

Prevalence of non-communicable disease risk factors in three sites across Papua New Guinea: a cross-sectional study

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To cite: 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 Health* 2017;**2**:e000221. doi:10.1136/bmjgh-2016-000221

Received 23 October 2016
Revised 21 February 2017
Accepted 13 March 2017

ABSTRACT

Papua New Guinea (PNG) is a culturally, environmentally and ethnically diverse country of 7.3 million people experiencing rapid economic development and social change. Such development is typically associated with an increase in non-communicable disease (NCD) risk factors.

Aim To establish the prevalence of NCD risk factors in three different regions across PNG in order to guide appropriate prevention and control measures.

Methods A cross-sectional survey was undertaken with randomly selected adults (15–65 years), stratified by age and sex recruited from the general population of integrated Health and Demographic Surveillance Sites in West Hiri (periurban), Asaro (rural highland) and Karkar Island (rural island), PNG. A modified WHO STEPS risk factor survey was administered along with anthropometric and biochemical measures on study participants.

Results The prevalence of NCD risk factors was markedly different across the three sites. For example, the prevalences of current alcohol consumption at 43% (95% CI 35 to 52), stress at 46% (95% CI 40 to 52), obesity at 22% (95% CI 18 to 28), hypertension at 22% (95% CI 17 to 28), elevated levels of cholesterol at 24% (95% CI 19 to 29) and haemoglobin A1c at 34% (95% CI 29 to 41) were highest in West Hiri relative to the rural areas. However, central obesity at 90% (95% CI 86 to 93) and prehypertension at 55% (95% CI 42 to 62) were most common in Asaro whereas prevalences of smoking, physical inactivity and low high-density lipoprotein-cholesterol levels at 52% (95% CI 45 to 59), 34% (95% CI 26 to 42) and 62% (95% CI 56 to 68), respectively, were highest in Karkar Island.

Conclusion Adult residents in the three different communities are at high risk of developing NCDs, especially the West Hiri periurban population. There is an urgent need for appropriate multisectoral preventive interventions and improved health services. Improved monitoring and control of NCD risk factors is also needed in all regions across PNG.

INTRODUCTION

Non-communicable diseases (NCDs) are the leading cause of death and morbidity

Key questions

What is already known about this topic?

- ▶ The prevalence of non-communicable diseases (NCDs) and their risk factors in Papua New Guinea is increasing but varied based on ethnicity, lifestyle and the living environment.
- ▶ Current prevalence of NCD and their risk factors is unknown in West Hiri, a community impacted by a gas mining project and two rural non-project impact areas, Asaro and Karkar Island.

What are the new findings?

- ▶ Our study provided a baseline prevalence of NCD risk factors in West Hiri and an up-to-date prevalence of NCD risk factors in Asaro and Karkar Island.
- ▶ Results suggest that socioeconomic and nutrition transition may be under way in all sites but more apparent in the West Hiri population.

Recommendations for policy

- ▶ The results strongly suggest an introduction of control measures particularly in West Hiri and continuous monitoring across the country.

throughout the world, with the greatest burden in low and middle-income countries (LMICs), where nearly 80% of NCD-related deaths and 82% of all NCD premature deaths occur.^{1 2} According to the WHO, approximately 46% of all NCD-related deaths in 2012 were due to cardiovascular diseases (CVDs), followed by cancers (22%), respiratory disease (11%) and diabetes (4%).² Furthermore, the global burden of diseases study reported that CVDs, such as ischaemic heart disease and stroke, continue to be among the top three leading causes of death globally.³

Papua New Guinea (PNG) is a country of approximately 7.3 million people located in the Western Pacific and renowned for its



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environmental, cultural and biological diversity.^{4,5} PNG is categorised as a lower-middle-income country according to the World Bank criteria⁶ and is experiencing rapid economic growth as a result of large-scale mineral and gas resource developments.⁷ Rapid economic growth in other LMICs has been associated with an epidemiological transition characterised by an increasing prevalence of NCDs and their risk factors with an often concomitant reduction in infectious disease.^{8,9} While infectious diseases such as acute respiratory tract infections, tuberculosis, malaria and HIV/AIDS are the leading causes of morbidity and mortality in PNG,¹⁰ the available evidence suggests this pattern is changing among those adult populations with longer exposure to modernisation. The latter is leading to rapid lifestyle changes associated with increases in CVD and diabetes.^{11–23} In addition, PNG still has high rates of childhood stunting,^{24–26} a risk factor for NCDs in adulthood.²⁷ The cost of treating and managing a growing NCD burden is already posing a substantial challenge to the country's economy, particularly given the challenges of the PNG health system, which include deteriorating infrastructure, poor governance, an ageing and inadequate healthcare workforce, and a paucity of specialist services.²⁸

