

# BMJ Open Understanding geographical variations in health system performance: a population-based study on preventable childhood hospitalisations

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## ABSTRACT

**Objective** To investigate interdistrict variations in childhood ambulatory sensitive hospitalisation (ASH) over the years.

**Design** Observational population-based study over 2008–2018 using the Primary Health Organisation Enrolment Collection (PHO) and the National Minimum Dataset hospital events databases.

**Setting** New Zealand primary and secondary care.

**Participants** All children aged 0–4 years enrolled in the PHO Enrolment Collection from 2008 to 2018.

**Main outcome measure** ASH.

**Results** Only 1.4% of the variability in the risk of having childhood ASH (intracluster correlation coefficient=0.014) is explained at the level of District Health Board (DHB), with the median OR of 1.23. No consistent time trend was observed for the adjusted childhood ASH at the national level, but the DHBs demonstrated different trajectories over the years. Ethnicity (being a Pacific child) followed by deprivation demonstrated stronger relationships with childhood ASH than the geography and the health system input variables.

**Conclusion** The variation in childhood ASH is explained only minimal at the DHB level. The sociodemographic variables also only partly explained the variations. Unlike the general ASH measure, the childhood ASH used in this analysis provides insights into the acute conditions sensitive to primary care services. However, further information would be required to conclude this as the DHB-level performance variations.

## INTRODUCTION

Ambulatory sensitive hospitalisation (ASH) refers to the hospital (hospitalisation) events related to the health conditions potentially preventable in the ambulatory care setting through prophylactic or therapeutic interventions.<sup>1–3</sup> Ambulatory care sensitive conditions are often defined within specific country contexts given their scope of health-care services and the purpose for which the indicator is used.<sup>3</sup>

In Aotearoa New Zealand (NZ), the Ministry of Health (MOH) has defined a list of ASH conditions. These conditions

## STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ It is a population-based study.
- ⇒ A new and robust measure of the socioeconomic deprivation, the Index of Multiple Deprivation, is used.
- ⇒ Macrolevel health system input variables are included besides the major socioeconomic, demographic and geographical measures.
- ⇒ Specific access barriers like transport could not be included.
- ⇒ The denominator population is retrieved from the source that includes only those who have had at least one contact with primary care service providers.

are intended to be used as proxy markers of access and quality of the primary care services and diagnostic measures for District Health Boards (DHBs) to identify and address disparities across different population groups.<sup>2</sup> NZ currently comprises 20 DHBs, which are the subnational administrative units responsible for planning, delivering and funding of health services in NZ.

NZ's healthcare delivery system is highly decentralised, although the core administration functions linked to the overall public sector management, for example, national service frameworks and the national-level contracts for some services, are centralised. The Ministry of Health is responsible for providing advice (stewardship role) on health services policy issues to the government, and 20 DHBs have been responsible for planning and funding of overall services for the last 20 years (from 2000 to 2021).<sup>4</sup>

Existing evidence shows the variations in ASH rates among different ethnic groups,<sup>5</sup> across socioeconomic gradients,<sup>6 7</sup> and on other general social determinants of health including health literacy.<sup>2</sup> Health system factors such as hospital admission policies,<sup>2</sup> available hospital beds and local supply of

general practitioners<sup>8</sup> also contribute to the overall ASH rates. Access to primary care is considered as one of the most important predictors of ASH.<sup>9 10</sup> Rurality and remoteness, including transport unavailability, are other common factors that affect access to care and may subsequently cause higher ASH rates.<sup>11–13</sup>

Within-country geographical variation is one aspect of unwarranted variation that has attracted considerable attention, and focused on the paediatric (<18 years),<sup>11</sup> adult<sup>14–16</sup> or general (all age)<sup>8 12 17</sup> population. For example, recent research has been about hospital districts in Finland,<sup>12</sup> counties in USA,<sup>11</sup> French regions,<sup>8</sup> metropolitan areas versus rural areas in Victoria, Australia,<sup>17</sup> South Korean districts,<sup>14</sup> hospitals in New South Wales, Australia,<sup>15</sup> Spanish health districts<sup>16</sup> and counties within the New York state, USA.<sup>18</sup> The studies generally confirm that ASH rates vary by geographical units. However, the Modifiable Area Unit Problem acknowledges that the strength of the association between ASH and demographic factors is heavily influenced by the size of geographical units used.<sup>19</sup>

More recently ASH has been used as an indicator of overall health system performance although the evidence relating to the effectiveness in measuring performance is reported to be mixed.<sup>15</sup> The ASH rate for children aged 0–4 (hereafter referred to as childhood ASH) is one of the six headline measures in the NZ System Level Measures framework since 2016.

