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Diversity of epidemiological transition in the Pacific: Findings from the application of verbal autopsy in Papua New Guinea and the Solomon Islands

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ABSTRACT

Background: Cause of death data are essential for rational health planning yet are not routinely available in Papua New Guinea (PNG) and Solomon Islands. Indirect estimation of cause of death patterns suggests these populations are epidemiologically similar, but such assessments are not based on direct evidence.

Methods: Verbal autopsy (VA) interviews were conducted at three sites in PNG and nationwide in Solomon Islands. Training courses were also facilitated to improve data from medical certificates of cause of death (MCCODs) in both countries. Data were categorised into broad groups of endemic and emerging conditions to aid assessment of the epidemiological transition.

Findings: Between 2017 and 2020, VAs were collected for 1,814 adult deaths in PNG and 819 adult deaths in Solomon Islands. MCCODs were analysed for 662 deaths in PNG and 1,408 deaths in Solomon Islands. The VA data suggest lower NCD mortality (48.8% versus 70.3%); higher infectious mortality (27.0% versus 18.3%) and higher injury mortality (24.5% versus 11.4%) in PNG compared to Solomon Islands. Higher infectious mortality in PNG was evident for both endemic and emerging infections. Higher NCD mortality in Solomon Islands reflected much higher emerging NCDs (43.6% vs 21.4% in PNG). A similar pattern was evident from the MCCOD data.

Interpretation: The cause of death patterns suggested by VA and MCCOD indicate that PNG is earlier in its epidemiological transition than Solomon Islands, with relatively higher infectious mortality and lower NCD mortality. Injury mortality was also particularly high in PNG.

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Introduction

In both Papua New Guinea (PNG) and the Solomon Islands, the cause of death data that are essential for an effective and re-

sponsive health system are not available. The population in both countries is predominantly rural with limited access to health-care. Cause of death data are not collected for the vast majority of deaths that occur outside of health facilities and the information that is available is not systematically compiled, analysed and made available to health decision makers in a timely manner. Mortality data that are available have, until recently, only reflected cause of

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death patterns for the minority of deaths that occur in health facilities, and these have mainly come from medical discharge forms as opposed to completion of official medical certificates of cause of death (MCCODs).

Until recently, the fact and cause of deaths occurring outside of health facilities in PNG and Solomon Islands were almost entirely unrecorded. In such remote areas, verbal autopsy (VA) is a method being used increasingly to improve understanding of causes of death. [1] Briefly, VA is a method for assessing causes of deaths using a structured interview with a relative of the deceased who was present during the final illness. The questionnaire includes questions on relevant, easily-observable signs and symptoms experienced by the deceased and automated computer algorithms are now commonly used to diagnose the most probable cause of death based on these responses. [2]

The Solomon Islands share a maritime boundary with the PNG island of Bougainville thus forming an archipelago extending south-east from the PNG outer islands. PNG and the Solomon Islands are both Melanesian countries. There are marked cultural and environmental similarities between the Solomon Islands and the PNG outer islands of New Britain, New Ireland, and Bougainville. However, distinct differences in health and mortality patterns have been reported previously. [3,4] A better understanding of similarities and differences in mortality patterns between PNG and Solomon Islands may help to inform health development strategies in these two countries, based on local, direct evidence about disease and injury patterns.

Since 2016, we have supported the governments of Solomon Islands and PNG with the implementation of interventions to improve mortality data, including the introduction of VA methods and training medical practitioners on completion of MCCODs. [5,6] In this paper, we examine the key differences in causes of death between these two countries at similar levels of development, using VA data for community deaths, and MCCOD data for facility deaths. Improved understanding of the diversity between these Pacific neighbours may contribute to a more reliable delineation of key health challenges in the region than is available from modelled estimates such as the Global Burden of Disease (GBD) Study. [7]

Methods

Papua New Guinea

In PNG, about 25% of deaths occur in health facilities, and the remainder occur in the community without any information on cause of death. [8] In collaboration with the government, training strategies to improve MCCOD data commenced in 2017 in targeted mortality surveillance sites: the districts of Alotau in Milne Bay Province, Tambul Nebilyer in Western Highlands Province, Talasea in West New Britain Province, and National Capital District (NCD). MCCOD training was of one day duration and included the importance of mortality data as well as the process of completing the form correctly to facilitate coding of the correct underlying cause of death. Implementation of VA activities commenced in the mortality surveillance sites in 2018, excluding the mainly urban NCD site. The sites were chosen to represent some of PNG's extreme cultural and geographical heterogeneity, encompassing the Highlands Region, Southern Region and Islands Region.

