



## Does mortality vary between Pacific groups in New Zealand? Estimating Samoan, Cook Island Māori, Tongan, and Niuean mortality rates using hierarchical Bayesian modelling

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### Abstract

**Background** Pacific mortality rates are traditionally presented for all Pacific people combined, yet there is likely heterogeneity between separate Pacific ethnic groups. We aimed to determine mortality rates for Samoan, Cook Island Māori, Tongan, and Niuean ethnic groups (living in New Zealand).

**Methods** We used New Zealand Census-Mortality Study (NZCMS) data for 2001–04, for 380,000 person years of follow-up of 0–74 year olds in the 2001-04 cohort for which there was complete data on sex, age, ethnicity (total counts), natality, and household income. Given sparse data, we used hierarchical Bayesian (HB) regression modelling, with: a prior covariate structure specified for sex, age, natality (New Zealand/Overseas born), and household income; and smoothing of rates using shrinkage. The posterior mortality rate estimates were then directly standardised.

**Results** Standardising for sex, age, income, and natality, all-cause mortality rate ratios compared to Samoan were: 1.21 (95% credibility interval 1.05 to 1.42) for Cook Island Māori; 0.93 (0.77 to 1.10) for Tongan; and 1.07 (0.88 to 1.29) for Niuean. Cardiovascular disease (CVD) mortality rate ratios showed greater heterogeneity: 1.66 (1.26 to 2.13) for Cook Island Māori; 1.11 (0.72 to 1.58) for Niuean; and 0.86 (0.58 to 1.20) for Tongan. Results were little different standardising for just sex and age. We conducted a range of sensitivity analyses about a plausible range of (differential) return migration by Pacific people when terminally ill, and a plausible range of census undercounting of Pacific people. Our findings, in particular the elevated CVD mortality among Cook Island Māori, appeared robust.

**Conclusions** To our knowledge, this project is the first time in New Zealand that clear (and marked in the case of CVD) differences in mortality have been demonstrated between different Pacific ethnic groups. Future health research and policy should, wherever possible and practicable, evaluate and incorporate heterogeneity of health status among Pacific people.

Pacific people have mortality rates intermediary between Europeans and Māori when considered as a single group.<sup>1</sup> But the Pacific population is heterogeneous, and health status (including mortality rates) is likely to vary between specific Pacific groups (e.g. Samoan, Tongan, Cook Island Māori, and Niuean).

First, there are demographic and migration variations between the Pacific ethnic groups that might generate variations in health status. For example, migration histories to New Zealand vary. Cook Islanders and Niueans have been New Zealand

citizens since 1901 and Tokelauans since 1916. Migration of these ethnic groups to New Zealand thus has a longer history and may have been less health-selective than other Pacific ethnic groups. With the increasing need for unskilled labour in the 1960s and 1970s, immigration from the Pacific grew. A Treaty of Friendship was signed with the Samoan Government in 1962, and the Western Samoan Quota scheme was established to facilitate migration from Samoa.

In 1945, the Pacific population in New Zealand was just over 2000 people, Samoans being the largest group. In recent times, the Pacific population was 202,233 in 1996, rising to 231,801 in 2001, and increasing further to 265,974 in March 2006.<sup>2</sup> The Cook Island Māori and Niuean population in New Zealand are now substantially higher than their respective 'home' population (4 and 14 times greater, respectively, at the 2006 Census) and more than 70% are New Zealand-born. In contrast, the 'home' Samoan population is larger than the New Zealand population, and 60% of those residing in New Zealand are born New Zealand. The highest overseas-born proportion is seen amongst Tongans.

Table 1 shows a range of sociodemographic characteristics for the four largest Pacific ethnic groups, Samoan, Cook Island Māori, Tongan, and Niuean. Cook Island Māori and Niuean are least likely to self-identify with a single ethnic group. Cook Island Māori have the lowest rate of formal qualifications, and Tongan the lowest median income.

Second, health-related risk factors vary between Pacific ethnic groups. At the 2006 Census, 38% of the Cook Island Māori population smoked, compared to 28% and 29% for Samoan and Tongan (Table 1). Sundborn et al (2008) have recently published estimates of a range of risk factors for Samoan, Tongan, Niuean, and Cook Island Māori participating in the Diabetes Heart and Health Study.<sup>3</sup>

Being a workforce survey, the population was considerably older than the census population. The smoking prevalence also differed from census data, raising concerns about representativeness of the Pacific population. Nevertheless, the study found substantial variation in health risk factors between different Pacific groups.

