. Johal SS. Psychosocial impacts of quarantine during disease outbreaks and interventions that may help to relieve strain. *N Z Med J* 2009;122:47-52.

61. Williams D, Begg A, Burgess K, et al. Influenza H1N1 2009 in Canterbury: a case study in pandemic response co-ordination. *J Prim Health Care* 2010;2(4):323-9.
62. Hughes FA. H1N1 pandemic planning in a mental health residential facility. *J Psychosoc Nurs Ment Health Serv* 2010;48(3):37-41.
63. Raymond NJ, Berry N, Blackmore TK, et al. Pandemic influenza A(H1N1)2009 in hospital healthcare workers in New Zealand. *Infect Control Hosp Epidemiol* 2012;33:196-9.
64. Webb SA, Seppelt IM. Pandemic (H1N1) 2009 influenza ("swine flu") in Australian and New Zealand intensive care. *Crit Care Resusc* 2009;11:170-2.
65. Kotsimbos T, Waterer G, Jenkins C, et al. Influenza A/H1N1_09: Australia and New Zealand's winter of discontent. *Am J Respir Crit Care Med* 2010;181:300-6.
66. Drennan K, Hicks P, Hart G. Impact of pandemic (H1N1) 2009 on Australasian critical care units. *Crit Care Resusc* 2010;12:223-9.
67. Harrigan PW, Webb SA, Seppelt IM, et al. The practical experience of managing the H1N1 2009 influenza pandemic in Australian and New Zealand intensive care units. *Crit Care Resusc* 2010;12:121-30.
68. Yung M, Slater A, Festa M, et al. Pandemic H1N1 in children requiring intensive care in Australia and New Zealand during winter 2009. *Pediatrics* 2011;127:e156-63.
69. Buckley E, Sidebotham D, McGeorge A, et al. Extracorporeal membrane oxygenation for cardiorespiratory failure in four patients with pandemic H1N1 2009 influenza virus and secondary bacterial infection. *Br J Anaesth* 2010;104:326-9.
70. Davies A, Jones D, Bailey M, et al. Extracorporeal Membrane Oxygenation for 2009 Influenza A(H1N1) Acute Respiratory Distress Syndrome. *JAMA* 2009;302:1888-95.
71. Sidebotham D. Extracorporeal membrane oxygenation--understanding the evidence: CESAR and beyond. *J Extra Corpor Technol* 2011;43:P23-6.
72. Jefferies S, Earl D, Berry N, et al. Effectiveness of the 2009 seasonal influenza vaccine against pandemic influenza A(H1N1)2009 in healthcare workers in New Zealand, June-August 2009. *Euro Surveill* 2010;16:pii=19761.
73. Petousis-Harris H, Poole T, Booy R, Turner N. Fever following administration of two inactivated influenza vaccines--a survey of parents of New Zealand infants and children 5 years of age and under. *Vaccine* 2011;29:2933-7.
74. Kelly HA, Mercer GN, Fielding JE, et al. Pandemic (H1N1) 2009 influenza community transmission was established in one Australian state when the virus was first identified in North America. *PLoS One* 2010;5:e11341.
75. Khandaker G, Dierig A, Rashid H, et al. Systematic review of clinical and epidemiological features of the pandemic influenza A (H1N1) 2009. *Influenza Other Respi Viruses* 2011;5:148-56.
76. Dawood FS, Iuliano AD, Reed C, et al. Estimated global mortality associated with the first 12 months of 2009 pandemic influenza A H1N1 virus circulation: a modelling study. *Lancet Infect Dis* 2012;[E-publication 26 June].
77. Louie JK, Jean C, Acosta M, et al. A review of adult mortality due to 2009 pandemic (H1N1) influenza A in California. *PLoS One* 2011;6:e18221.
78. Bandaranayake D, Jacobs M, Baker M, et al. The second wave of 2009 pandemic influenza A(H1N1) in New Zealand, January-October 2010. *Euro Surveill* 2011;16.
79. Ministry of Health. Influenza. In: *Immunisation Handbook*. Wellington: Ministry of Health, 2011. <http://www.health.govt.nz/system/files/documents/publications/15influenza.pdf>
80. Armstrong P, Dowse G, Effler P, et al. Epidemiological study of severe febrile reactions in young children in Western Australia caused by a 2010 trivalent inactivated influenza vaccine. *BMJ Open* 2011;(30 May). doi: 10.1136/bmjopen-2010-000016.
81. Ministry of Health. Report on Exercise Cruickshank. Wellington: Ministry of Health, 2007. <http://www.health.govt.nz/publication/report-exercise-cruickshank>
82. Zarychanski R, Stuart TL, Kumar A, et al. Correlates of severe disease in patients with 2009 pandemic influenza (H1N1) virus infection. *CMAJ* 2010;182:257-64.

83. Gilca R, De Serres G, Boulianne N, et al. Risk factors for hospitalization and severe outcomes of 2009 pandemic H1N1 influenza in Quebec, Canada. *Influenza Other Respi Viruses* 2011;5:247-55.
84. Ward KA, Spokes PJ, McAnulty JM. Case-control study of risk factors for hospitalization caused by pandemic (H1N1) 2009. *Emerg Infect Disease* 2011;17:1409-16.
85. Wilson N, Baker M, Jennings L, et al. A design fault in New Zealand's health research funding system exposed by pandemic influenza. *N Z Med J* 2009;122(1304):121-2.
86. Wilson N, Thomson G, Mansoor O. Print media response to SARS in New Zealand. *Emerg Infect Dis* 2004;10:1461-4.
87. Higgins AM, Pettila V, Harris AH, et al. The critical care costs of the influenza A/H1N1 2009 pandemic in Australia and New Zealand. *Anaesth Intensive Care* 2011;39:384-91.
88. Wilson N, Nghiem N, Higgins A, et al. A national estimate of the hospitalisation costs for the influenza (H1N1) pandemic in 2009. *N Z Med J* 2012;125(1365).
<http://journal.nzma.org.nz/journal/125-1365/5430>
89. Kelly HA. A pandemic response to a disease of predominantly seasonal intensity. *Med J Aust* 2010;192:81-3.
90. Leung GM, Nicoll A. Reflections on pandemic (H1N1) 2009 and the international response. *PLoS Med* 2010;7.