Reducing childhood ASH is a policy priority in NZ. The routinely collected data illustrates that the childhood ASH rate vary across the DHBs.<sup>2</sup> However, there is no information about the extent to which the variation comes from the differences in sociodemographic and economic characteristics of the population between DHBs. In this paper, we investigate interdistrict variations in childhood ASH over the years, adjusting for the effects of the key socio-demographic, economic, geographical and health system characteristics across the DHBs. Answering this question is helpful in determining the suitability of childhood ASH as an indicator of health system performance at the district level.

## METHODS

### Data sources

We obtained anonymised, individual-level datasets from the National Collections division of the NZ Ministry of Health. The National Minimum Dataset hospital events provided childhood ASH data. The dataset provides national collection of public and private hospital discharge information that contains clinical and individual demographic data in NZ.<sup>20</sup> Additional sociodemographic data (age, sex and self-reported ethnicity) for the study population were provided from the Primary Health Organisation Enrolment Collection (PHO), a nationwide collection of patient enrolment with primary care providers reported quarterly and available since 2005.<sup>21</sup>

The NZ Index of Deprivation, NZDep, provides a small area ordinal scale (deciles) of relative deprivation status, with each decile representing 10% of areas, and updated after every census.<sup>22</sup> We also accessed the more recent Index of Multiple Deprivation (IMD), which used 28 indicators grouped into 7 domains (income, employment, crime, housing, health, education and access), thus allowing us to consider overall deprivation and its drivers (ie, domains) separately.<sup>23</sup>

Rurality of the study population's Domicile was mapped against the Area Unit 2013 as reflected in the Geographic Concordance file, a publicly available customised dataset of Stats NZ,<sup>24</sup> and the Census domicile code table. Area Unit represents a non-administrative single geographical entity with a unique name formed by aggregating adjacent census Mesh blocks (the smallest geographical area unit) with coterminous boundaries. It is then regrouped into urban and non-urban categories based on the urban–rural description 2018.<sup>24</sup> Similarly, NZ Health Workforce Survey reports and the Health Workforce Information Programme<sup>25</sup> provided human resource data, number of general practice (GP) full time equivalents per 100 000 population and DHB staffed total health workforce full time equivalents respectively, aggregated by the DHBs and study years. The financial data (Annual Health Expenditure per Capita) was obtained from the MOH through the Official Information Act requests.

### Patient and public involvement

The ethics approval covers the privacy and confidentiality aspect of using the secondary data. We declare no direct involvements of patients or the public in the research process.

### Measurements

Childhood ASH is defined as the acute or arranged hospitalisation events related to the ambulatory sensitive conditions among children aged 0–4 years. The clinical conditions included are as per the MOH 2018 lists of the International Classification of Diseases-10 Australia Modifications diagnosis codes<sup>26</sup> (online supplemental appendix 1). We included only the acute conditions for the primary diagnosis events except for dental conditions, where elective cases were also included. 'Acute' is defined as having one of the following admission type codes: AA (Arranged Admission), AC (Acute admission) or RL (Psychiatric patient returned from leave); and 'Elective', having one of the following admission type codes: AP (Private hospital elective admission) or WN (Admitted from waiting list—normal). The non-case mix events, those aged less than 29 days at admission, and events with an overseas or unknown DHB of Domicile were excluded. We followed the childhood ASH analysis methodology as recommended by the NZ Child and Youth Epidemiology service.<sup>27</sup>

### Data analysis

We screened the eligible childhood ASH events for the calendar years 2008 to 2018 separately and identified

each patient's number of events for the respective years. The coverage of the denominator population before 2008 were less than 90% of the total estimated resident population, and therefore, excluded from the analysis. At the time of request, 2018 was latest year for which the data was available. The childhood ASH records were then merged with a population dataset for all the registered population aged 0–4 years for the respective calendar year.

