Appendix

Rationale used for creating the PAH and PAHHE groups

Anderson *et al.* used five selection criteria which drew on literature linking Government health and social policies to the socioeconomic determinants of health and to child health outcomes. Their methodology is summarised below, and can be seen in further detail in their 2012 publication.[1]

Child health professionals (N=17, majority paediatricians) studied this literature and scored the selected conditions from 0 (almost totally unavoidable) to 4 (almost entirely avoidable) for each of the five specified criteria. If mean score was ≥2, then condition was included as PAH.

Potentially avoidable hospitalisations (PAH) included those which might potentially be avoided by:

• Government policies which ensured adequate socioeconomic resources were available to families with children (e.g. income support, childcare, assistance for solo parents returning to workforce).

• Central and local government policies which ensured that families with children had access to high quality housing and a safe physical environment (e.g. availability, quality and affordability of state and other housing options).

• Access to timely, appropriate and affordable primary healthcare.

• The implementation of population based health promotion strategies aimed at improving child health (e.g. adult smoking cessation).

• Central and local government policies which ensured that the principles of the Treaty of Waitangi (between indigenous Māori and the Crown) were taken into account when making resource allocation decisions affecting families.

Where a mean score of ≥2 was identified for the second criteria, this condition was also grouped in the potentially attributable to housing/the physical environment (PAHHE) group.

Rationale used for creating the Crowding group

A systematic review of the literature was performed to investigate the relationship between exposures to household crowding density and outcomes of close contact infectious diseases (CCIDs) by researchers at the University of Otago Wellington. Articles published before 8th July 2012 in Medline, Embase, Scopus, Web of Science, Index New Zealand, Cochrane Library and Lancet Infectious Diseases were included. Additional articles were identified by searching references and expert recommendation. A total of 9,852 articles were identified and 345 studies were eligible for the narrative synthesis following review. Of these 345 studies, 116 provided odds ratios or risk ratios adjusted for age and socioeconomic status and were eligible for meta-analysis. Combined estimates were calculated for ten different categories of CCIDs based on 82 studies. A number of diseases were found to be significantly associated with exposure to household crowding.[2] The Crowding group was developed on the basis of this systematic review findings and refined in conjunction with expert opinion of the lead author on the report, Prof. Baker.

Rationale used for creating the Ministry of Health group

Taking into account the association between household crowding and rheumatic fever, as well as the strong evidence linking household crowding and other infectious disease, it was agreed by

staff at the NZ Ministry of Health (MoH) that reducing household crowding would be an important intervention for reducing rheumatic fever. Consequently children who were admitted to hospital with a set of close contact or housing related conditions were eligible to be referred to housing programmes - this set of conditions was selected based on expert opinion of the MoH staff consulted. In other words, the conditions were selected because it was thought they were associated with household crowding rather than because they are strongly associated with ARF.

It was not the intention to directly identify those at risk of rheumatic fever, but rather to identify children at risk for increased transmission of Group A streptococcal infections - which can lead to rheumatic fever. And this relates directly to one of the three key strategies of the NZ rheumatic fever prevention programme (RFPP): "To reduce household crowding and therefore reduce household transmission of strep throat bacteria within households".[3]

Additional Statistical Findings

Models were tested for proportionality of hazards. The proportional hazards assumption is essentially an assumption that the regression coefficient β does not change over time.[4] We tested this assumption using Grambsch and Therneau's global test of goodness of fit test in the cox.zph function of R's 'survival' library [4,5], which rejected the proportional hazards assumption for all of the models used (all p values < 0.001). We further examined the relationship between hazards and time for each of the variables within each of the Cox models by fitting spline smoothed curves to the standardised Schoenfeld residuals for each of the model covariates in each of the models. This showed that age at diagnosis, ethnicity, deprivation and sex all approximately satisfied the proportional hazards assumption; however, the main exposures of

interest (i.e. hospitalisation for housing-related disease) violated this assumption, with β declining over time. Given that Grambsch and Therneau (1994) suggest that the smoothed Schoenfeld residuals is a good estimate of the true form of β(t) at large sample sizes,[4] these smoothed curves were shown to demonstrate the effect (raw and adjusted) of hospitalisation across the entire study duration, with naïve hazard ratios essentially representing 'average' effect. This effectively extends the Cox model to allow β to change with time, without specifying the form of this relationship.