The aim of this paper, therefore, is to present mortality rates for the four largest Pacific ethnic groups living in New Zealand, using linked census-mortality data for 2001–04, thereby bypassing the problems of non-comparable collection of data for Pacific ethnic groups between census and mortality data (i.e. numerator-denominator bias). However, mortality is an uncommon outcome, and Pacific populations are small and young. Thus, given the small number of deaths in some Pacific strata, we have used hierarchical Bayesian (HB) regression modelling that allows smoothing of posterior mortality rates by shrinkage towards a prior covariate structure.<sup>4</sup>

**Table 1. Demographic data for Samoan, Cook Island Māori, Tongan, and Niuean living in New Zealand at the 2006 census (and 2001 census for selected variables)**

Variable	Census year	Samoan	Cook Island Māori	Tongan	Niuean
Number	2006	131,103	58,011	50,478	22,476
	2001	115,000	52,600	40,700	20,100
% of total Pacific population	2006	49%	22%	19%	8%
	2001	50%	23%	18%	9%
Sole any-Pacific † #	2006	77%	66%	82%	68%
Sole group-specific Pacific ‡ #	2006	66%	53%	71%	41%
Median age (years) #	2006	20.9	18.9	18.6	19.6
Current smokers #	2006	28%	38%	29%	33%
% adults with formal educational qualification #	2006	69%	55%	64%	60%
% living in Auckland #	2006	67%	60%	80%	79%
Born in NZ	2006	60%	73%	56%	74%
	2001	58%	70%	53%	70%
% speaking own language	2006	63%	16%	61%	25%
% reporting religion	2006	86%	70%	90%	70%
% living in extended family	2006	35%	32%	39%	35%
Median personal income for adults	2006	\$21,400	\$19,800	\$17,500	\$21,500
Own home (a)	2006	23%	21%	19%	21%
Access to telephone	2006	83%	76%	81%	79%

(a) % of adults in fully or partly owned home

† ‘Sole any-Pacific’ mean the person did not self-identify as any non-Pacific groups, but might have self identified as two or more specific Pacific groups (e.g. Samoan and Niuean).

‡ ‘Sole specific-Pacific’ means the person only identified one Pacific ethnic group—and nothing else (e.g. Samoan only)

# Only 2006 reported due to either missing data for 2001 or little change from 2001.

Source of much of the 2006 data, Pacific Profiles: 2006, <http://www.stats.govt.nz/analytical-reports/pacific-profiles-2006/default.htm>

## Methods

**Data**—Linked census-mortality data from the 2001–04 cohort of the New Zealand Census-Mortality Study (NZCMS) were used; details of the linkage, weighting for incomplete linkage of mortality data to census data, and variables specifications can be found elsewhere.<sup>5</sup> Data was restricted to 380,000 person-years for 0–74 year olds with non-missing data on ethnicity, sex, age, and equivalised household income (62% of all eligible person years). Analyses were conducted on aggregated data for the 240 strata formed by cross-classifying ethnicity (4 groups) by sex (dichotomous) by age (5 groups) by income (tertiles) by natality (New Zealand-born versus overseas-born).

The ethnicity variable was classified using a “total count” definition.<sup>6,p13</sup> For example, all of the following people would be categorised as Niuean: self-identified Niuean only; self-identified Niuean and Samoan; self-identified Niuean and New Zealand European; and self identified Niuean and Māori. Based on these examples, using the total count method, the Niuean and Samoan person would be

counted in both Niuean and Samoan groups in this paper. (The contribution of Pacific self-identification to health status of European and Māori responses are not directly addressed in the paper.)

For the HB modelling, five age-groups were used: 0–14 years, 15–34 years, 35–44 years, 45–64 years, and 65–74 years, centred at the 35–44 age group, and scaled so that each unit increase in scaled age corresponded to an actual increase of 10 years. Thus, the above age ranges are represented by their end-points which, after centring and scaling become elements from the set  $\{-3, -1, 0, 2, 3\}$ . To allow for the non-linear increase in mortality with age, a linear spline for age with knots at the 35–44 and 45–64 age groups was included in the prior mean [equation (3), below].