We merged the numerator dataset with the denominator population by six variables: Year (2008–2018), Domicile-codes, sex (male and female), age groups (0–1 year, 1–2 years and 2–4 years) and ethnicity (non-Māori non-Pacific—NMNP, Māori and Pacific Peoples; prioritised ethnicity groups as defined in the respective datasets. NZ Census allows individuals to identify with multiple ethnic groups. Then, it is presented in three aggregated forms—total response, prioritised and sole/combination. Prioritised ethnicity, the most common form in the health and disability sector, allocates individuals to only one of the groups that they identified with in the priority order of: Māori, Pacific, Asian, European/other. For example, a person identified as Chinese and Māori is labelled as Māori. Consistent with previous ASH research in NZ,<sup>28</sup> the cases with 'no data' for the childhood ASH variable in the merged file were assumed to have had no ASH events in the respective year and thus coded accordingly.

When predictor variables representing the same aspect (eg, area deprivation) were colinear, only one predictor was retained based on the relevancy. For example, since NZDep, and IMD were strongly correlated in this analysis ( $R=0.83$ ,  $p<0.001$ ) and both measured a relative area-level socioeconomic deprivation, IMD demonstrating a stronger relationship to the outcome variable was chosen for further analysis. The final dataset allowed us to conduct population-based cross-sectional analyses.

The dataset structure was hierarchical, with the outcome variable and demographic variables measured at the individual level, socioeconomic status (deprivation) and rurality measured at domicile level, and finance and human resource variables measured at DHB level. We followed the 2010 definition of DHBs when Otago DHB and Southland DHB were amalgamated to form the new Southern DHB. It reduces the total number of DHBs from 21 to 20.

Understanding DHB-level geographical variations in childhood ASH was the primary objective of this research. Therefore, we undertook analyses using a mixed effects logistic regression model (a hierarchical random intercept model) with DHB as a random effect variable and the rest of the predictors as (stepwise) fixed effect variables. A 'lme4' package in R was used.<sup>29</sup> The proportion of the variation in childhood ASH attributable to the DHB is estimated by calculating intraclass correlation (ICC). ICC is a measure of the effects of the cluster itself on subject outcomes for hierarchical structure data and estimates between and within cluster variance. ICC values

range from 0 to 1, with 0 indicating no effect and 1 as 100% (completely explained).<sup>30</sup>

The variance estimates of the random effect variable were transformed into median OR (MOR) using the MOR function in R.<sup>31</sup> MOR is considered to be a more meaningful and interpretable scale in multilevel logistic regression analysis because this can be compared with the OR of the fixed effect variables.<sup>30</sup>

The number of clusters/groups in this analysis ( $n=20$ ) is less than that recommended for a multilevel model (eg, 50/50 rules).<sup>32–33</sup> Similarly, the distributions of the total number of individuals (and the outcomes) within each of the clusters/groups are highly variable. Some literature suggests that when the number of clusters is small and ICC is minimal, single-level fixed effect regression results are similar to the mixed effect model with minimal computations required.<sup>34</sup> Other literature suggests comparing the results from both single and multilevel models.<sup>35</sup>

Therefore, we performed both multilevel logistic regression (mixed effect random intercept model, labelled as 'model 1'), and single-level multiple logistic regression (fixed-effect model labelled as 'model 2'). The estimates for the fixed-effect variables were compared and found to be consistent (as shown in online supplemental appendix 2).

In model 2, we entered childhood ASH (yes/no) as outcome variable and DHB, age (age groups), sex, ethnicity (three categories), year (grouped into four categories), deprivation (IMD deciles, three categories), rurality (two groups) and human resource or finance (continuous) variables entered as fixed factors. The R software's 'glm' function with the logit link (RStudio V.1.2.5019) was used for the analysis. The numerical covariates (finance or human resource) were rescaled between 0 and 1 using the 'scales' library.<sup>36</sup> The variable having higher effects in the unadjusted (bivariate) analysis was prioritised first.<sup>37</sup>

We also examined the trajectories of the DHBs over the years by including DHB and year (grouped—3 years windows) interaction term. The model did not converge in the random-effect structure but worked well in the fixed-effect one. This is the third model in this analysis labelled as 'model 3'.

Multicollinearity of the predictor variables in the models were checked using the R package 'car' (V.3.0–7).<sup>38</sup> The decision criteria were based on the variance inflation factor<sup>39</sup> with a cut-off of  $<3$  for main effects and  $<20$  for interaction effects.<sup>40</sup> Because of the high correlation of the workforce and finance variable, we generated the estimates with only finance variable except in the model with GP (General Practice Full Time Equivalent per 100,000 population) variable.