The following figures demonstrate the relationship between the Cox-regression coefficients and time. Dashed lines indicate the naïve coefficient.

Figure 1A: Rehospitalisations over time, PAH group, unadjusted survival curve

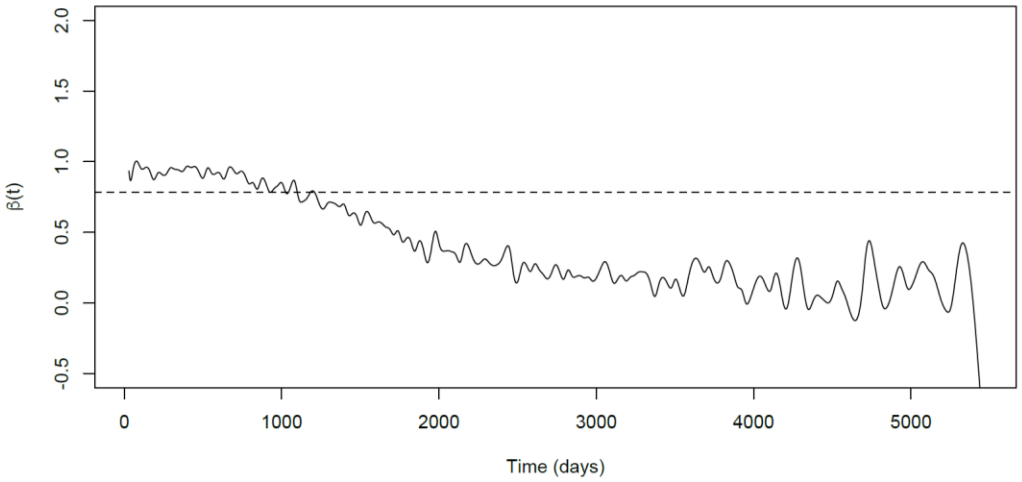

Figure 1B: Rehospitalisations over time, PAH group, unadjusted survival curve