NCDs and associated risk factors, such as smoking, excessive alcohol consumption, stress, unhealthy diet, physical inactivity, obesity, hypertension and abnormal lipid profiles, have not been well investigated in PNG. Several small studies conducted among specific populations over the past few decades have identified an increasing, or relatively high, prevalence of NCDs and NCD risk factors.^{18,19,21,29–34} They suggest variations in NCD risks within PNG based on lifestyle and living environment^{18,19,21,29} and on ethnic origin.^{33,34} Furthermore, a lack of physical activity, particularly among urban migrants, increases the risk of acquiring an NCD^{19,21}; and urban dwellers of any ethnic origin in PNG are at higher risk of CVDs and diabetes relative to their rural peers.^{19,21,31,32,35} The 2007/2008 PNG NCD Risk Factor STEPS study reported that the majority of surveyed adults were at risk of developing NCDs.³⁶ Since the STEPS survey, there has been limited up-to-date information on the prevalence of NCD risk factors across the diverse populations of PNG. Major resource developments have occurred since the STEPS survey last decade, and there is a need for a comprehensive NCD risk survey during this period of development. Currently in PNG, there is no systematic monitoring of NCD prevalence, or the associated risk factors, to measure the anticipated epidemiological transition across the country.

The present study was undertaken during the construction phase of a large-scale gas development which was projected to more than double the gross domestic product of PNG.⁷ Our study was designed to provide baseline prevalence data on NCD risk factors in the initial years of a gas project impact site (West Hiri) and in two non-project impact sites (Asaro and Karkar). It was also anticipated that the study findings would provide up-to-date NCD prevalence data to help the national government plan

services and develop cost-effective interventions. In this paper, we describe the methods used and present the initial findings for NCD risk factors in a survey of three different sociodemographic populations of PNG.

METHODS

Study design

Between April 2013 and October 2014, we undertook a cross-sectional, community-based survey in three integrated Health and Demography Surveillance Sites (iHDSS) set up by the PNG Institute of Medical Research (PNGIMR).^{37,38} The study included the completion of a standardised questionnaire based on the WHO STEPwise approach for NCD Risk Factor surveillance,³⁹ which included physical measurements and biological sample collection from randomly selected adults (aged 15–65 years) from the general population of each iHDSS. Information on health service utilisation was not collected but can be incorporated and reported in future NCD risk factor surveys and analysis. Further cross-sectional surveys of NCD risk factors and prevalence are planned for each iHDSS in the future, pending additional funding.

Sample size and selection

Using a simple random sampling procedure, a total of 300 adult participants, stratified by sex and age (15–29, 30–44, 45–65 years), were sought from each iHDSS (ie, 100 participants from each of the three age groups, 50 male and 50 female) and invited to take part in the study. The sampling frame was a full population census of the adult general population of each iHDSS. The target sample size (n=900) was estimated to confer 80% power to detect a 10% absolute difference in the proportion of most risk factors for all ages combined between each site or a 10% relative difference in means at the 0.05 significance level (two sided).

Study sites

The three iHDSS were West Hiri (Central Province), Asaro (Eastern Highlands Province) and Karkar Island (Madang Province) as shown in [figure 1](#). The West Hiri iHDSS comprises villages with a baseline (2011) population of 11 531 people³⁷ of Austronesian ancestry,⁴⁰ distributed along a 20–30 km stretch of coastline north-west of Port Moresby, the national capital and largest city in PNG. The West Hiri site was selected because it represents a periurban population affected by a large gas development project. The villages surround a gas processing plant and their close proximity to Port Moresby has changed the traditional diet, social cohesion and skilled activities such as fishing and gardening.⁴¹ The Asaro iHDSS comprises a baseline (2011) population of 10 034 people^{37,38} of non-Austronesian ancestry,⁴⁰ situated 40–45 km north-east of Goroka, the largest town in the Eastern highlands. People in Asaro are primarily subsistence farmers, but earn cash through smallholder production of coffee, employment on plantations and selling garden produce.⁴² The Karkar Island

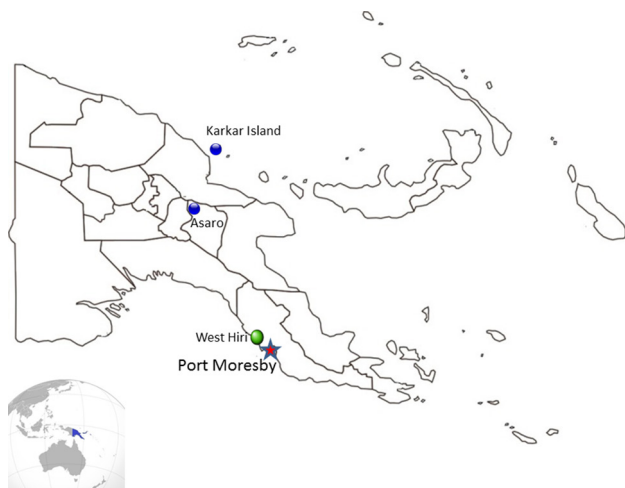


Figure 1 Map of Papua New Guinea showing the three survey sites: West Hiri (periurban) and two rural communities, Asaro and Karkar Island.