We undertook a separate analysis for the dataset having GP variable (human resource input) that has information for only up to 2016. This analysis was done in the fixed-effect structure, equivalent to the models 2 and 3 as above but GP variable replacing the finance variable. [Table 1](#) summarises the three primary models analysed:

**Table 1** Details of the models

| Models  | Structure  | Variables   | Note   |
|---------|--|---|--|
| Model 1 | Multilevel random intercept model (logistic regression)          | Random effect variable: DHB<br>Fixed effect variables: age, ethnicity, sex, deprivation, rurality, finance and year-window (stepwise) | All model terms had $\text{Pr}( > \chi^2 )$ value $< 0.001$  |
| Model 2 | Fixed effect multiple logistic regression model                  | Age, DHB, ethnicity, sex, deprivation, rurality, year-window and finance (orderly)  | As above   |
| Model 3 | Fixed effect multiple logistic regression model with interaction | Model 2 variables plus DHB-year interaction term  | all model terms had $\text{Pr}( > \chi^2 )$ value $< 0.001$ , and all VIFs including that for the interaction terms were less than five except for finance variable (VIF=5.06) |

DHB, District Health Board; VIF, Variance Inflation Factor.

The R prediction function estimated the childhood ASH events for the focal variables (DHB and year) by keeping all other covariates constant, defined at the mean for the numerical variable and the reference category for each of the categorical variables.<sup>41</sup> Auckland DHB that features a good mix of the population characteristics is taken as a reference category for the geographical variation analyses.

We also conducted sensitivity analysis for the DHB-wide variation to test the effects of hospital admission and coding practices that varies across the DHBs<sup>2 42</sup> by excluding the patients discharged in an emergency department specialty after a length of stay of  $< 2$  days from the dataset based on the fixed-effect model (model 2).

## RESULTS

The composition of the study population in the DHBs varied by ethnicity, rurality and area-level deprivation. For example, the proportion of the indigenous Māori children (0–4) in our dataset range from 28% in (Auckland DHB) to 46% in (Tairāwhiti DHB) and the proportion of Pacific children ranging from 29% to four percent across the DHBs. In case of deprivation, Northland (61%) has the highest proportion of children (0–4) living in the deciles 7–10 in contrast to that in South Canterbury (4%).

The average childhood ASH admissions range from 46.2 per 1000 PHO enrolled population in South Canterbury to 98.9 per 1000 population in Whanganui for the study period. Similarly, the distributions of the causes or conditions of the childhood hospitalisations also vary, with Asthma, gastroenteritis and upper respiratory tract infection representing more than half of the total causes (table 2). Details of district-wide variation of the observed childhood ASH events over the years is in online supplemental appendix 3.

The hierarchical logistic regression model with the DHBs added as a random effect variable (model 1) found that only 1.4% of the variability in the risk of childhood ASH (intracluster correlation coefficient, ICC=0.014) is explained at the level of DHB. When adjusted for the

effects of the predictor variables, the ICC of DHB as a cluster variable is reduced to less than 1.0% (ICC=0.006). The MOR estimates show that a typical pair of randomly chosen DHB will differ in odds of having childhood ASH by a factor of 1.23, which reduces to 1.14 when adjusted for the available predictor variables as shown in the table 3.

The odds of childhood ASH vary across the districts (DHB as an independent predictor variable in the fixed-effect model—model 2); with the lowest among those living in South Canterbury DHB (OR=0.86, 95% CI 0.81 to 0.92) and highest in Southern DHB (OR=1.39, 95% CI 1.33 to 1.46) compared with that in Auckland. Six DHBs demonstrated no significantly different odds of childhood ASH from the reference DHB (figure 1).

Table 4 details the relationship of predictor variables and the likelihood of childhood ASH (parameters from the fixed-effect model (model 2)). The adjusted odds of overall childhood ASH declined by 2% (OR=0.98, 95% CI 0.96 to 0.99) in 2010–2012 compared with that in 2008–2009. Then, it increased in the successive years (OR=0.96, 95% CI 0.94 to 0.98) in 2013–2015 and (OR=0.96, 95% CI 0.94 to 0.99) in 2016–2018.