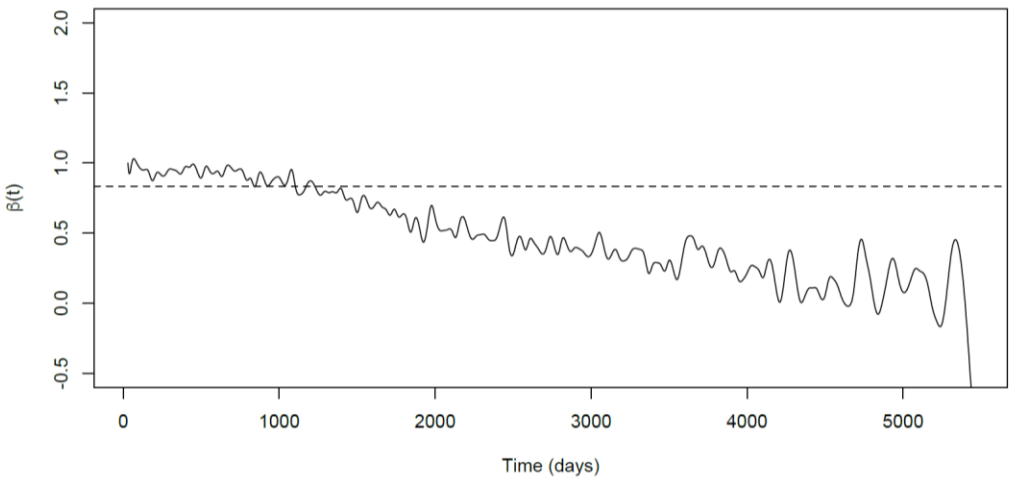

Figure 2A: Rehospitalisations over time, PAHHE group, unadjusted survival curve

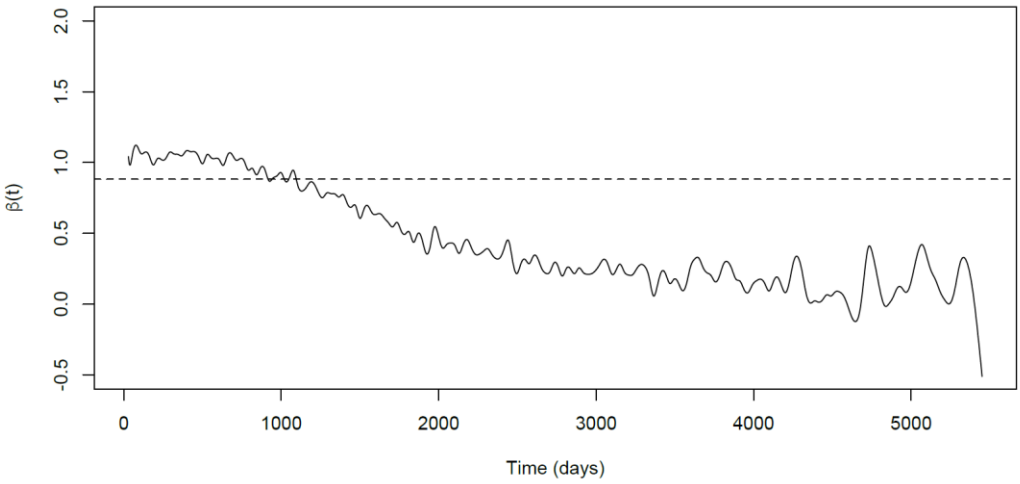

Figure 2B: Rehospitalisations over time, PAHHE group, adjusted survival curve

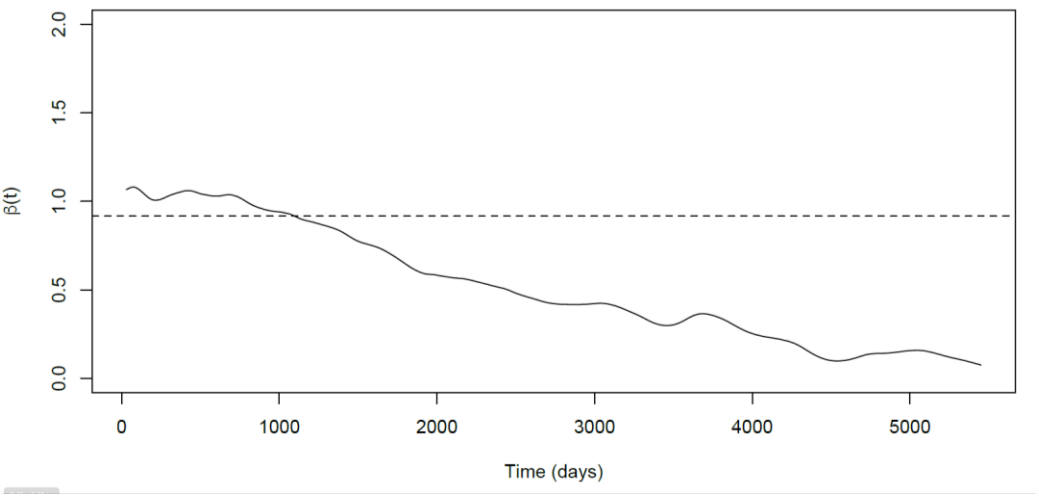

Figure 3A: Rehospitalisations over time, Crowding group, unadjusted survival curve