We used equivalised household income, categorised into tertiles within strata of sex and age-group, and based on income for the New Zealand Pacific population. Income ranks were median centred and scaled (divided by 10). Thus, income ranks (coded as 1, 2, 3) are transformed to  $(-0.1, 0, 0.1)$  and the income effect was assumed to be log linear.

**Hierarchical Bayesian Poisson regression**—We largely follow the HB methods used previously in the NZCMS by Young et al (2006).<sup>4</sup> In brief, the method was as follows. Assuming death is a Poisson process such that for Pacific ethnicity  $j (= 1, \dots, 4)$  and stratum  $i (= 1, \dots, 60)$  with deaths  $d_{ij}$ , mortality rate  $\lambda_{ij}$ , and person-years at risk  $P_{ij}$ , and using the notation  $x \sim D[a, b]$  to represent a random variable  $x$  distributed as  $D$  with mean  $a$  and variance  $b$ , a three-level Poisson model was defined by:

$$d_{ij} | \lambda_{ij}, P_{ij} \sim \text{Poisson} [\lambda_{ij} P_{ij}, \lambda_{ij} P_{ij}], \quad (1)$$

$$\lambda_{ij} | X_i, \beta_j, \zeta \sim \text{gamma}[\mu_{ij}, \mu_{ij} / \zeta^2], \quad (2)$$

$$\log(\mu_{ij}) = X_i \beta_j, \quad (3)$$

$$\beta_j, \zeta \sim \pi. \quad (4)$$

The mortality rate  $\lambda_{ij}$  had a gamma distribution with mean  $\mu_{ij}$  and variance  $\mu_{ij}/\zeta^2$ , and the prior mean  $\mu_{ij}$  had a structure that depended on covariates  $X_i$  and parameters  $\beta_j$  through a log-link function. Second-level parameters,  $\beta_j$  (the regression “hyper-parameters”) and  $\zeta$  (the mortality rate variance or “shape” hyper-parameter) were assigned independent prior distributions (“hyper-priors”) at the third level of the hierarchy.

Extending the Young *et al* (2006) model to allow for variation by Pacific ethnicity, the regression hyper-parameter vector was partitioned as  $\beta_j = (\beta_{0j}, \beta_{sex}, \beta_{age}, \dots)$  to allow the intercepts ( $\beta_{0j}$ ) to vary by Pacific ethnicity. A standard approach was adopted for  $\beta_j$ , with uniform prior distributions for each component.

The prior covariate structure influences the mean of the posterior rate, but the degree of influence depends on the overall support for the prior covariate structure in the data, as well as on how much local information is available. Given the structure of the model defined by equations (1) and (2), the conditional posterior distribution for the mortality rate is also gamma with mean

$$E[\lambda_{ij} | y, \beta_j, \zeta] = B_{ij} \mu_{ij} + (1 - B_{ij}) y_{ij}, \quad (5)$$

where  $y_{ij} = d_{ij} / P_{ij}$  is the observed mortality rate in the  $i$ th stratum of the  $j$ th ethnicity,

$y = (y_1, y_2, \dots)$  and

$$B_{ij} = \zeta / (\zeta + \mu_{ij} P_{ij}). \quad (6)$$

Thus, the conditional mean for  $\lambda_{ij}$  is a weighted average of the prior mean  $\mu_{ij}$  and the observed mortality rate ( $y_{ij}$ ). The  $B_{ij}$ , which lie between zero and one, are known as shrinkages because larger values shrink the conditional posterior mean mortality rates towards the prior mean. The gamma shape parameter  $\zeta$  provides a measure of the influence of the prior mean. The relatively uninformative uniform shrinkage prior of Christiansen and Morris (1997) was adopted for  $\zeta$ .<sup>7,8</sup>

A priori, following previous NZCMS work<sup>1,4</sup>, we expected interaction of age and income, and sex and income as predictors of the mortality rate. Thus the components of the regression hyper-parameters in equation (3) for the most complex prior model were

$$\beta_j = (\beta_{0j}, \beta_{sex}, \beta_{age}, \beta_{CoB}, \beta_{inc}, \beta_{age \times inc}, \beta_{sex \times inc}). \quad (7)$$

To allow comparison across the four ethnic groups, posterior mortality rates were directly standardised to the total Pacific population distribution using three combinations of sex, age, income and natality (country of birth; CoB). The first model (model 1) computed posterior mortality rates for each age, sex, ethnicity stratum using underlying data stratified by the same variables. Standardisation was by sex and age. Model 2 computed posterior rates for each age, sex, natality, and ethnicity stratum, using underlying data stratified by the same variables, and standardised by sex, age, and natality. Model 3 (the “full” model) added income as well.