The likelihood of childhood ASH varies across ethnic categories (table 4). Overall, Māori children have 75% (OR=1.75, 95% CI 1.73 to 1.77) and Pacific children have more than twofold (OR=2.05, 95% CI 2.03 to 2.08) higher odds of being hospitalised than that among NMNP children. In the case of those living in urban areas, the odd of childhood ASH is 25.1% higher than that in non-urban, and 46.6% and 21.6% higher among those living in deciles 7–10 and deciles 5–6, respectively, compared with those in deciles 1–4.

The relationship of the distributions of DHB-level annual health expenditure per capita with the risk of children (0–4 years) being hospitalised for ambulatory sensitive conditions is positive. The distributions of GP per 100 000 population demonstrate a significant relationship only when DHB and year interaction effect was allowed in the adjusted model (see table 4 notes).

**Table 2** Childhood ASH conditions by major cause categories

| Causes                                    | 2008      |        | 2018      |        |
|---|-----------|--------|-----------|--------|
|   | Frequency | %      | Frequency | %      |
| Asthma                                    | 3595      | 18.51  | 5087      | 23.05  |
| Lower respiratory tract infections        | 899       | 4.63   | 1607      | 7.28   |
| Cellulitis                                | 1533      | 7.89   | 1513      | 6.86   |
| Constipation                              | 314       | 1.62   | 426       | 1.93   |
| Dermatitis                                | 488       | 2.51   | 446       | 2.02   |
| Dental                                    | 2581      | 13.29  | 2744      | 12.43  |
| Gastroenteritis                           | 3646      | 18.78  | 3021      | 13.69  |
| Gastro-oesophageal reflux diseases (GORD) | 278       | 1.43   | 200       | 0.91   |
| Nutrition                                 | 30        | 0.15   | 77        | 0.35   |
| Rheumatic fever                           | 2         | 0.01   | 2         | 0.01   |
| Upper respiratory tract infection         | 3696      | 19.03  | 5162      | 23.39  |
| Vaccine preventable diseases              | 32        | 0.16   | 37        | 0.17   |
| Acute pneumonia                           | 2324      | 11.97  | 1745      | 7.91   |
| Total                                     | 19418     | 100.00 | 22067     | 100.00 |

The childhood ASH events are as per the hospitalisation register (not the merged population dataset used for further analysis); standard exclusion criteria applied, for example, only primary diagnosis, only acute conditions except for the dental conditions, aged 29 days to 4 years at admission, casemix events only, excluded unknown or overseas DHB domicile. ASH, ambulatory sensitive hospitalisation; DHB, District Health Board.

The time-trend varies across the districts, although there is no obvious pattern (estimates based on the model with DHB-year interaction term (model 3) in [figure 2](#)). For example, Tairāwhiti DHB demonstrated a gradual decline in the likelihood of childhood ASH events over the years, estimated events (reference: aged 0–1 year, female, deprivation (deciles 1–4), non-urban and mean expenditure) among NMNP declined from approximately 50 to <30 per 1000 PHO registered population in 2008–2009 and 2016–2018, respectively. In four other districts (Counties Manukau, Nelson Marlborough, Whanganui and Lakes) the estimated number of events declined significantly in 2010–2012 but remained unchanged after that.

## DISCUSSION

Ethnicity, deprivation and rurality are the factors most strongly associated with childhood ASH. The result largely

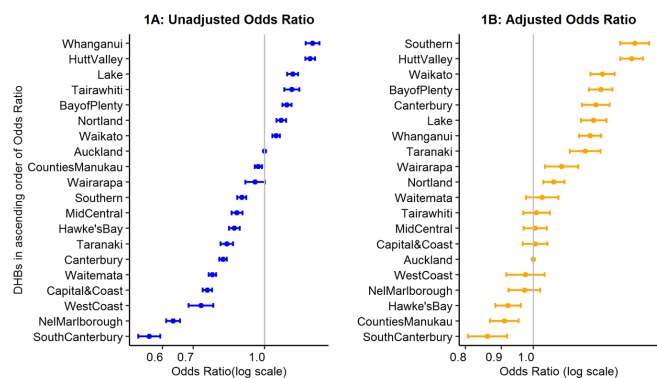
confirms the conclusion drawn by another NZ study that reported overall ASH for the years 2001–2009,<sup>28</sup> although we noticed further different trajectories at the district level. The ethnicity-wise variation is significant in terms of health system performance in NZ as it indicates a failure to uphold Māori rights under the Treaty of Waitangi (the founding constitutional document in NZ between Māori and the British Crown) to good governance, self-determination and equity.<sup>43 44</sup>