Notification of community deaths, the prerequisite for obtaining cause of death data through VA, is a particular challenge in rural areas of both Solomon Islands and PNG, and we have supported pilot strategies using different notification agents and data systems. [9,10] The notification systems trialled in PNG required the notification agent, usually a ward recorder or village health volunteer, to inform the nearest health centre of deaths in their designated

area, using paper forms or electronic methods. Receipt of death notifications at the health centre was the trigger for health workers to organise community visits during which they would validate the notification data and enter it in a tablet computer, as well as conduct the VA interviews. VAs were conducted for community deaths only. Health workers used Android devices to perform the interviews and data were uploaded over mobile telecommunication networks or health centre wi-fi connections to a central server accessed at the National Department of Health.

MCCODs were collected from four hospitals: Alotau Hospital (Milne Bay Province); Kimbe Hospital (West New Britain Province); Mt Hagen Hospital (Western Highlands Province); and Port Moresby General Hospital (NCD) in 2017 and 2018, following training of doctors on MCCOD completion. Doctors are generally not located outside of the main provincial hospitals and few MCCODs would be completed in the health centres.

Solomon Islands

In Solomon Islands, the automated VA methodology was introduced in 2016 and implemented in all ten of the country's administrative provinces by 2018. Inclusion of those health-facility related deaths that did not undergo MCCOD (e.g. dead-on-arrival cases) in the VA data collection, is a notable difference between the Solomon Islands and PNG VA methodology. However, VA interviews for facility-related deaths were excluded for this analysis in order to compare community deaths between the countries.

Once information about a death was received at a local health facility, VA interviews were conducted at the facility or during outreach visits by trained nursing officers from hospitals and Area Health Centres using Android devices. While some could directly upload the VA data into the database, due to limited internet connectivity, data in the tablets were often copied onto a storage device by supervisory staff during field visits and uploaded to the database. Additionally, supervisory staff themselves conduct VA interviews during these field visits.

MCCOD data for this study were collected between 2016 and 2019 following MCCOD training at the National Referral Hospital (NRH) in Honiara, which is the largest hospital in the country and accounts for more than 90% of annual hospital deaths.

Data analysis

Completeness of death notification was calculated for each mortality surveillance district in PNG using the estimated district populations (projecting the 2011 census data to the data collection mid-point using the district population growth rate between the 2000 and 2011 censuses) and crude death rates (CDRs) derived from provincial mortality estimates (Milne Bay CDR = 7.2/1000; Western Highlands CDR = 5.3/1000; West New Britain CDR = 6.2/1000). Deaths occurring between January 2018 and September 2019 (i.e. 21 months) were included for completeness calculations as VAs were conducted retrospectively for any deaths that occurred during this period. [8,11] Completeness of death notification was calculated in Solomon Islands using the estimated adult mortality rate for 2018, covering the mid-point of VA data collection. [12]

In both countries, VA interviews were conducted using the PHMRC shortened questionnaire and analysed using the SmartVA Tariff 2.0 algorithm. [2,13] When the symptom pattern from a VA interview was not sufficiently clear for the algorithm to predict a cause of death (known as "undetermined"), reallocation to other specified VA causes was done at the population level in two ways. Firstly, each VA with an undetermined COD was proportionally redistributed to all VA causes, based on the likelihood of each cause being "undetermined" from the gold standard database used to

Table 1
Age distribution of verbal autopsies collected by site in Papua New Guinea and Solomon Islands.