All analyses and plots were done using the R environment (<http://www.r-project.org>) for statistical computation v2.2.0 available from the Comprehensive R archive Network (CRAN) website (<http://cran.r-project.org>) or SAS v8.2 (SAS Institute Inc., Cary, North Carolina). All HB analyses used WinBugs 1.4, available from (<http://www.mrc-bsu.cam.ac.uk/bugs/winbugs/contents.shtml>), and the R2WinBUGS package version 2.0-4.

**Sensitivity analyses**—We examined the likely impact of two possible biases: return migration and census under-enumeration. Methods were straightforward and are best described along with the results are presented below.

## Results

Posterior mortality rates standardised for sex and age (model 1), plus natality (model 2) plus income (model 3), are shown in Table 2. The relative positions of the four ethnic groups did not alter greatly with this sequential posterior standardisation process. For the final fully standardised model, all-cause mortality rate ratios compared to Samoan were: 1.21 (95% credible interval 1.05 to 1.42) for Cook Island Māori; 0.93 (0.77 to 1.10) for Tongan; and 1.07 (0.88 to 1.29) for Niuean.

**Table 2. Posterior all-cause mortality rates (per 100,000) and rate ratios (95% credibility intervals) by Pacific groups from models extended to include natality and household income**

Rates				Rate ratios c.f. Samoan		
Group	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
Cook Island	288 (255–325)	295 (260–333)	294 (260–332)	1.18 (1.02,1.37)	1.22 (1.05–1.41)	1.21 (1.05–1.42)
Niuean	252 (208–297)	257 (211–306)	260 (215–308)	1.03 (0.84–1.24)	1.06 (0.86–1.28)	1.07 (0.88–1.29)
Samoan	244 (224–266)	243 (222–264)	243 (222–265)	1	1	1
Tongan	234 (197–269)	228 (193–264)	226 (190–262)	0.96 (0.80–1.12)	0.94 (0.79–1.11)	0.93 (0.77–1.10)

Model 1 = data stratified by ethnic group, sex and age only; sex and age included as independent variables in prior model; posterior rates directly standardised to the NZ Pacific population using a total definition of ethnicity; Model 2 = model 1, but extended to be additionally stratified by natality; additionally including natality as independent variable; posterior rates standardised as for model 1; Model 3 = model 2, but extended similarly for household income.

**Table 3. Posterior all-cause and cause-specific mortality rates (per 100 000) and rate ratios (95% credibility intervals) by Pacific groups for the fully adjusted model 3**

Group	All-cause	CVD	Cancer	Injury/Suicide	All-cause	CVD	Cancer	Injury/Suicide
Cook Island	294 (260–332)	111 (90, 135)	64 (50–80)	31 (21–42)	1.21 (1.05–1.42)	1.66 (1.26–2.13)	0.85 (0.56–1.09)	0.93 (0.60–1.34)
Niuean	260 (215–308)	75 (51–104)	66 (44–88)	18 (6.0–32)	1.07 (0.88–1.29)	1.11 (0.72–1.58)	0.87 (0.54–1.19)	0.53 (0.17–0.99)
Samoan	243 (222–265)	68 (57–79)	76 (65–89)	33 (26–42)	1	1	1	1
Tongan	226 (190–262)	58 (40–78)	73 (56–94)	27 (16–41)	0.93 (0.77–1.10)	0.86 (0.58–1.20)	0.96 (0.71–1.26)	0.82 (0.46–1.28)

HB models used data stratified by sex, age, country-of-birth, and income. Standardisation was to the total Pacific population using a total definition of ethnicity.

