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Published in:
F1000Research

DOI:
[10.12688/f1000research.21145.1](https://doi.org/10.12688/f1000research.21145.1)

Published: 11/11/2019

Document Version:
Publisher's PDF, also known as Version of record

[Link to publication in Bond University research repository.](#)

Recommended citation(APA):

Scott, A., Bakhit, M., Clark, J., Vermeulen, M., Jones, M. A., Looke, D. F. M., Del Mar, C. B., & Glasziou, P. P. (2019). Australian state influenza notifications and school closures in 2019 [version 1; peer review: 1 approved with reservations]. *F1000Research*, 8, [1899]. <https://doi.org/10.12688/f1000research.21145.1>

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RESEARCH ARTICLE

Australian state influenza notifications and school closures in 2019 [version 1; peer review: 1 approved with reservations]

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V1 First published: 11 Nov 2019, 8:1899 (<https://doi.org/10.12688/f1000research.21145.1>)
 Latest published: 11 Nov 2019, 8:1899 (<https://doi.org/10.12688/f1000research.21145.1>)

Abstract

Background: The impact of school holidays on influenza rates has been sparsely documented in Australia. In 2019, the early winter influenza season coincided with mid-year school breaks, enabling us the unusual opportunity to examine how influenza incidence changed during school closure dates.

Methods: The weekly influenza data from five Australian state and one territory health departments for the period of week 19 (mid-May) to week 35 (early September) 2019 were compared to each state’s public school closure dates. We used segmented regression to model the weekly counts and a negative binomial distribution to account for overdispersion due to autocorrelation. The models’ goodness-of-fit was assessed by plots of observed versus expected counts, plots of residuals versus predicted values, and Pearson’s Chi-square test. The main exposure was the July two-week school vacation period, using a lag of one week. The effect is estimated as a percent change in incidence level, and in slope. We also dichotomized the change in weekly counts into decreases versus increases (or no change). The proportion of decreases were then compared for each of three periods (pre-vacation, vacation, post-vacation) using Fishers exact test.

Results: School holidays were associated with significant declines in influenza incidence. The models showed acceptable goodness-of-fit. The numbers and percentages of decreases in weekly influenza counts from the previous week for all states combined were: 19 (33%) pre-vacation; 11 (92%) decreases during the vacation; and 19 (59%) decreases post-vacation (P=0.0002). The first decline during school holidays is seen in the school aged (5-19 years) population, with the declines in the adult and infant populations being smaller and following a week later.

Conclusions: Given the significant and rapid reductions in incidence, these results have important public health implications. Closure or extension of holiday periods could be an emergency option for state governments.

Open Peer Review

Reviewer Status ?

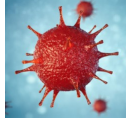
	Inited Reviewers
	1
version 1 11 Nov 2019	 report

- 1 **Casey Zipfel** , Georgetown University, Washington, USA
- Shweta Bansal** , Georgetown University, Washington, USA

Any reports and responses or comments on the article can be found at the end of the article.

Keywords

Influenza, influenza epidemic, child, adolescent, school closure, school holidays, absenteeism



This article is included in the [Disease Outbreaks gateway](#).

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Author roles: **Scott AM:** Data Curation, Investigation, Project Administration, Supervision, Writing – Original Draft Preparation, Writing – Review & Editing; **Bakhit M:** Data Curation, Investigation, Writing – Review & Editing; **Clark J:** Data Curation, Investigation, Writing – Review & Editing; **Vermeulen M:** Data Curation, Investigation, Visualization, Writing – Review & Editing; **Jones M:** Formal Analysis, Methodology, Visualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Looke D:** Conceptualization, Methodology, Writing – Original Draft Preparation, Writing – Review & Editing; **Del Mar C:** Conceptualization, Methodology, Writing – Original Draft Preparation, Writing – Review & Editing; **Glasziou P:** Conceptualization, Formal Analysis, Supervision, Writing – Original Draft Preparation, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: The author(s) declared that no grants were involved in supporting this work.