Age Category*	Papua New Guinea				Solomon Islands n (%)
	Alotau n (%)	Talasea n (%)	Tambul-Nebilyer n (%)	PNG Total n (%)	
Adult and adolescent (12+ years)	598 (86.8)	530 (87.9)	686 (87.6)	1,814 (87.4)	819 (92.1)
12-19 years	23 (3.9)	16 (3.0)	37 (5.6)	76 (4.3)	24 (3.1)
20-29 years	61 (10.3)	56 (10.6)	112 (16.8)	229 (12.8)	40 (5.2)
30-39 years	49 (8.3)	59 (11.1)	102 (15.3)	210 (11.8)	60 (7.9)
40-49 years	57 (9.6)	54 (10.2)	111 (16.7)	222 (12.4)	81 (10.5)
50-59 years	89 (15.1)	75 (14.2)	105 (15.8)	269 (15.1)	118 (15.2)
60-69 years	112 (19.0)	125 (23.6)	137 (20.6)	374 (20.9)	135 (17.4)
70-79 years	98 (16.6)	92 (17.4)	56 (8.4)	246 (13.8)	156 (20.1)
80-89 years	77 (13.0)	46 (8.7)	6 (0.9)	129 (7.2)	113 (14.6)
90+ years	25 (4.2)	7 (1.3)	0 (0.0)	32 (1.8)	47 (6.1)
Child (1 month – 11 years)	46 (6.7)	45 (7.5)	68 (8.7)	159 (7.7)	62 (7.0)
Neonate (<28 days)	45 (6.5)	28 (4.6)	29 (3.7)	102 (4.9)	8 (0.9)
Total	689 (100)	603 (100)	783 (100)	2,075 (100)	889 (100)

* Age was not recorded for 27 adults in PNG (7 in Alotau, 0 in Talasea, and 20 in Tambul-Nebilyer) and for 44 adults in Solomon Islands

produce the algorithm. [2,14] Some conditions, such as pneumonia, for example, are inherently more difficult to diagnose using VA methods than specific injuries. Secondly, this proportional redistribution was weighted according to the estimated age-sex cause of death distribution for the country, based on GBD models of the relationship of causes of death with various covariates.

The VA interview consists of age-specific modules for neonates, children and adults. Analyses presented here focus on adult and adolescent deaths (12 years of age and older) due to relatively low numbers of child deaths being recorded during the period of data collection, many of which would have occurred in hospital. For comparison, MCCOD causes were mapped to the SmartVA cause list. For the main analyses, we have classified VA and MCCOD data into five broad causes to assist in assessing the epidemiological transition (Supplementary tables 1 and 2). [15] The categorisation groups conditions that are expected to be endemic in communities and those that may emerge and increase in prominence with the epidemiological transition. Endemic infections, such as malaria and pneumonia, and emerging infections, such as tuberculosis and HIV/AIDS, correspond to GBD Group I (communicable, maternal, nutritional and neonatal diseases). [7] Endemic non-communicable diseases (NCDs), such as chronic respiratory disease and most cancers, and emerging NCDs, such as diabetes and ischaemic heart disease, correspond to GBD Group II. Injuries correspond to GBD Group III.

In addition to the proportion of deaths at each site by the five broad cause categories, cause specific mortality rates were estimated for the two countries using VA cause-specific mortality fractions and CDRs for ages 12 and above. [8,12] Leading specific causes of death are also presented; although there is less certainty around these estimates, they are useful to inform discussion and interpretation of the broad cause patterns.

Results

Death notification completeness was estimated at the intervention sites in PNG to be 37% in Alotau, 20% in Talasea, and 69% in Tambul-Nebilyer; and in Solomon Islands, 57%. The PNG sample included 2,075 VAs collected from the three selected sites of Alotou, Talasea and Tambul-Nebilyer. A single nationwide sample of 889 VAs was used for the Solomon Islands. At all sites, more than 85% of VAs were conducted for adult and adolescent deaths, including 1,814 VAs in PNG, and 819 in Solomon Islands (Table 1). The median age for the sample of adult and adolescent deaths was higher in Solomon Islands (63 years) than PNG (55 years), shown in Table 2. A greater proportion of VAs were conducted for male

than female deaths at the study sites: 56–66% males in PNG, and 60% in Solomon Islands.

The distribution of causes of death, classified according to the categories proposed by Gouda *et al.* is shown in Table 3. Infectious mortality, including both endemic and emerging infections, was higher at all of the sites in PNG compared to Solomon Islands. NCD mortality overall was higher in the Solomon Islands, accounting for seven in ten deaths (70.3%) compared to five in ten (48.8%) in PNG. The main driver of the difference in NCD mortality was the proportions of emerging NCDs, which comprised 21.4% of deaths in PNG and more than double that (43.6%) in Solomon Islands. Injury deaths were twice as common in the PNG sample (24.5% versus 11.4% in Solomon Islands). To aid interpretation of comparative differences in mortality between the countries, estimated mortality rates per 100,000 population are available in Supplementary table 3. For example, the NCD cause specific mortality fraction was approximately 45% higher in Solomon Islands, whilst the NCD mortality rate was a little over 20% higher in Solomon Islands, reflecting lower mortality rates overall compared to PNG.