iHDSS comprises a rural baseline population of 18 623 people^{37 38} of both Austronesian and non-Austronesian ancestries⁴³ located 30 km off the northern coastline of Madang Province. Most adult residents of Karkar Island are subsistence farmers and/or unskilled labourers. The island's soil is fertile and large plantations produce the island's main exports of cocoa and coconut and provide most of the local employment opportunities.^{37 38} The majority of PNG's population live in rural areas and about 87% of the adult population is engaged in both subsistence farming and commercial activities.^{5 44} Therefore, Asaro and Karkar Island populations reflect rural communities that largely depend on subsistence farming and cash cropping in highlands and lowlands/coastal PNG, respectively.

Study measures and collection methods

Interviews were conducted at participants' homes or community health facilities. Eligibility criteria included recorded residence within the respective iHDSS and ages between 15 and 65 years at the time of survey. Women were excluded if they were pregnant at the time of recruitment. All survey forms and procedures were completed at a single time point by the survey team.

Interviews

The NCD study tool was adapted from the WHO STEPS NCD Risk Factor Survey.³⁹ Question domains included: participant demographics; self-reported health status; self-reported stress; consumption of vegetables, fruits, protein, fried food, salt and sugar; food security; tobacco, betel nut and alcohol use; physical activity; participant history of NCD and/or associated treatments. The self-reported stress, diet and physical activity questions were all developed specifically for this study and for use with PNG-based populations. The questionnaire was available in English and *Tok Pisin*, the local creole language that

the interviewers could speak fluently. All questionnaires were piloted extensively prior to survey commencement.

Measurement

Weight in kilograms (kg) was measured using a Seca digital scale to 100 g precision and height (cm) to 0.1 cm precision using a Seca Leicester stadiometer. Participants were able to wear light clothes, but no shoes. A Seca figure finder constant tension tape was used to measure to 0.1 cm precision the hip (level of widest part of the buttocks) and waist circumferences (midpoint between lower rib and iliac crest) in centimetre (cm). After participants had rested for 10 min in a sitting position their blood pressures (BP) were measured using an OMRON T9P digital automated sphygmomanometer. Three readings were taken at 1 min intervals using appropriate cuff sizes and the average of the three readings was used for the analysis.

Biochemical measures

Capillary blood from a finger prick was taken on the spot and analysed for haemoglobin levels using a HemoCue device (HemoCue Hb201⁺, Angelholm, Sweden). If haemoglobin levels were above 6 g/dL, a further 30 mL of non-fasting venous blood was collected. The initial 10 mL of blood was collected using EDTA vacutainers and analysed for haemoglobin A1c (HbA1c) levels using the DCA Vantage Analyzer from Siemens Healthcare Australia and New Zealand. The remaining 20 mL was collected using two 10 mL serum vacutainers which were aliquoted and stored initially at -20°C in each study site before they were transported to the Port Moresby PNGIMR laboratory. The serum samples were analysed for lipids (cholesterol and high-density lipoprotein-cholesterol (HDL-C)) using Vitros 250/350 Biochemistry System from Ortho Clinical Diagnostics, in batches within a month of collection. After analysis, aliquots of plasma, serum and cell pallets were stored initially at -20°C freezer in Port Moresby before archiving in -80°C freezer for long-term storage.

Measurement of NCD risk factors

Daily tobacco smoking was defined as current tobacco smoking on a daily basis and current alcohol consumption was defined as alcohol consumption within the last 30 days. Betel nut chewing which consists of areca nut, betel leaf/bean and slaked lime is widely practised across PNG and current use was defined as betel nut chewing within the last 30 days. Insufficient physical activity was defined as spending less than 75 or 150 min/week on vigorous and moderate physical activities, respectively.⁴⁵ Body mass index (BMI) was calculated as weight (kg) divided by height in metres squared (m^2). Overweight and obesity were defined as $\text{BMI} \geq 25$ – $29.9 \text{ kg}/\text{m}^2$ and $\geq 30 \text{ kg}/\text{m}^2$, respectively.⁴⁶ Central obesity in men and women was defined as a waist-to-hip ratio ≥ 0.90 and ≥ 0.85 for men and women, respectively.⁴⁷ Hypertension was defined as the average of the three systolic and/or diastolic BP readings of $\geq 140 \text{ mm Hg}$ and/or $\geq 90 \text{ mm}$