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How to cite this article: Scott AM, Bakhit M, Clark J *et al.* **Australian state influenza notifications and school closures in 2019 [version 1; peer review: 1 approved with reservations]** F1000Research 2019, **8**:1899 (<https://doi.org/10.12688/f1000research.21145.1>)

First published: 11 Nov 2019, **8**:1899 (<https://doi.org/10.12688/f1000research.21145.1>)

Introduction

In 2009, the United Kingdom experienced a summer influenza pandemic, with the National Health Service resorting to pharmacy dispensed oseltamivir to slow the growth. However, when schools closed in August for the six-week summer break, the epidemic dropped to almost zero within a few weeks¹. This was an extreme example of an association that has been documented in other countries, though generally for shorter closures²⁻⁴. A 2013 review of both deliberate and non-deliberate school closures concluded that even without co-interventions, closure of schools could reduce flu transmission during an outbreak^{3,5}.

The association of school closure and influenza rates has been only sparsely documented in Australia, partly because school holidays generally fall outside the peak influenza period. However, 2019 saw an early epidemic of influenza in Australia with rates around five times normal for the May-July period, with consequent hospitalisation and deaths also increased. Because of the early high rates, winter influenza in 2019 also coincided with the mid-year school breaks, which appeared to be associated with a dip in influenza incidence.

To explore any relationship between the holiday school closure and influenza cases, we examined the relationship between changes in influenza incidence with the school closure dates in 2019 using the different holiday dates that apply in the Australian states and territories.

Methods

Setting

Influenza is a notifiable disease in all Australian states and territories⁶. We collected influenza data notified weekly to state and territory health departments, for the period of week 19 (mid-May) to week 35 (early September) 2019, which corresponds to the flu season in Australia.

We included data from five states (New South Wales, Queensland, Victoria, South Australia, Western Australia) and one territory (Australian Capital Territory); we excluded data from one state (Tasmania) and one territory (Northern Territory) due to paucity of available data and small population sizes.

Data sources and extraction

States and territories differ in how they collect and report data on flu cases. New South Wales⁷ and Queensland⁸ report the number of samples that test positive for Influenza A and B (lab-confirmed); Australian Capital Territory⁹ reports the number of influenza (lab) notifications to the state; and Western Australia¹⁰, Victoria¹¹ and South Australia¹² report the number of lab-confirmed influenza cases (strains unspecified).

We collected flu data as it was reported by each jurisdiction. We collected data on public school closures between week 19 and week 35 from each state or territory's education department website.

Weekly, numerical flu data were available from reports produced by the Health Departments in New South Wales,

Queensland, Western Australia, Victoria, and Australian Capital Territory. For South Australia, the number of lab-confirmed influenza cases for weeks 19–24 were extracted from a figure (using *webplotdigitiser*¹³) since weekly numerical data were available only for weeks 25–35. Data on school holidays were extracted from each state or territory's website. Raw data are provided (see *Data availability* section)¹⁴.

Statistical methods

Due to differences in the population numbers of each state and territory, differences in the methods of data collection, and insufficient number of states to reliably fit a random effects model, analysis was conducted separately by state.

We used segmented regression¹⁵ to model the weekly counts and specified a negative binomial distribution to account for overdispersion due to autocorrelation. Explanatory factors included the linear effect of week (slope), initial effect of vacation (change in level), change in linear effect of week after start of vacation (change in slope), initial effect of returning to school, and change in linear effect of week after school return (Appendix 2, *Extended data*)¹⁶. Goodness-of-fit of the models was assessed by plots of observed versus expected counts, plots of residuals versus predicted values, and Pearson's Chi-square test. The main exposure for our analysis was the July school vacation period of two weeks. Due to the delay from exposure to the virus to confirmation of infection status, we included a lag of one week¹⁷. The effect of school vacation is reported as a percentage change in level (with 95% confidence interval) as well as a percentage change in slope (with 95% confidence interval). We hypothesized that the vacation period (lagged by one week) would lead to reductions in weekly counts of influenza cases.

In a separate analysis, for each state, we calculated the change in weekly counts from the previous week and dichotomized into decreases versus increases (or no change). For example, a change from 100 influenza cases in the previous week to 50 influenza cases in the current week would be classified as a decrease. The proportion of decreases were then compared for each of three periods (pre-vacation, vacation, post-vacation) using Fishers exact test.

Statistical analysis was conducted using SAS University Edition 9.4 for Windows.

Results

Figure 1 shows the rates of influenza for the included states and territory. Figures for each individual state or territory are provided in Appendix 3, *Extended data*¹⁶.