The leading VA causes of death in PNG and Solomon Islands are shown in Table 4. Chronic respiratory disease, stroke, ischaemic heart disease and pneumonia were in the top 5 causes in both countries, although with different comparative rankings, plus malaria in PNG and diabetes in Solomon Islands. Chronic respiratory disease was the leading cause in PNG (and was twice as high as in Solomon Islands); whereas ischaemic heart disease and stroke were the leading causes in Solomon Islands (and were twice as high as in PNG). Road traffic deaths were more than four-fold higher in PNG than Solomon Islands, with the highest proportion in Tambul-Nebilyer, where the major Highlands Highway is a common location for serious accidents. The full distribution of cause specific mortality fractions of the two countries are presented in Supplementary table 4. The percentage of cases for which a specific cause was not assigned before applying the redistribution algorithm was 14.2% for Solomon Islands and 7.8% for PNG.

The MCCOD cause distribution reflects similarities to the cause patterns evident between the countries in the VA data (Table 5). The proportion of NCD mortality was lower in health facilities in PNG, accounting for six in ten (60.4%) facility deaths, compared to more than seven in ten (72.3%) in Solomon Islands. This pattern was driven in particular by lower emerging NCDs in PNG, which, similar to the VA pattern, were less than half the levels in Solomon Islands (14.4% vs 32.9%). The main emerging NCDs causing health facility deaths in Solomon Islands were ischaemic heart diseases (11.4%), diabetes (11.2%) and stroke (8.7%). The leading specific causes of death in health facilities in PNG were tuberculo-

Table 2

Selected characteristics of adult and adolescent deaths in the Papua New Guinea and Solomon Islands verbal autopsy samples.

Characteristic	Papua New Guinea Alotau	Talasea	Tambul-Nebilyer	PNG Total	Solomon Islands
Age in years (median, IQR)	61 (42–74)	60 (40–71)	47 (31–61)	55 (36–68)	63 (48–77)
Male (%)	56.2	64.2	66.2	62.3	60.3
Duration of data collection	Jun 2018 to Dec 2020	Sep 2018 to Dec 2020	Sep 2018 to Dec 2020	Jun 2018 to Dec 2020	Jan 2017 to Dec 2020

Table 3

Cause specific mortality fractions for adult and adolescent deaths from verbal autopsy by 5 broad cause categories and site in Papua New Guinea and Solomon Islands.

Cause classification	Papua New Guinea				Solomon Islands
	Alotau	Talasea	Tambul-Nebilyer	Total	
	%	%	%	%	
Endemic Infections	17.1	14.4	23.3	18.7	12.9
Emerging Infections	6.9	14.8	4.3	8.3	5.4
<i>All infections</i>	<i>24.0</i>	<i>29.2</i>	<i>27.6</i>	<i>27.0</i>	<i>18.3</i>
Endemic NCDs	37.2	37.8	10.6	27.4	26.7
Emerging NCDs	18.7	19.9	25.1	21.4	43.6
<i>All NCDs</i>	<i>55.9</i>	<i>57.7</i>	<i>35.7</i>	<i>48.8</i>	<i>70.3</i>
<i>All Injuries</i>	<i>20.1</i>	<i>13.3</i>	<i>36.8</i>	<i>24.5</i>	<i>11.4</i>
<i>Total</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>	<i>100</i>

Table 4

Leading causes of death from verbal autopsy in adolescents and adults (12 years of age and older) in Papua New Guinea with comparison to Solomon Islands cause specific mortality fractions for these causes.