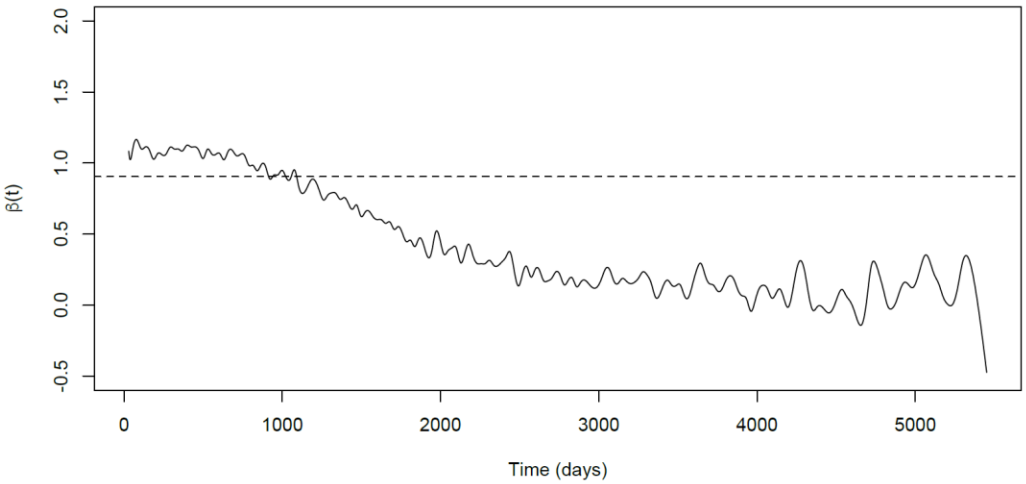

Figure 3B: Rehospitalisations over time, Crowding group, adjusted survival curve

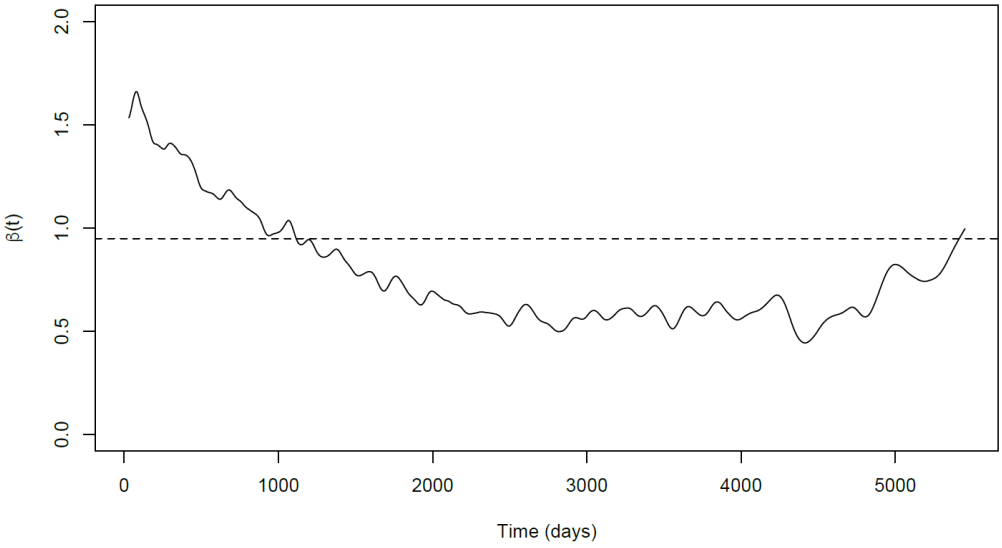

Figure 4A: Rehospitalisations over time, MoH group, unadjusted survival curve

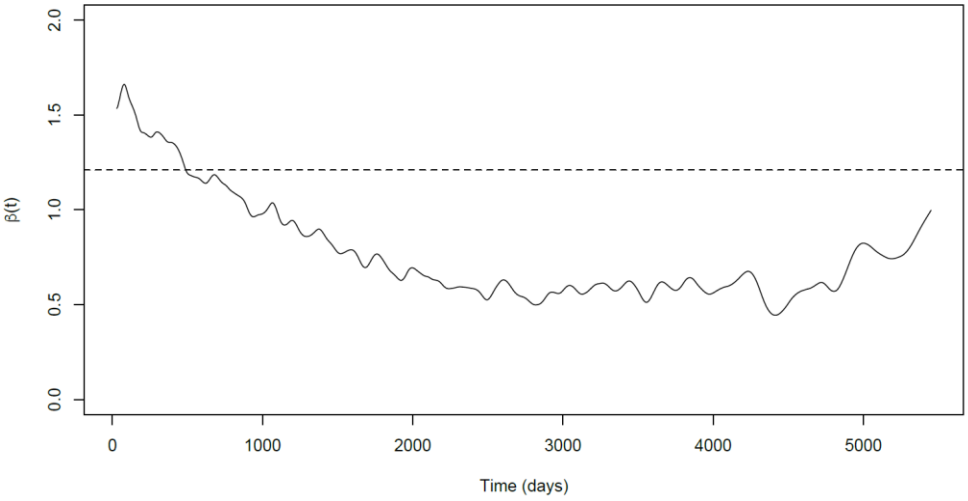

Figure 4B: Rehospitalisations over time, MoH group, adjusted survival curve

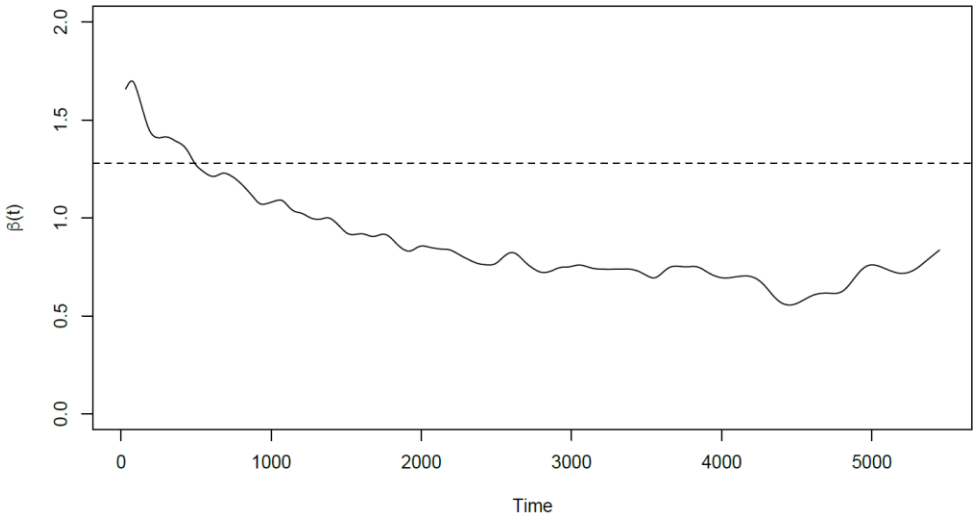

Table 1 shows the standard error (SE) when calculating measures of effectiveness for the three disease groups. The measure-of-effectiveness statistics were normally distributed (by testing of the distribution of bootstrap replicates by quantile-quantile plotting).

Table 1: Standard Errors

	PAHHE ($x10^{-3}$)	Crowding ($x10^{-3}$)	MoH ($x10^{-3}$)
Sensitivity	1.195758	1.255811	1.247141
Specificity	1.795894	1.747473	1.346682
NPV	1.764722	1.612864	1.235331
PPV	1.268007	1.370975	2.527037

REFERENCES

1. Anderson P, Craig E, Jackson G, Jackson C. Developing a tool to monitor potentially avoidable and ambulatory care sensitive hospitalisations in New Zealand children. *N Z Med J* 2012; **125**(1366): 25-37.
2. Baker MG, McDonald A, Zhang J, Howden-Chapman P. Infectious diseases attributable to household crowding in New Zealand: A systematic review and burden of disease estimate. Wellington: He Kainga Oranga/ Housing and Health Research Programme, University of Otago, 2013, 2013.
3. Jessamine S. Preventing rheumatic fever. Update on rheumatic fever prevention & control; 2016 9 Feb 2016; University of Otago, Wellington: University of Otago; 2016.
4. PM Grambsch, TM Therneau. Proportional hazards tests and diagnostics based on weighted residuals. *Biometrika* 1994: 515-26.
5. Therneau T. Survival: A Package for Survival Analysis in S. version 2.38, URL: https://CRAN.R-project.org/package=survival. 2015.