The estimates for the initial effect and the subsequent slopes (**Table 1**) show significant declines for all states except South Australia, which had already passed its peak by the time of the school holidays (Appendix 3, *Extended data*)¹⁶. The models showed acceptable goodness-of-fit (Appendix 4, *Extended data*)¹⁶ with Pearson's Chi-square tests all indicating insufficient evidence of lack of fit ($P > 0.05$).

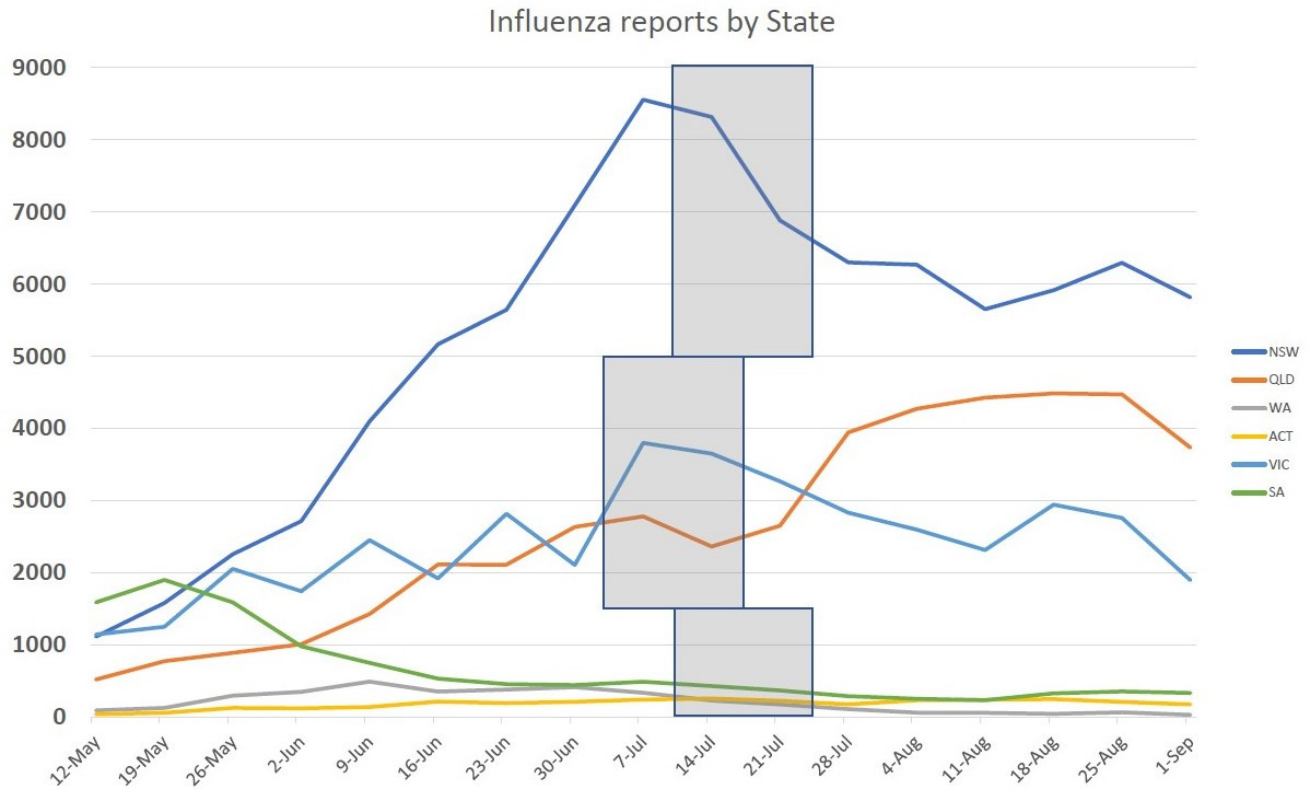


Figure 1. Rates of influenza for the included Australian states and territory (boxes show school holidays periods). NSW, New South Wales; QLD, Queensland; WA, Western Australia; ACT, Australian Capital Territory; VIC, Victoria; SA, Southern Australia.

Table 1. Estimates and 95% confidence intervals from segmented regression models of weekly influenza counts.