Literature from other high-income countries generally reports a higher likelihood of ASH in rural areas,<sup>17 45</sup> but we found it higher in the urban areas. It may be because of the healthcare-seeking practices (eg, overcrowding at emergency department in the urban areas)<sup>46</sup> or that related to the age group of the study population; children aged 0–4 in our case vs all age (general population)<sup>17 45</sup> or those aged under 15 years.<sup>11</sup> Furthermore, in our analysis,

**Table 3** Details of the mixed-effect model (model 1)

| Covariates   | Variance | SD    | ICC   | MOR  |
|--|----------|-------|-------|------|
| A.DHB only   | 0.046    | 0.216 | 0.014 | 1.23 |
| B.Adjusted (individual level variables)—age, sex, ethnicity  | 0.026    | 0.161 | 0.008 | 1.17 |
| C.Adjusted (individual and area level variables)—age, sex, ethnicity, deprivation and rurality                     | 0.02     | 0.141 | 0.006 | 1.14 |
| D.Adjusted (individual, area and DHB level variables)—age, sex, ethnicity, deprivation, rurality and finance       | 0.018    | 0.135 | 0.005 | 1.14 |
| E.Adjusted (individual, area and DHB level variables)—age, sex, ethnicity, deprivation, rurality, finance and year | 0.018    | 0.135 | 0.005 | 1.14 |

DHB, District Health Board; ICC, intracluster correlation coefficient; MOR, median OR.



**Figure 1** Fixed effect OR of childhood ambulatory sensitive hospitalisation (0–4 years) by District Health Boards (DHBs). Notes: model  $p < 0.001$ , model covariates: 1A=DHB only, 1B (model 2)=age, DHBs, ethnicity, gender, deprivation, rurality, year-window and finance; deprivation: Index of Multiple Deprivation (IMD1=decile 1–4, IMD2=decile 5–6, IMD3=decile 7–10; finance (AHE-PP): annual health expenditure per capita rescaled (0–1).

the definition of urban includes a wide range of urban-type areas, for example, small urban areas as well as the major urban areas.<sup>24</sup> Further investigation into it may be helpful given that both sociodemographic<sup>47</sup> and health service characteristics (eg, availability of GP) tend to vary within the specific urban categories as well as between the urban and non-urban settings.<sup>45</sup> We could not go into depth as we concentrated more on the DHB level analysis. Some of the DHBs (eg, Auckland and Capital and Coast) have less than 5% of the study population from the non-urban areas.

The distribution of GPs plays important roles not only as gatekeepers of the NZ medical care system but also in delivering core medical and preventive care through an integrated approach.<sup>48</sup> Along with the studies in France and Australia that reported an inverse association between GP supply and general ASH rates,<sup>8 15</sup> we also found that a higher number of GP is associated with a lower likelihood of childhood ASH. Given that the number of GP varies across the DHBs, this could be an important factor making the DHBs different.

Hospital admission criteria are another important health system factors reported to affect ASH rates.<sup>2</sup> According to the Ministry of Health, DHBs had different admission practices from 1999 to 2012, and the differences in data reporting are likely to vary by the causes of the hospitalisations.<sup>42</sup> We did not find any changes in the patterns of the variations except that in Auckland DHB (the reference group) having a dedicated Starship Children's Hospital, which manages the majority of the cases in an emergency department setting, thereby resulting in the lowest odds of childhood ASH, compared with that by all other DHBs (online supplemental appendix 4).

This analysis also features a few limitations.

First, the denominator population comes from the PHO enrolment dataset. The total number of children aged 0–4 years included in the dataset for the overall

study period was 3 003 340 that range from 276 961 in 2008 to 281 125 in 2018. The proportion of the estimated resident population covered in the data was 91.0% in 2008 and 98.7% in 2018. The inherent limitations that apply to the PHO enrolment system, particularly around the differential likelihood of the groups being enrolled depending on the population characteristics,<sup>49 50</sup> and that related to the dataset itself—accurate and up to date address data (eg, Domicile Code)<sup>51</sup>—apply to our results as well. Nevertheless, the distribution of the numerator population (childhood ASH events from the hospitalisation dataset) and the denominator population (PHO enrolled) with a complete set of information available across the study variables were broadly consistent, with an average of 95.2% and 95.7% coverage of the original datasets respectively. Similarly, the share of the total population by the DHBs in our dataset (2008–2018) compares well with that in the estimated resident population for the same period. For example, the highest difference is of only two percentage points (higher in our dataset) in Auckland, Southern and Waitemata DHBs, and close to zero in all other DHBs.