Hg, respectively or diagnosed hypertensive cases on antihypertensive drugs.⁴⁸ Prehypertension was defined as systolic and diastolic BPs of >120–139.9 mm Hg and >80–89.9 mm Hg, respectively.⁴⁸ Elevated cholesterol levels were defined as cholesterol levels of >6.2 mmol/L. Low HDL-C levels were defined as <1 mmol/L and <1.3 mmol/L for men and women, respectively.^{49 50} Participants with elevated HbA1c were defined to have HbA1c levels $\geq 5.7\%$. In accordance with the American Diabetes Association Standards of Medical Care in Diabetes, diabetes mellitus type 2 (DMT2) was diagnosed if the participant was on antidiabetic drugs or when the participants' HbA1c was $\geq 6.5\%$.⁵¹

Data analysis

STATA/SE V.13.0 (StataCorp LP) was used for all data analyses. Analysis was limited to descriptive summaries of all major measures and inferential analyses to assess intersite differences for major outcome variables using Pearson's χ^2 test, Fisher's exact test and one-way analysis of variance where appropriate. Risk factor prevalence with 95% CI for binary variables and the means with SD for continuous variables were examined by study site. More detailed analyses exploring relationships between specified risk factors and NCDs as well as lung function, haemoglobin and urine microalbumin levels, detailed dietary and physical activity results will be presented in subsequent publications. The totals (No.) presented in all tables are denominators unless otherwise stated. Tobacco, betel nut and alcohol questions were not originally included in the NCD questionnaire, and as a result, these questions were not asked of all participants. To address missing values, available case analysis was used.

Ethics approval

The study was given ethical approval by the PNGIMR Institutional Review Board (IRB) and the PNG Medical Research Advisory Committee (MRAC) (IRB No. 1208, 23 March 2012; MRAC No. 12.34, November 2012). Written, informed consent was obtained prior to study participation. Any participant identified with hypertension, DMT2, hyperlipidaemia or chronic obstructive pulmonary disease was referred to the local general hospital for further investigation and management.

RESULTS

Of the total 900 randomly selected participants, 785 (87.2%) adults participated in the survey. Here we present the results of the 772 participants who completed the survey and had their blood collected. Table 1 presents the demographic characteristics of the overall study population and by iHDS. The three study sites were comparable in terms of participants' age and sex. Overall, 33% of study participants received an education past primary school level and only 16% were engaged in paid employment. Across the sites, West Hiri participants were better educated and more likely to be in paid employment compared with participants from Asaro and Karkar

Island, where the majority were subsistence farmers/cash croppers.

Participants were asked about their weekly consumption of vegetables, fruits, protein, sugar, salt and fried food. As shown in table 2, 65% and 58% of all participants reported the consumption of root and green vegetables, respectively, for at least 5 days of the week but this varied across sites ($p < 0.001$). Residents of West Hiri reported the lowest percentage of root vegetable (17%) and greens (14%) consumption; however, they reported the highest percentage of fruit (24%) and animal protein (canned 52% and fresh 48%) consumption. The addition of at least 6 teaspoons of sugar in a hot drink daily was highest in both Asaro (20%) and West Hiri (20%) compared with Karkar Island (11%) ($p < 0.03$). Fried food consumption also varied across the sites with Asaro participants (43%) recording the highest consumption of fried food at home, 5 or more days per week, relative to West Hiri (16%) and Karkar Island (0%) ($p < 0.001$). The lowest salt consumption was reported by Karkar Island participants (22%) compared with those in West Hiri and Asaro.

Participants were asked if a health worker had previously diagnosed them with one or more of a range of specified NCDs. Overall, as shown in table 3, very few participants reported having received a diagnosis of any of the stated conditions and all diagnoses, except hypertension, chronic lung disease and cancer, were from West Hiri. Participants from Karkar and Asaro reported the least number of NCD diagnoses.