Cause (ICD-10 code)	Papua New Guinea				Solomon Islands	
	Alotau (Milne Bay)	Talasea (West New Britain)	Tambul-Nebilyer (Western Highlands)	Total		
	%	%	%	%	%	%
Chronic Respiratory (J40-J46)	20	12.5	3.8	11.7		6.0
Malaria (B50-B54)	4.5	3.2	15.8	8.4		2.7
Stroke (I60-I69)	4.5	5.0	14.0	8.2		16.1
Ischaemic Heart Disease (I20-I25)	7.1	5.4	10.8	8.0		17.1
Pneumonia (J10-J22, J85)	7.0	5.2	6.0	6.1		6.3
Tuberculosis (A15-19)	4.4	11.1	1.5	5.3		1.6
Other NCDs ^{>}	5.0	11.9	0.3	5.2		4.3
Diabetes (E10-E14)	6.1	9.3	0.3	4.8		9.3
Road Traffic (V01-V89)	0.7	3.6	9.0	4.7		0.9
Other Injuries ^{>}	4.3	1.3	6.3	4.2		3.4
Total	63.6	68.5	67.8	66.6		67.7

[>] ICD codes available in Supplementary table 2.**Table 5**

Causes of death in health facilities based on medical certification of cause of death, 5 broad cause categories, Papua New Guinea (Western Highlands, Milne Bay, West New Britain and National Capital District) and Solomon Islands, 2017–2020.

Cause classification	Papua New Guinea n (%)	Solomon Islands n (%)
Endemic Infections	71 (10.7)	256 (18.2)
Emerging Infections	122 (18.4)	45 (3.2)
All infections	193 (29.2)	301 (21.4)
Endemic NCDs	305 (46.1)	464 (39.4)
Emerging NCDs	95 (14.4)	554 (32.9)
All NCDs	400 (60.4)	1018 (72.3)
All Injuries	42 (6.3)	54 (3.8)
Undetermined	27 (4.1)	35 (2.5)
Total	662 (100)	1408 (100)

P codes and Q codes were excluded.

sis (12.8%), chronic respiratory disease (7.9%), stroke (5.0%) and diabetes (4.7%). Full MCCOD cause distributions are available in Supplementary table 5. The percentage of injury deaths was considerably lower in facilities (6.3% and 3.8% in PNG and Solomon Islands, respectively) than was evident for community deaths from VA.

Discussion

This paper reports the first comparison of cause of death patterns in both the community and health facilities between

Solomon Islands and PNG, based on comparable data collection and synthesis methods. A total of 1,814 adult and adolescent community deaths were followed up with VA at three sites in PNG and compared to 819 VAs completed in Solomon Islands. The most striking finding is the higher infectious mortality and lower NCD mortality in the PNG sample, suggesting PNG may be earlier in the epidemiological transition than Solomon Islands. The MCCOD data suggest similar patterns in NCD and infectious mortality in facilities in the two countries as were evident for community deaths. And further, this study suggests that cause of death distribution may be similar amongst in-facility and community deaths in both countries.

The difference in NCD mortality was driven by emerging NCD mortality being twice as high in Solomon Islands compared to PNG. Indeed, the major emerging NCDs that we use to assess the epidemiological transition – stroke, IHD and diabetes – were all in the order of two-fold higher in Solomon Islands. Chronic respiratory illness, on the other hand, was more than twice as high in the PNG sample. Chronic respiratory illness is classified as an endemic NCD, due to high levels of fibrotic lung disease in traditional populations in PNG. [16] However, a major driver of chronic respiratory illness is now likely to be smoking habits. Smoking has increased in recent decades in cities and coastal areas of PNG and chronic respiratory illness has been a leading cause of death in previous VA studies in PNG dating back to the 1970s. [15] Smoking prevalence is estimated to be higher than 50% for males in Solomon Islands

and chronic respiratory mortality may be expected to increase in the coming years. [17]

Infectious mortality, both endemic and emerging, was higher at all the PNG sites than in the Solomon Islands. Pneumonia mortality was similar across all sites and between the two countries. Malaria mortality varied considerably by site in PNG, as would be expected for a disease that naturally exhibits significant spatial heterogeneity; overall prevalence was more than twice as high in PNG compared to Solomon Islands. Evidence from the latest malaria indicator survey in PNG suggests malaria prevalence has increased in recent years to 7.1% in the at-risk population. [18] Malaria is stable in Solomon Islands with high levels of immunity and consequently less severe disease in adults. The majority of emerging infectious mortality in PNG was due to tuberculosis, prevalence of which has increased steadily in recent years. [19] Tuberculosis and HIV/AIDS mortality vary considerably by site in PNG, much of which is believed to be related to economic activity and associated migration. Both tuberculosis and HIV mortality were very low in Solomon Islands.