The variations we reported for the DHB-level geographical administrative units could have been influenced by the sociodemographic factors within the DHBs.<sup>19</sup> However, we could not go into the further details because of the smaller population size of some of the DHBs. The finance variable used is a macrolevel overall DHB-level health system input variable, not specific to the childhood ASH interventions. Variables related to the socioeconomic status and access are also proxy, area-level measures.

Furthermore, we could not include the specific Access variable available in the IMD dataset<sup>23</sup> that measures geographical access to essential services at the 'data zone' level, which is different to the Domicile. Lack of transport is one of the important factors affecting access to health services in society.<sup>13</sup> The New Zealand Health Survey 2020/2021<sup>52</sup> reports that 1% of the children aged 0–14 years had unmet need for GP services due to lack of transport, which is higher among Māori and Pacific children and those living in the most deprived areas. We could not include a transport variable in the analysis as no individualised DHB-level information was available for the study population over the study years. The overall IMD classification, however, incorporates access effects within it (in contrast to the NZDep13).<sup>23</sup> Our results are not directly comparable to previous research in NZ that used either individual socioeconomic position or NZDep as their measures of social position.

Another minor limitation, particularly around the geographical analysis based on the cross-sectional dataset, is that we could not capture the potential inter-DHB movements of the population within the study period. The DHB of domicile, rurality and deprivation of the study population represent the place as reflected in the PHO dataset for the particular year. Therefore, longitudinal studies following a specific population cohort may provide robust estimates of the individuals' risk across the

**Table 4** Fixed effect estimates of OR of childhood ambulatory sensitive hospitalisation (0–4 years) by other covariates

| Variables  | Unadjusted OR |                  | Adjusted OR |                   |
|--|---------------|------------------|-------------|-------------------|
|  | OR            | 95% CI           | OR          | 95% CI            |
| Year windows   |               |                  |             |                   |
| 2008–2009  | Ref           |                  | Ref         |                   |
| 2010–2012  | 1.0176        | 1.0041 to 1.0313 | 0.9783      | 0.9623 to 0.9946  |
| 2013–2015  | 1.0209        | 1.0074 to 1.0347 | 0.9595      | 0.9398 to 0.9795  |
| 2016–2018  | 1.0513        | 1.0374 to 1.0654 | 0.9653      | 0.9404 to 0.9909  |
| Age—group  |               |                  |             |                   |
| 0–1 year   | Ref           |                  | Ref         |                   |
| 1–2 years  | 0.8274        | 0.8178 to 0.8371 | 0.8250      | 0.8153 to 0.8347  |
| 2–4 years  | 0.7666        | 0.7591 to 0.7741 | 0.7668      | 0.7593 to 0.7744  |
| Gender   |               |                  |             |                   |
| Female   | Ref           |                  | Ref         |                   |
| Male   | 1.1984        | 1.1880 to 1.2089 | 1.1977      | 1.1873 to 1.2083  |
| Ethnicity (prioritised)                                  |               |                  |             |                   |
| NMNP   | Ref           |                  | Ref         |                   |
| Māori  | 1.9669        | 1.9476 to 1.9864 | 1.7465      | 1.7277 to 1.7655  |
| Pacific  | 2.2482        | 2.2209 to 2.2758 | 2.0556      | 2.0274 to 2.0843  |
| Deprivation (IMD)—three categories                       |               |                  |             |                   |
| IMD 1 (deciles 1–4)                                      | Ref           |                  | Ref         |                   |
| IMD 2 (deciles 5–6)                                      | 1.3949        | 1.3785 to 1.4114 | 1.2158      | 1.2007 to 1.2311  |
| IMD 3 (deciles 7–10)                                     | 1.9852        | 1.9641 to 2.0066 | 1.4664      | 1.4476 to 1.4854  |
| Urban-rural locality                                     |               |                  |             |                   |
| Non-urban  | Ref           |                  | Ref         |                   |
| Urban  | 1.3754        | 1.3580 to 1.3930 | 1.2506      | 1.2335            |
| Finance (Annual Health Expenditure per Capita, rescaled) |               |                  |             |                   |
| AHE_PP   | 1.4547        | 1.4233 to 1.4869 | 1.4250      | 1.3085            |
| Human Resource (GP FTE per 100,000 population, rescaled) |               |                  |             |                   |
| GP_FTE*  | 1.0224        | 1.0032 to 1.0418 | 0.9851*     | 0.9231 to 1.0512* |