Table 4 presents data on behavioural and clinical NCD risk factors. Tobacco smoking was common across all three sites but we found significant differences between the sites in the type of tobacco smoked. West Hiri participants only smoked manufactured tobacco, but Karkar Island and Asaro reported higher prevalence of smoking home-grown tobacco as compared with manufactured tobacco. Prevalence of betel nut use was also high across all three sites, although current alcohol consumption was comparatively lower, especially in Karkar Island (7%). Higher proportions of men than women smoked tobacco and drank alcohol. Overall, 32% of participants reported currently feeling stressed. The prevalence of stress was significantly higher in West Hiri and Asaro compared with Karkar Island ($p < 0.001$). The prevalence of insufficient physical activity was highest in Karkar Island (34%) compared with Asaro (6%) and West Hiri (23%) ($p < 0.001$). Overall, 19% and 11% of participants were categorised as overweight or obese, respectively. There was a statistically significant difference between the sites with higher prevalence of overweight (25%) and obesity (22%) in West Hiri compared with the other two sites ($p < 0.001$). However, Asaro had a higher percentage (90%) of participants with central obesity, based on the waist-to-hip ratio, than the other two sites and this difference was statistically significant ($p < 0.001$). There was also a statistically significant difference in the prevalence of hypertension between the sites, with Karkar Island

Table 1 Demographic characteristics of the participants of the non-communicable disease study by iHDSS. The values are numbers and percentages (95% CI)

	Overall (n=772)		West Hiri (n=266)		Asaro (n=254)		Karkar Island (n=252)	
	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)
Sex								
Male	361	47 (43 to 50)	114	43 (37 to 49)	130	51 (45 to 58)	117	46 (40 to 53)
Female	411	53 (50 to 57)	152	57 (51 to 63)	124	49 (43 to 55)	135	54 (48 to 60)
Age group (years)								
15–29	216	28 (25 to 31)	73	27 (22 to 33)	69	27 (22 to 33)	74	29 (24 to 35)
30–44	261	34 (31 to 37)	93	35 (29 to 41)	88	35 (29 to 41)	30	32 (8 to 17)
45–65	295	38 (35 to 42)	100	38 (32 to 44)	97	38 (32 to 45)	98	39 (33 to 45)
Education								
Primary or lower	519	67 (64 to 71)	119	45 (39 to 51)	198	78 (72 to 83)	202	80 (75 to 85)
Some/complete secondary	159	21 (18 to 24)	92	35 (29 to 41)	28	11 (8 to 16)	39	16 (11 to 21)
Vocational/tertiary	26	3 (2 to 5)	20	8 (5 to 11)	3	1 (0 to 3)	3	1 (0 to 3)
Don't know	68	9 (7 to 11)	35	13 (9 to 18)	25	10 (7 to 14)	8	3 (1 to 6)
Employment								
Home duties	157	20 (18 to 23)	92	35 (29 to 41)	15	6 (3 to 10)	50	20 (15 to 25)
Subsistence/cash cropper	349	45 (42 to 49)	23	9 (6 to 13)	179	71 (64 to 76)	147	58 (52 to 65)
Paid employment	121	16 (13 to 18)	89	34 (28 to 40)	15	6 (3 to 10)	17	7 (4 to 11)
Unemployed/retired/student	114	15 (12 to 18)	55	21 (16 to 26)	24	10 (6 to 14)	35	14 (10 to 19)
Not given	31	4 (3 to 6)	7	3 (1 to 5)	21	8 (5 to 12)	3	1 (0 to 3)
Marital status								
Single/never married	155	20 (17 to 23)	62	23 (18 to 29)	38	15 (11 to 20)	55	22 (17 to 27)
Married	508	66 (62 to 69)	167	63 (57 to 69)	157	62 (56 to 68)	184	73 (67 to 78)
Separated/divorced	33	4 (3 to 6)	6	2 (1 to 5)	22	9 (6 to 13)	5	2 (1 to 5)
Widowed	33	4 (3 to 6)	14	5 (3 to 9)	14	6 (3 to 9)	5	2 (1 to 5)
Not given	43	6 (4 to 7)	17	6 (4 to 10)	23	9 (6 to 13)	3	1 (0 to 3)

participants having the lowest prevalence of hypertension (5%) compared with West Hiri (22%) and Asaro (22%) ($p < 0.001$). Higher percentages of elevated cholesterol (24%) and HbA1c (34%) were observed among West Hiri participants compared with Asaro and Karkar.

DISCUSSION

The results from our study provide baseline prevalence of NCD risk factors in three sites in PNG. Combined with earlier data from Asaro and Karkar sites, there is evidence of an increase in some key NCD risk factors; however, there is substantial variation among the three communities due to demographic and socioeconomic differences. The NCD risk appears greatest in the peri-urban site of West Hiri, relative to the rural sites of Asaro and Karkar Island. Similar rural-urban differences have been seen in other PI nations such as Fiji and Western Samoa.^{52 53} Previous studies found non-Austronesian populations to be less susceptible to developing diabetes and other NCDs.^{34 54} The Asaro population of non-Austronesian origin, however, recorded the highest central

obesity and prehypertension prevalence, indicating a rural population at very high risk of developing CVDs. West Hiri, an Austronesian population, as expected, had a higher prevalence of CVD and DMT2 risk factors. Karkar Island, a mixed Austronesian and non-Austronesian population, had low prevalence of some risk factors such as overweight and obesity, hypertension and elevated HbA1c levels. It also recorded the highest prevalence of tobacco smoking, insufficient physical activity and low HDL-C levels, indicating an increased risk for developing NCDs.