State	Change in level due to school vacation*	Change in slope due to vacation*
NSW	-50% (-35%, -61%); P<0.0001	-27% (-2%, -46%); P=0.037
QLD	-41% (-27%, -52%); P<0.0001	-9% (15%, -29%); P=0.41
VIC	-2% (41%, -32%); P=0.91	-21% (20%, -48%); P=0.27
WA	-65% (-20%, -85%); P=0.012	-44% (43%, -78%); P=0.22
SA	28% (-13%, 90%); P=0.21	-6% (50%, -41%); P=0.80
ACT	-41% (-11%, -61%); P=0.011	-35% (5%, -60%); P=0.08

*Compared to pre-vacation period.

NSW, New South Wales; QLD, Queensland; VIC, Victoria; WA, Western Australia; SA, South Australia; ACT, Australian Capital Territory.

For the analysis of changes in weekly influenza counts from the previous week (as described in the statistical methods section, third paragraph) for all states combined, there were 19 (33%) decreases pre-vacation; 11 (92%) decreases during the vacation; and 19 (59%) decreases post-vacation (P=0.0002).

The data on influenza rates by age group (Figure 2) show the first decline during school holidays is seen in the school aged (5–19 years) population, with the decline in the adult aged (20–64 years) population being smaller and following a further week later, and with even smaller and delayed drops in the

Influenza reports by age group

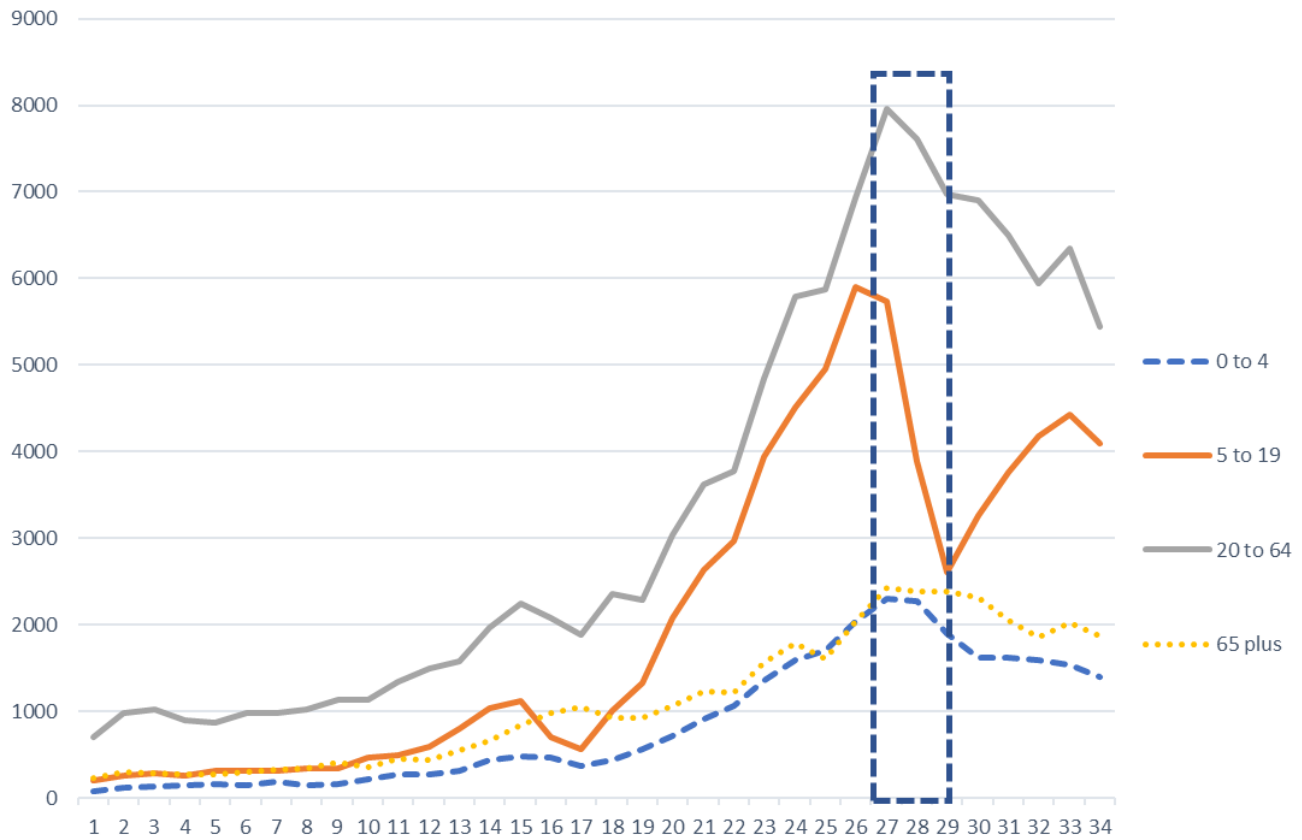


Figure 2. Influenza reports by age group (boxes show school holidays periods).

infant (1–4) and elderly (65+ years) age groups. We did not have access to the state specific age bands, and hence have indicated the school closure dates with the largest population groups.