Model covariates (model 2): age, DHBs, ethnicity, gender, deprivation, rurality, years and finance (orderly).

\*GP FTEs rescaled (0–1), analysed in a separate dataset (2008–2016), the adjusted OR values are based on the fixed-effect model without interaction terms (equivalent to the model 2). The corresponding OR value when DHB\*year interaction term was included (equivalent to model 3) is 0.8685 (0.7873, 0.9579). Finance variable not included in the equivalent models with GP\_FTE variable as these two variables were correlated strongly, VIF of all but GP FTE terms <5 reported in this equivalent model 3, with 5.15 for the GP\_FTE term.

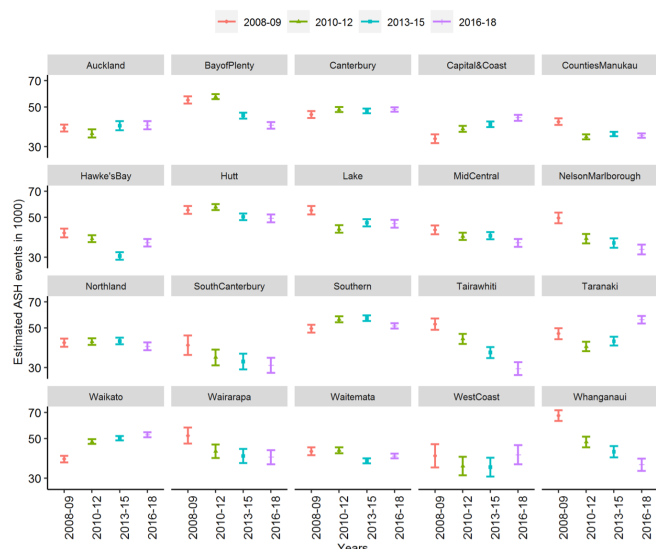
.AHE\_PP, Annual Health Expenditure Per Capita, rescaled; DHB, District Health Board; GP, General Practice; GP\_FTE, General Practice Full Time Equivalent; IMD, Index of Multiple Deprivation; NMNP, non-Māori non-Pacific; VIF, Variance Inflation Factor.

DHBs. Further investigations by the cause of deaths were not possible because of too few cases in some DHBs. Separate studies at the aggregated level may help understand the dynamics within each of the major cause-categories with large number of events like asthma, gastroenteritis and upper respiratory tract infection.

Childhood ASH as an indicator of health system performance is relatively unique to NZ. In one of the recent performance frameworks, the system level measures framework, childhood ASH was expected to indicate the contributions of the primary care sector and the secondary and community care to overall health system performance and measure and manage the performance

of the DHBs. Given that almost one-third of childhood hospital discharges for the acute and arranged medical and surgical cases fall under ASH,<sup>53</sup> prioritising interventions around reducing childhood ASH may have helped DHBs improve their overall health outcomes.

The roles played by health sector organisations' initiatives within the districts over the years potentially explain the residual variation in childhood ASH. The DHBs may have responded to the issue differently, with some having more specific targeted interventions than their other counterparts and it is yet to be reflected at the national level performance results.<sup>54</sup> Still, attributing the unexplained variations solely to the DHB-level health



**Figure 2** Estimated childhood ambulatory sensitive hospitalisation (ASH) events by District Health Boards (DHBs) based on model 3 (with DHB-year interaction term included) reference group: female children aged 0–1 year, living in non-urban deciles 1–4 (Index of Multiple Deprivations), with an average (mean) DHB level per capita expenditure.

system-specific performance should be done cautiously, mainly because of the minimal proportion of the overall variation explained at the level of DHBs. Some of the strong determinants of childhood ASH that tend to vary within the categories and between the DHBs (eg, ethnicity and deprivation) require interventions from the sectors beyond health.

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