This is the first NCD study in West Hiri and having a diet low in vegetables compared with Asaro and Karkar Island reflects limited subsistence farming. However, more participants are in paid employment with regular income, which may explain the comparatively high alcohol and cigarette use and a diet high in sugar, salt and animal protein. Its close proximity to Port Moresby has resulted in a longer exposure to modernisation and the consequent increased risk of developing DMT2 and other NCDs.^{9 32 52} This study provides evidence of an

Table 2 Study participants' self-reported food consumption in a typical week by iHDSS. Values are in numbers and percentages (95% CI)

Food consumption	Overall n=772		West Hiri n=266		Asaro n=254		Karkar Island n=252		p Value*
	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)	n	% (95% CI)	
Root vegetables >5 days/week†	503	65 (62 to 69)	46	17 (13 to 22)	211	83 (78 to 88)	245	98 (94 to 99)	<0.001
Greens >5 days/week†	451	58 (54 to 62)	36	14 (10 to 18)	168	66 (60 to 72)	247	98 (95 to 99)	<0.001
Fruits >5 days/week†	97	13 (10 to 15)	64	24 (19 to 30)	33	13 (9 to 18)	0	0 (0 to 1)	<0.001
Fresh protein 5 days/week†	216	28 (25 to 31)	128	48 (42 to 54)	4	2 (0.4 to 4)	84	33 (28 to 40)	<0.001
Canned protein 5 days/week†	181	23 (21 to 27)	138	52 (46 to 58)	26	10 (7 to 15)	17	7 (4 to 11)	<0.001
Teaspoon sugar >6 tsp daily	132	17 (15 to 20)	53	20 (15 to 25)	51	20 (15 to 26)	28	11 (8 to 16)	0.026
Sugary drinks 3+ days/week‡	43	6 (4 to 7)	34	13 (9 to 17)	9	4 (2 to 7)	0	0 (0 to 1)	<0.001
Purchased fried food >5 days/week†	18	2 (1 to 4)	4	2 (0 to 4)	14	6 (3 to 9)	0	0 (0 to 1)	<0.001
Home fried food >5 days/week†	151	20 (17 to 23)	41	16 (11 to 20)	109	43 (37 to 49)	1	0.4 (0 to 2)	<0.001
Stock cube 7 days/week§	5	1 (0 to 2)	2	1 (0.1 to 2.7)	1	0 (0 to 2)	2	1 (0 to 3)	0.377
Salt directly on food 7 days/week§	361	47 (43 to 50)	162	61 (55 to 67)	144	57 (50 to 63)	55	22 (17 to 27)	<0.001

*p Values were obtained by Pearson's χ^2 test and Fisher's exact test where appropriate, †Consumed for at least 5 days in a typical week, ‡Consumption of soft drink for at least 3 days in a typical week, §Consumption for 7 days of the week. iHDSS, integrated Health and Demographic Surveillance Sites.

existing high prevalence of NCD risk factors in the West Hiri population. The NCD risk factor burden is expected to increase further, especially with the socioeconomic transition occurring in this population, which may be accelerated due to its Austronesian ancestry and close proximity to PNG's fastest growing city, and through the steep increase in local disposable incomes (via salaries, wages and royalty payments from the gas project).

The prevalence of daily tobacco smoking in our study (41%) is far higher than the 26.3% prevalence reported in the 2009/2010 national Household Income and Expenditure Survey (HIES),⁵⁵ yet consistent with the 43.7% and 47.7% in the 2007/2008 PNG STEPS and Global Youth Tobacco Survey, respectively.^{36,56} Our findings confirm that tobacco smoking rates have been high for a long period. There are even higher prevalences of current tobacco smokers in other Pacific countries, some of which were very high as in Kiribati, Wallis and Futuna, Tokelau and Fiji.⁵⁷ As tobacco smoking increases the risk of developing CVDs and other NCDs,^{58,59} our findings suggest public health efforts are needed to identify appropriate measures to reduce the consumption of both manufactured and home-grown tobacco. Increasing tobacco tax has reduced consumption

of manufactured tobacco elsewhere,⁶⁰ but may not be effective in populations where home-grown tobacco is widely used. Accordingly, in addition to WHO's 'Best Buy' interventions,⁶¹ public awareness campaigns highlighting the harmful effects of smoking, inclusive of home-grown tobacco, are required throughout PNG.