Discussion

The 2019 Australia influenza notification data show a significant association between school holidays and declines in influenza incidence in most states in Australia. We also found the earliest and largest declines in influenza incidence were in the school aged group (5–19 years), with still later and smaller declines in the adult group (20–64), and least impact on the preschool and over 65’s.

Our findings are consistent with previous reports³ of school closure for both usual holiday periods and emergency closure for epidemics.

The size of the declines is also consistent with those predicted by models of transmission for school closures¹⁸. Some states experienced a rebound within weeks of school restarting

whereas others saw a continued decline. We do not have a simple explanation for this difference.

The association of school closure with declines in influenza has several potential explanations besides a causal effect. First, cases of influenza might be underreported because of delayed presentation or non-presentation during the school holiday period, for example, because with parents able to care for them they do not attend for medical certificates. However, if this were true, we would expect to see an immediate restart after school returns, which is not the case. Second, it could be because of other societal changes, such as parents also being on holiday and hence less transmission at work. However, if this were true, we would expect to see a simultaneous reduction in both child and adult cases. A final issue is that, even if reduction in incidence is real, it not clear whether there is a net annual decrease or merely a delay in total annual cases.

There are some limitations to both our data and the analysis. Good quality, numerical weekly flu data were unavailable for all states – e.g., South Australia reports its data as a mix of

figures and numbers. This may have introduced some errors into the accuracy of the numbers for those states. We contacted the Australian National Notifiable Diseases Surveillance System, which coordinates the national surveillance of influenza in Australia, to obtain raw data for each state and territory. However, the raw data underlying the notifications for 2019 will not be available for release until July 2020. There is also likely to be differences in the accuracy of different states' data, due to the different methods of collection. For the analysis, we used a lag of one week to allow for the delay from exposure to the virus to confirmation of infection status¹⁷. In a sensitivity analysis we refitted the model without a lag and produced consistent results (Appendix 5, *Extended data*)¹⁶.

Given the size of the effect, these results have important public health implications as no other intervention has comparable effects. Hence closure or extension of holiday periods could be an emergency option for state governments. In addition to encouraging flu vaccination, the Centres for Disease Control has a number of suggestions in their guidance, such as encouraging students and staff to stay home when sick, liberalising sickness policies during epidemics, encouraging respiratory etiquette, encouraging hand hygiene, regular cleaning of shared surfaces such as door handles and faucets, and providing a "sick room" to quarantine students with flu-like

illnesses¹⁹. An additional strategy is to consider face masks, which, with hand hygiene, appear to substantially reduce transmission. All these strategies would need to be triggered by health departments to schools at an appropriate point in an epidemic or pandemic.

Data availability

Underlying data

Bond University Research Portal: Australian state influenza notifications and school closures in 2019: Appendix 1 – Underlying data. <https://doi.org/10.26139/5c47ae4cd8e16>¹⁴

Extended data

Bond University Research Portal: Australian state influenza notifications and school closures in 2019: Appendix 2–5 – Extended data. <https://doi.org/10.4225/57/555d781f8f2a3>¹⁶

Data are available under the terms of the [Creative Commons Attribution 4.0 International license \(CC-BY 4.0\)](#).

Acknowledgements

We would like thank Nancy Glasziou for pointing out the potential of school closure, and for comments on the manuscript.