PNG traditionally consisted of relatively small, mostly isolated populations, leading to highly variable presence of infectious diseases and pathogen species. Large mortality differentials are expected between different sites in the country, now reflecting even greater complexity due to variable economic development, urban expansion, access to healthcare, and transport links enabling the spread of infectious diseases and NCD risk factors. [4] The targeted sites chosen for mortality surveillance in PNG were also sites for the introduction of an electronic national health information system (eNHIS) and, although all have remote, hard-to-reach populations, the results may not reflect patterns for the whole country, especially areas with the poorest access to healthcare. Even so, the differences in mortality between the PNG islands and lowland areas, and Solomon Islands, is striking, again reflecting the huge heterogeneity in PNG and, perhaps, that both Alotau and New Britain have more isolated inland populations, which is not the case with Solomon Islands.

Injury mortality was higher at all sites in PNG than in the Solomon Islands, particularly at the Tambul-Nebilyer site, comprised of significant proportions of road traffic accidents, poisonings and other injuries. Homicide comprised more than 3% of mortality in PNG compared to 0.7% in Solomon Islands. Tribal conflict is a continuing issue in many parts of PNG and whilst VA may not be able to identify all of these deaths due to sensitivities related to reporting them, they are more likely to be identified by community visits for VA than MCCOD in health facilities. Indeed, both countries report substantially lower injury mortality in the MCCOD data compared to VA, which is expected due to death often occurring rapidly from injuries and therefore these cases often not presenting to health facilities. Prior to VA being available, it is likely that with little information available on community deaths, injury mortality was significantly underestimated.

Notification of vital events is a major challenge to completeness of VA data for community deaths in PNG and Solomon Islands. We have supported trials of several strategies to increase notification, including incentivising notification agents at the ward level to inform health centres about deaths in PNG. [10] Many of the challenges are related to extremely remote and hard-to-reach locations but the notification and VA teams endeavoured to visit and support collection of VAs from the majority of local government areas across the study sites. Whilst it would be preferable to achieve full death notification, the estimated completeness in this study, from a broad geographical area of each district, is expected to be adequate to estimate mortality fractions, particularly for broad cause groupings. The fact that the age distribution of VAs completed at the sites was not greatly dissimilar to the GBD estimates for these countries (adult, child and neonatal deaths, respec-

tively, for Solomon Islands: 86%, 8% and 6%; and PNG: 81%, 12% and 7%) is reassuring. [7] One clear difference was the lower proportion of neonatal deaths in Solomon Islands (0.9%), likely reflecting sensitivities related to the reporting of child and neonatal deaths that are usually apparent in VA programs and tend to decrease over time with increased acceptance and understanding of the intervention. Further to the potential for bias due to differences in completeness of community death notification, a difference in the proportion of deaths occurring in health facilities could also contribute to differences in CSMFs between the countries. However, in PNG, the hospital discharge records indicate that 22–28% of all deaths were recorded in health facilities; and approximately 25% in Solomon Islands. [8,20] Therefore, the proportion of deaths occurring in health facilities is not expected to be a factor in explaining CSMF differences between the two countries.

VA methodology has limitations in cause of death prediction compared to completion of MCCODs by physicians. However, in settings where MCCOD is impractical, VA is increasingly accepted as a reliable means of improving community cause of death estimates. Inevitably, some VAs have an undetermined cause of death; this may be expected to be approximately 15%, depending on the age structure of the population and clarity of symptom patterns. [6] In this study, approximately 14% of VAs were undetermined in Solomon Islands and 8% in PNG. It is likely that the greater proportion of infectious and injury mortality in PNG, with more clearly defined symptom patterns, contributed to this difference. The proportion of undetermined deaths in the MCCOD data was relatively low in this study (4.1% in PNG and 2.5% in Solomon Islands), which is likely to be partly influenced by the broad mapping to the SmartVA cause list, enabling categorisation of some poorly specified causes to “other” categories, such as “Other NCDs”.