The prevalence of betel nut chewing was highest in the two coastal communities, where it is grown, compared with the highlands community of Asaro, and this is similar to a 1968 study which showed very high prevalence of betel nut chewing in two coastal communities, compared with a highlands community whose betel nut use was far lower.⁶² The overall prevalence of betel nut chewing is higher than the 2009/2010 national HIES,⁵⁵ but supports the 2007/2008 STEPS³⁶ prevalence. Even reported prevalences from other countries as Taiwan and Malaysian Borneo were lower than the findings from our study.⁶³ Chewing of betel nut has been associated with oral cancer, elevated glucose and increased risk of CVDs.⁶⁴⁻⁶⁷ It is deeply embedded into PNG's social and cultural traditions and is prevalent across the country,^{36,55,62} even among pregnant women.⁶⁸ Therefore, it will be important to monitor the impacts of this

Table 3 Study participants' self-reported diagnoses of non-communicable diseases and risk factors by iHDSS. Values are numbers and percentages (95% CI)

Diseases	Overall		West Hiri		Asaro		Karkar Island		p Value*	
	N	n	% (95% CI)	N	n	% (95% CI)	N	n		% (95% CI)
Stroke	769	3	0.4 (0 to 1)	266	3	1 (0 to 3)	253	0	0 (0 to 1)	0.111
Heart disease	767	4	1 (0 to 1)	265	4	2 (0 to 4)	252	0	0 (0 to 1)	0.037
Diabetes mellitus T2	771	5	1 (0 to 2)	266	5	2 (1 to 4)	254	0	0 (0 to 1)	0.012
Chronic lung disease/ asthma	772	16	2 (1 to 3)	266	10	4 (2 to 7)	254	4	2 (0 to 4)	0.065
Hypercholesterolaemia	769	1	0.1 (0 to 1)	264	1	0.4 (0, 2)	254	0	0 (0 to 1)	1.00
Hypertension	767	26	3 (2 to 5)	266	20	8 (5 to 11)	250	5	2 (1 to 5)	<0.001
Cancer	771	2	0.3 (0 to 1)	266	1	0.4 (0 to 2)	254	0	0 (0 to 1)	0.772

*p Value obtained by performing Fisher's exact test.
iHDSS, integrated Health and Demographic Surveillance Sites.

habit and provide appropriate public health messages combined with stronger and sustainable measures to reduce its use. A betel nut ban has recently been implemented in Port Moresby⁶⁹ and a robust evaluation should be conducted in order to establish the public health benefit, if any, from this intervention.

Our study found a higher prevalence of current alcohol use among the periurban West Hiri (43%) relative to rural Asaro (22%) and Karkar (7%) and this may be due to the high employment rate and increased availability of cash among the West Hiri population. A similar pattern reported in 1977 saw an increased alcohol use among men with high social status in the two communities of Karkar Island and Lufa.⁷⁰ However, our results showed a similar 'binge drinking' pattern (low frequency, high volume consumption) across all sites which was a common finding among Pacific youths in New Zealand.⁷¹ The national HIES (9%) and STEPS (15%) survey reported lower prevalence of alcohol consumption than our findings. Studies from neighbouring PI nations, however, recorded much higher alcohol consumption rates.⁵⁷ This binge drinking pattern in PNG previously reported to contribute to law and order problems affecting one's health, work and family.⁷² As such, adoption of appropriate measures such as WHO's 'best buys'⁶¹ is needed to control excessive alcohol consumption in the country which may include increased tax in the manufacture and sale of alcohol, ban on alcohol advertisement and awareness through education.

The findings from our study reveal that one in every three participants reported stress. However, there were significant differences across the sites, where Karkar participants reported the least percentage of stress relative to West Hiri and Asaro. Karkar participants live on an island further away from the nearest town compared with West Hiri and Asaro who are closer to towns, relying more on cash economy for the purchase of goods and services. A recent study identified two major sources of stress among PNG women: one is economic and supply instability and the other is stress associated with relationships with others.⁷³ Changes associated with urbanisation are likely to affect both. Further studies are needed to investigate the degree of stress as well as identify the stress vulnerable groups faced in PNG.

Our study found a higher prevalence of physical inactivity in both Karkar Island and West Hiri, compared with Asaro. The overall prevalence of insufficient physical activity is higher than that reported in the STEPS survey. PNG has one of the lowest prevalences of physical inactivity in the Pacific region where rates greater than 50% in both women and men have been reported.⁵⁷ Culturally appropriate interventions are needed to promote sufficient physical activity across PNG to help reduce the risk of developing NCDs. With towns and urban areas becoming unsafe for walking or jogging, most people commute only by vehicle,⁷⁴ pointing to a need for urban planners to incorporate safety plans to enable the use of public space for leisure activities.