**Figure 1. Posterior all-cause and cause-specific mortality rates (per 100,000; 95 % credible intervals) by Pacific groups for the fully adjusted model (model 3)**

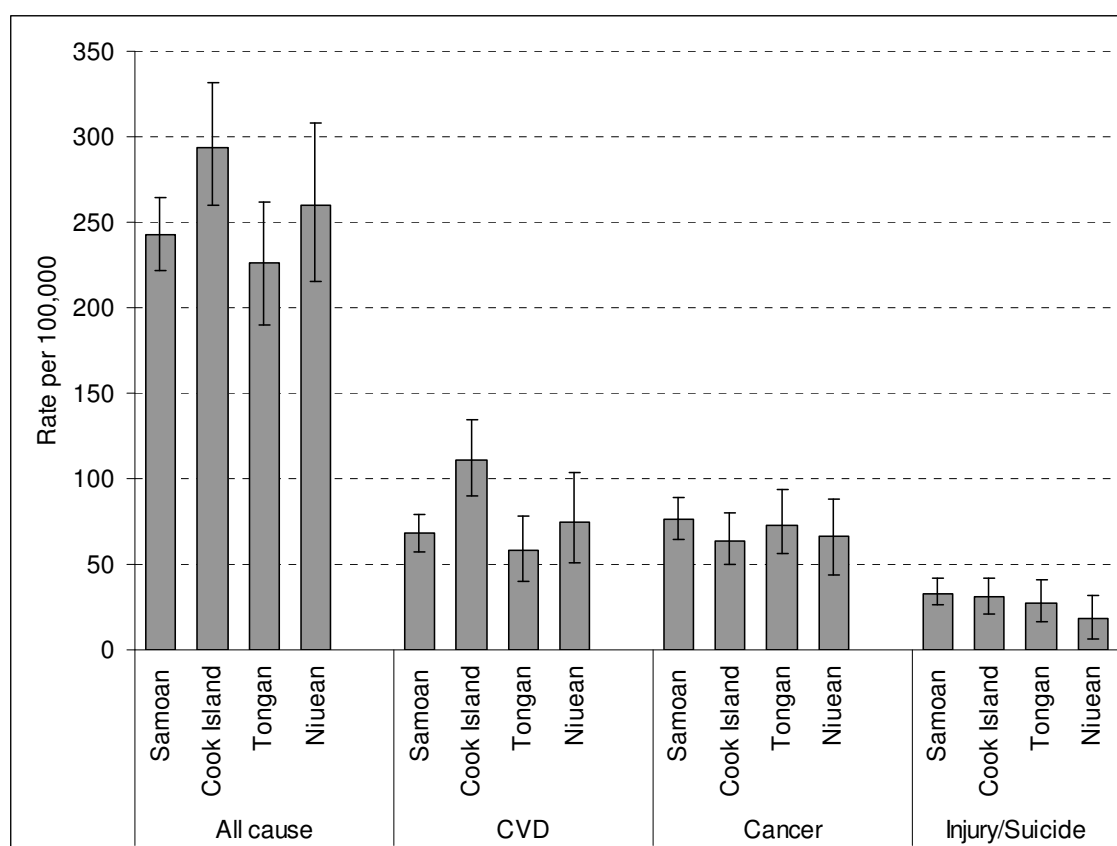


Table 3 and Figure 1 show the all-cause and cause-specific mortality rates and rate ratios for the fully adjusted model. Cardiovascular disease (CVD) mortality rate ratios, compared to Samoan, were: 1.66 (1.26 to 2.13) for Cook Island Māori; 1.11 (0.72 to 1.58) for Niuean; and 0.86 (0.58 to 1.20) for Tongan. That is, CVD mortality was nearly twice as high among Cook Island Māori compared to Tongan.

Moderating these strong CVD differences were weaker (and perhaps opposing) non-statistically significant differences in cancer. For injury/suicide mortality combined, Niuean people had a rate ratio of 0.53 (0.17 to 0.99) compared to Samoan people. Injury/suicide mortality rates for Samoan, Cook Island Māori, and Tongan groups were similar.

Checks of posterior predictive distributions of mortality rates against empirical estimates produced no evidence of model lack-of-fit.