The evidence from VA and MCCOD suggests that two neighbouring populations, with similar sociodemographic index (PNG: 0.4481; Solomon Island: 0.4614), can be at quite different stages of the epidemiological transition. [21] The data suggest PNG is experiencing a high residual endemic infectious burden as well as emerging infections, particularly tuberculosis. In addition, the health system in PNG must combat the increasing burden of NCDs and a substantial proportion of injury mortality, newly identified from VA, that is likely to have been previously underreported. In the Solomon Islands, the epidemiological transition appears to have progressed further, with substantially higher NCD mortality. This may be influenced by relative political stability in Solomon Islands, and effective control of some infectious diseases, for example there has been a more than ten-fold reduction in malaria cases between 1992 and 2015 and the government continues to prioritise tackling malaria and tuberculosis. [22] NCD risk factors also vary considerably across the Pacific region and between provinces and smaller areas within PNG, which may contribute to significant heterogeneity in the epidemiological transition. [17,23] The pattern in Solomon Islands more closely matches GBD estimates, which appear to overestimate the epidemiological transition in PNG. [7] The GBD models for PNG could be biased by the epidemiological situation in neighbouring countries due to limited local data. The GBD estimate of broadly similar COD patterns in these two neighbouring countries appears to be an oversimplification from the new data now available.

This study highlights the disparity in cause of death patterns between PNG and Solomon Islands, and how in countries with few data available, the complex GBD models may be biased towards the epidemiological situation in neighbouring countries. In particular, the epidemiological transition appears less advanced in PNG with continuing high infectious mortality, compared to a preponderance of emerging NCD mortality in Solomon Islands. This novel comparison emphasises the requirement for collection of high-quality local mortality data to understand the major health

challenges in these settings. This is especially true in PNG, due to highly heterogeneous cultural, social and economic indicators, and consequently mortality patterns, in the country.

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Research in context

Evidence before this study

Very few data are available on cause of death patterns in Papua New Guinea (PNG) and Solomon Islands. Much of the evidence currently used is derived from estimates and models, such as the Global Burden of Disease Study. Reporting of facility deaths has until recently been incomplete and not to an international standard that enables allocation of an underlying cause of death, which is essential for health policy purposes. Community deaths have been almost completely unreported in these countries, resulting in neither the fact of death nor cause of death being available for statistical purposes. Previous research studies have reported causes of community deaths using verbal autopsy (VA) in PNG but not in Solomon Islands. The VA studies in PNG have been relatively small and not part of broader government programs.

Added value of this study

This program supported the governments of Solomon Islands and PNG to implement VA methods and train physicians on medical certification of cause of death. Here, we present cause of death data from both the community and facilities in these countries. The empirical data now available suggest that current modelled estimates, such as GBD, may overestimate the epidemiological transition, particularly in PNG.

Implications of all the available evidence

This novel comparison highlights the need for high-quality local mortality data in order to understand the major health challenges in these settings. The evidence suggests this is especially true in PNG, where mortality patterns are highly heterogeneous, likely related to the country's rich diversity and variation in cultural, social and economic indicators.

Role of the funding source

The funder, Bloomberg Philanthropies, had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Author contribution

This study was designed by JDH, DM, IDR and ADL. JDH, PKBM and TA analysed the data and JDH, PKBM, VK, MR, HRC, GJ, RJ, BK, RR, PD, PR, DF, TL, IDR and ADL were involved in data interpretation. Project administration was conducted by VK, GJ, RJ, BK, RR, PD, PR, DF, TL and DM. The manuscript was written by JDH, PKBM, VK, MR and HRC; all authors approved the final version.

Declaration of Competing Interests

The authors have no conflicts of interest.

Data sharing statement

The data used in this study are available from the civil registration and vital statistics systems of Papua New Guinea and Solomon Islands. However, restrictions apply to the availability of these data,

which were used with permission for the current study. Applications for the use of the data should be made directly with the governments of Papua New Guinea and Solomon Islands.

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at [doi:10.1016/j.lanwpc.2021.100150](https://doi.org/10.1016/j.lanwpc.2021.100150).