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Open Peer Review

Current Peer Review Status: 

Version 1

Reviewer Report 16 January 2020

<https://doi.org/10.5256/f1000research.23276.r57787>

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Summary:

Australia's influenza season does not typically coincide with school holidays. However, in 2019, the influenza season occurred earlier than usual, allowing the opportunity to evaluate the impacts of school closure on influenza dynamics in Australia. In this article, the authors present state and territory-level influenza data by week, and perform segmented regression, comparing influenza incidence before and after the school holiday. They also count weekly increases and decreases before, during, and after the school holiday, and show age-based dynamics. This article asks an important question of public health relevance to non-pharmaceutical interventions in a setting where it has not been previously investigated in a concise manner. However, this article could be strengthened through additional framing, increased statistical rigor, and more nuanced interpretation.

Comments:

- The introduction leaves several unanswered questions that would help to more clearly identify the importance of the study. The relationship between school closure and influenza dynamics has been explored in a number of previous papers, with both epidemiological data and mechanistic models. Thus, it is unclear to me why is it important to consider this relationship in Australia, specifically. Do the authors have hypotheses regarding trends or mechanisms that might be different from other countries? Is it important for public health planning? This question seems especially salient to me since school closures and the influenza season in Australia do not typically coincide, so these epidemiological trends may not be typical for Australia.
- The article concludes that there is a significant reduction in influenza in most states in Australia based on the results of segmented regression comparing influenza incidence level and slope before and after the holiday period. I am not totally convinced by this conclusion, as Table 1 shows that the change in level is not significant for Victoria, Australian Capital Territory, and Southern Australia, and the change in slope is not significant for Queensland, Victoria, Western Australia, and Southern Australia. This is contrary to the section of the results that states that "the estimates

for the initial effect and the subsequent slope show significant declines for all states except South Australia". These results could be more carefully interpreted. This would give rise to an interesting question: what are the differences between the states/territories that result in different dynamics?

- I think this article could be strengthened with a more robust time series modeling approach, like ARIMA modeling. This would be particularly useful because the predicted vs. residual plot in Appendix 4 appears to indicate heteroskedasticity in the data. Including model terms in a time series model could handle this issue, as well as temporal autocorrelation.
- The results also provide the percent of weeks in the pre-vacation, during-vacation, and post-vacation period in which there is a weekly decrease in influenza incidence, indicating that there is a higher proportion of decreases in the during and post-vacation period. However, the pre-vacation period seems to include all of the early part of the season. If there were numerous decreases in this time period, then the onset of the influenza season would not have occurred. Thus, this finding may be a bit circular.
- It would be useful to compare this influenza season, which co-occurs with the holiday period, with another influenza season that does not co-occur with the holiday period, as a control. This could help to isolate the impact of school closure on influenza dynamics.
- The authors specify mid-May to early September as their study period. However, it's unclear what total population and age-specific dynamics looked like post week 35. Past studies have shown that school holidays simply delay dynamics so that the epidemic wave recovers to pre-holiday rates after the holiday. I would be curious if this is the case here.
- In the model, a one-week lag was assumed. Is there evidence about care-seeking and influenza surveillance/reporting to support this? The discussion mentions a sensitivity analysis performed with no lag, but I wonder if the lag could be longer due to a combination of delay to seeking healthcare and delay in reporting.
- The fourth paragraph of the discussion comments on the possible causes of the association between school closure and influenza. This paragraph rules out several possible explanations but does not then provide a plausible explanation.

Minor comments:

- A y-axis label on Figure 1 and Figure 2 would be helpful. The Figure 1 caption says it is the influenza rate, so I assume it is influenza cases per week, but this could be clearer.
- Is the x-axis in Figure 2 the week number? It would be easier to interpret if it was put into the same units as Figure 1, with dates instead of week counts.
- Does Figure 2 include cases for all of the states and territories combined?
- In Table 1, it is unclear whether the changes described (in both slope and level) are comparing the during-vacation period or the post-vacation period to the pre-vacation period. The observed and predicted plots in Appendix 3 appear to show 3 different segments fit for each of these periods, but it is unclear what change is reported in Table 1.

Is the work clearly and accurately presented and does it cite the current literature?

Partly

Is the study design appropriate and is the work technically sound?

Partly

Are sufficient details of methods and analysis provided to allow replication by others?

Yes

If applicable, is the statistical analysis and its interpretation appropriate?

Partly

Are all the source data underlying the results available to ensure full reproducibility?

Yes

Are the conclusions drawn adequately supported by the results?

Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Modeling social and spatio-temporal dynamics of infectious disease, with specific experience in seasonal influenza.

We confirm that we have read this submission and believe that we have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however we have significant reservations, as outlined above.

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