**Sensitivity analyses: return migration and census under-enumeration—**The results of basic sensitivity analyses about the sex and age-adjusted (only) HB mortality rates for 0–74 year olds are shown in Table 4. The sensitivity analyses are crude. For example, input parameters (e.g. percentage returning to Pacific country) are applied to overall rates, not by strata of sex, age and so on. We consider return



migration and census under-enumeration in this paper, but other possible systematic biases are considered elsewhere.<sup>9</sup>

Return migration might occur when people are unwell, and they decide to return to their home country (country of birth, one would assume) to die. We set 8% as the best estimate of underestimation of Pacific deaths due to return migration, and 4% and 12% as low and high scenarios (see elsewhere for justification<sup>9</sup>). When such bias is the same for all four Pacific ethnic groups, the rates vary but rate ratios do not (Table 5), meaning no bias in the rate ratios estimated in this project. However, would return migration when terminally ill be the same for the four Pacific groups in this project? We view return migration as more likely among Tongan and Samoan people, because: there are still substantial Samoan and Tongan populations (and health care facilities) in the home Island to act as 'pull factors' for return migration; and lower proportions of Samoan and Tongan people are born in New Zealand, probably predicting greater return migration for these groups when terminally ill.

Scenario A (10% of terminally ill Samoan and Tongan people returning home to die, and 5% of Niuean and Cook Island Māori returning home to die when terminally ill) is our best estimate of such differential bias. For all cause-mortality, this would reduce the Cook Island: Samoan excess rate ratio by about a quarter from 1.21 to 1.15, but would only reduce the CVD rate ratio by about 13% from 1.63 to 1.55. The two remaining differential return migration scenarios (B = 12% Samoan and 3% Cook Island Māori; C = 25% Samoan; 0% Cook Island Māori) are both in our view unlikely, if not implausible. Thus we conclude differential return migrant bias is an unlikely cause of differences between Pacific-specific ethnic groups in CVD mortality.

Census under-enumeration of Pacific people is likely, and we selected a 4% undercount as an overall estimate, and 2% and 6% as low and high scenarios about this estimated census undercount (see elsewhere for justification<sup>9</sup>). With respect to the calculation of mortality rates, these percentages cause an overestimate of the mortality rate.

Pacific mortality rates adjusted for such overestimation, when nondifferential across the four Pacific groups, have no impact on the rate ratios compared to Samoan (Table 5)—just the rates themselves. Is it plausible that census undercounting might vary between the four Pacific groups, and hence overestimation of mortality rates might vary by Pacific group? As Niuean and Cook Island Māori have automatic New Zealand citizenship, there might be less willingness among Samoan and Tongan population to be enumerated due to the history of action against 'over-stayers'.

We posited a 2% census undercount for Niuean and Cook Island Māori, and 6% for Samoan and Tongan people. However, this only serves to widen the mortality gap between Cook Island Māori and Samoan people (Table 4). Therefore, we conclude that differential census under enumeration across the four Pacific groups in our study is very unlikely (if not impossible) to cause the observed differences between mortality rates for Pacific-specific ethnic groups.



**Table 4. Sensitivity analyses about hierarchical Bayesian (HB) all-cause and cardiovascular disease (CVD) mortality rates for scenarios of; return migration when terminally ill; census undercounting**

		Rates				Rate ratios			
		Cook	Niuean	Samoan	Tongan	Cook	Niuean	Samoan	Tongan
<b>HB all-cause rate and rate ratios</b>		294	260	243	226	1.21	1.07	1	0.93
<i>Amount of return migration for terminally ill</i>									
Non-differential	Best estimate = 8%	320	283	264	246	1.21	1.07	1	0.93
	Low scenario = 4%	306	271	253	235	1.21	1.07	1	0.93
	High scenario 12%	334	295	276	257	1.21	1.07	1	0.93
Differential, about best estimate of 8% as average	A. 10% Samoan and Tongan; 5% Niuean and Cook	309	274	270	251	1.15	1.01	1	0.93
	B. 12% Samoan; 3% Cook	303		276		1.10		1	
	C. 25% Samoan; 0% Cook	294		324		0.91		1	
<i>Amount of census undercount</i>									
Non-differential	Best estimate = 4%	282	250	233	217	1.21	1.07	1	0.93
	Low scenario = 2%	288	255	238	221	1.21	1.07	1	0.93
	High scenario = 6%	276	244	228	212	1.21	1.07	1	0.93
Differential, about best estimate of 4% as average	6% Samoan and Tongan; 2% Niuean and Cook	288	255	228	212	1.26	1.12	1	0.93
<b>HB CVD rate and rate ratios †</b>		111	75	68	58	1.63	1.10	1	0.85
<i>Amount of return migration for terminally ill</i>									
Non-differential	Best estimate = 8%	121	82	74	63	1.63	1.10	1	0.85
	Low scenario = 4%	116	78	71	60	1.63	1.10	1	0.85