References

- [1] de Savigny D, Riley I, Chandramohan D, et al. Integrating community-based verbal autopsy into civil registration and vital statistics (CRVS): system-level considerations. *Glob Health Action* 2017. doi:10.1080/16549716.2017.1272882.
- [2] Serina P, Riley I, Stewart A, et al. Improving performance of the Tariff method for assigning causes of death to verbal autopsies. *BMC Med* 2015. doi:10.1186/s12916-015-0527-9.
- [3] Taylor R, Bampton D, Lopez AD. Contemporary patterns of Pacific Island mortality. *Int J Epidemiol* 2005. doi:10.1093/ije/dyh337.
- [4] Riley I. *Demography and the epidemiology of disease in Papua New Guinea*. PNG Med J 2009.
- [5] Hart JD, Sorchik R, Bo KS, et al. Improving medical certification of cause of death: Effective strategies and approaches based on experiences from the data for health initiative. *BMC Med* 2020. doi:10.1186/s12916-020-01519-8.
- [6] Hazard RH, Buddhika MPK, Hart JD, et al. Automated verbal autopsy: from research to routine use in civil registration and vital statistics systems. *BMC Med* 2020;18(1):60. doi:10.1186/s12916-020-01520-1.
- [7] Roth GA, Abate D, Abate KH, et al. Global, regional, and national age-sex-specific mortality for 282 causes of death in 195 countries and territories, 1980–2017: a systematic analysis for the global burden of disease study 2017. *Lancet* 2018. doi:10.1016/S0140-6736(18)32203-7.
- [8] Kitur U, Adair T, Lopez AD. Patterns of all-cause mortality in Papua New Guinea, 2011. *Asia-Pacific J Public Heal* 2019. doi:10.1177/1010539519841492.
- [9] Adair T, Rajasekhar M, Bo KS, et al. Where there is no hospital: improving the notification of community deaths. *BMC Med* 2020;18(1):65. doi:10.1186/s12916-020-01524-x.
- [10] Hart J, Kwa V, Dakulala P, et al. Mortality surveillance and verbal autopsy strategies in Papua New Guinea: experiences, challenges and lessons learnt. *BMJ Glob Heal* 2020;5:e003747. doi:10.1136/bmjgh-2020-003747.
- [11] Papua New Guinea National Statistics Office. *National Population and Housing Census of Papua New Guinea*. 2011.
- [12] [United Nations Population Division World population prospects: the 2019 revision](https://www.un.org/en/development/desa/population/publications/). New York: United Nations; 2019.
- [13] Serina P, Riley I, Stewart A, et al. A shortened verbal autopsy instrument for use in routine mortality surveillance systems. *BMC Med* 2015. doi:10.1186/s12916-015-0528-8.
- [14] Murray CJL, Lopez AD, Black R, et al. Population health metrics research consortium gold standard verbal autopsy validation study: design, implementation, and development of analysis datasets. *Popul Health Metr* 2011. doi:10.1186/1478-7954-9-27.
- [15] Gouda HN, Hazard RH, Maraga S, et al. The epidemiological transition in Papua New Guinea: new evidence from verbal autopsy studies. *Int J Epidemiol* 2019. doi:10.1093/ije/dyz018.
- [16] Riley I, Lehmann D. The demography of Papua New Guinea: migration, fertility, and mortality patterns. In: Attenborough R, Alpers M, eds. *Human Biology in Papua New Guinea: The Small Cosmos*. Oxford University Press; 1992.
- [17] Kessaram T, McKenzie J, Girin N, et al. Noncommunicable diseases and risk factors in adult populations of several Pacific Islands: results from the WHO stepwise approach to surveillance. *Aust N Z J Public Health* 2015. doi:10.1111/1753-6405.12398.
- [18] Hetzel M, Saweri O, Kuadima J, et al. *Papua New Guinea Malaria indicator survey 2016–2017: malaria prevention*. *Infect Treat* 2018;20:27–43.

- [19] Aia P, Wangchuk L, Morishita F, et al. Epidemiology of tuberculosis in Papua New Guinea: analysis of case notification and treatment-outcome data, 2008–2016. *West Pacific Surveill response J WPSAR* 2018. doi:10.5365/wpsar.2018.9.1.006.
- [20] Jilini G, Jagilly R, Kamoriki B, et al. Generating cause of death information to inform health policy: application of automated verbal autopsy methods in the Solomon Islands. *Prep* 2021.
- [21] Global Burden of Disease Collaborative Network. Global burden of disease study 2015 (GBD 2015) socio-demographic index (SDI) 1980–2015. Seattle, United States *Inst Heal Metrics Eval* 2016.
- [22] Solomon Islands Demographic and Health Survey 2015. Prepared by Solomon Islands national statistics office, Solomon Islands ministry of health and medical services. *Pacific Community* 2017.
- [23] Rarau P, Vengiau G, Gouda H, et al. Prevalence of non-communicable disease risk factors in three sites across Papua New Guinea: a cross-sectional study. *BMJ Glob Heal* 2017. doi:10.1136/bmjgh-2016-000221.