	High scenario 12%	126	85	77	66	1.63	1.10	1	0.85
Differential, about best estimate of 8% as average	A. 10% Samoan and Tongan; 5% Niuean and Cook	117	79	76	64	1.55	1.04	1	0.85
	B. 12% Samoan; 3% Cook	114		77		1.48		1	
	C. 25% Samoan; 0% Cook	111		91		1.22		1	
<i>Amount of census undercount</i>									
Non-differential	Best estimate = 4%	107	72	65	56	1.63	1.10	1	0.85
	Low scenario = 2%	109	74	67	57	1.63	1.10	1	0.85
	High scenario = 6%	104	71	64	55	1.63	1.10	1	0.85
Differential, about best estimate of 4% as average	6% Samoan and Tongan; 2% Niuean and Cook	109	74	64	55	1.70	1.15	1	0.85

† Note that the CVD rate ratios are not identical to those in Table 4 due to use of integer values for the rates as the starting point for sensitivity analyses. E.g. for Cook Island Maori the rate ratio in Table 4 is 1.66; nevertheless  $111/68 = 1.63$  for purposes of Table 5.

## Discussion

To our knowledge, this project is the first in New Zealand to show clear (and marked in the case of CVD) differences in mortality have been demonstrated between Pacific ethnic groups. This finding is important for further health research and policy. At present, policy approaches to Pacific health disparities often assume that they are the same across ethnic subgroups.

Our results demonstrate that this is not the case. There is parallel emerging evidence from the New Zealand Ministry of Health and University of Auckland on differences between Pacific groups in youth health status (work in progress) and some indicators relating to adult health status (Health and Disability Intelligence, Ministry of Health, work in progress), as well as published evidence of diversity among Pacific ethnic groups for mental health.<sup>10</sup>

We have also demonstrated the added value of using hierarchical Bayesian methods for sparse data problems. We anticipate that the use of such methods will accelerate in the future both within New Zealand and internationally, for a range of research questions including the monitoring and understanding of the health of ethnic minorities.

We present quantitative sensitivity analyses in this paper about return migration to the Pacific when terminally ill, as well as census under enumeration of Pacific people, and conclude that neither bias could plausibly give rise to the observed variations in mortality—especially the elevated CVD mortality among Cook Island Māori.

Migration to New Zealand due to ill health should also not alter the findings in this paper, as we had data on usual residency on the 2001 census cohort and years in New Zealand on the mortality data that (assuming reasonable data accuracy) allowed us to exclude non-residents and ineligible deaths. We have also conducted basic comparative analyses on the 1996-99 NZCMS cohort<sup>9</sup>; Cook Island Māori also had an elevated CVD mortality rate in this period.

Explanations for the elevated CVD mortality risk of Cook Island Māori relative to the other Pacific ethnic groups include: (1) lesser degrees or greater waning of health-selective migration, and (2) greater degree of uptake of adverse risk factors (as evidenced, for example, by their higher smoking prevalence). Against these hypotheses is that inclusion of natality in our models had little effect.

In summary, Cook Island Māori have notably elevated CVD mortality compared to Samoan, Tongan and Niuean ethnic groups, and Niueans have lower injury and suicide mortality. No obvious explanation for these differing mortality risks is evident from our analysis. Researchers should, if at all possible, try to analyse and interpret results separately for specific ethnic groups within the Pacific grouping. This additional analysis should not only aim to explain the causes and contexts of these differences but also should assist in the development of policies that overcome these within-Pacific group disparities.

Policymakers and their advisors need to be aware of differences in health status and risks between Pacific ethnic groups, and consider Pacific ethnic group-specific policies and programmes where relevant, alongside pan-Pacific approaches.

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**Acknowledgements:** We acknowledge the expert advice of Patrick Graham and June Atkinson on statistical and data issues, respectively. Rachel Foster provided assistance with final editing of the paper. This study was funded as part of the Official Statistics Research programme. The New Zealand Census-Mortality Study (NZCMS) was initially funded by the Health Research Council of New Zealand, and receives ongoing funding from the Ministry of Health. Access to the NZCMS data used in this study was provided by Statistics New Zealand under conditions designed to give effect to the security and confidentiality provisions of the Statistics Act 1975.

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