Table 4 Overall distribution of prevalence of major non-communicable disease risk factors by iHDSS. The values are numbers and percentages (95% CI) and means (SD)

NCD risk factors	Overall			West Hiri			Asaro			Karkar Island			p Value*	
	N	n	% (95% CI)	N	n	% (95% CI)	N	n	% (95% CI)	N	n	% (95% CI)		
	Daily tobacco smoker†	526	253	48 (44 to 53)	155	64	41 (34 to 50)	171	85	50 (42 to 57)	200	104		52 (45 to 59)
Male	248	171	69 (63 to 75)	71	47	66 (54 to 77)	90	62	69 (58 to 78)	87	62	71 (61 to 80)	0.588	
Female	278	82	29 (24 to 35)	84	17	20 (12 to 30)	81	23	28 (19 to 40)	113	42	37 (28 to 47)	0.035	
Types of tobacco smoked	224			60			76			88				
Manufactured filtered cigarette	27			21			35 (23 to 48)	6		8 (3 to 17)	0		0 (0 to 4)	<0.001
Unfiltered dark tobacco (spear/ nutrus)	42			39			65 (52 to 77)	2		3 (0 to 9)	1		1 (0 to 6)	<0.001
Home-grown tobacco (brus)	155			0			0 (0 to 6)	68		89 (80 to 95)	87		99 (94 to 100)	<0.001
Current alcohol consumption‡	523	118	23 (19 to 26)	152	66	43 (35 to 52)	171	38	22 (16 to 29)	200	14	7 (4 to 12)	0.001	
Male	248	96	39 (33 to 45)	71	49	69 (57 to 79)	90	33	37 (27 to 47)	87	14	16 (9 to 26)	0.002	
Female	275	22	8 (5 to 12)	81	17	21 (13 to 31)	81	5	6 (2 to 14)	113	0	0 (0 to 3)	0.004	
Alcohol frequency past 12 months	185			89			60			36				
Daily	5			0			0 (0 to 4)	5		8 (3 to 18)	0		0 (0 to 10)	0.023
5–6 days/week	7			0			0 (0 to 4)	7		12 (5 to 23)	0		0 (0 to 10)	0.004
1–4 days/week	12			6			7 (3 to 14)	5		8 (3 to 18)	1		3 (0 to 15)	0.513
1–3 days/month	58			40			45 (34 to 56)	12		20 (11 to 32)	6		17 (6 to 33)	0.004
Less than once a month	103			43			48 (38 to 59)	31		52 (38 to 65)	29		81 (64 to 92)	0.016
Chewing betel nut§	520	386	74 (70 to 78)	155	145	94 (89 to 97)	168	93	55 (47 to 63)	197	148	75 (68 to 81)	<0.001	
Male	245	179	73 (67 to 79)	71	64	90 (81 to 96)	89	52	58 (47 to 69)	85	63	74 (63 to 83)	<0.001	
Female	275	207	75 (70 to 80)	84	81	96 (90 to 99)	79	41	52 (40 to 63)	112	85	76 (67 to 83)	<0.001	
Betel nut with betel bean and slaked lime	386	357	92 (89 to 95)	145	128	88 (82 to 93)	93	84	90 (83 to 96)	148	145	98 (94 to 100)	0.012	
Stress	771	246	32 (29 to 35)	266	122	46 (40 to 52)	254	112	44 (38 to 50)	252	12	5 (2 to 8)	<0.001	

Continued

Table 4 Continued

NCD risk factors	Overall				West Hiri				Asaro				Karkar Island				P Value*
	N	n	% (95% CI)	N	n	% (95% CI)	N	n	% (95% CI)	N	n	% (95% CI)	N	n	% (95% CI)		
	Male	360	115	33 (28 to 38)	114	49	43 (34 to 53)	130	61	47 (38 to 56)	117	5	4 (1 to 10)	117	5	4 (1 to 10)	
Female	411	131	31 (26 to 35)	152	73	48 (40 to 56)	124	51	41 (32 to 50)	135	7	5 (2 to 10)	135	7	5 (2 to 10)		
Insufficient physical activity [†]	504	101	20 (17 to 24)	169	39	23 (17 to 30)	186	12	6 (4 to 11)	149	50	34 (26 to 42)	149	50	34 (26 to 42)		
Male	233	37	16 (11 to 21)	76	14	18 (10 to 29)	94	5	5 (2 to 12)	63	18	29 (18 to 41)	63	18	29 (18 to 41)		
Female	271	64	24 (19 to 29)	93	25	27 (18 to 37)	92	7	8 (3 to 15)	86	32	37 (27 to 48)	86	32	37 (27 to 48)		
Mean (SD) BMI (kg/m ²)	767	767	23.9±5.7	264	264	26±7.1	252	252	24.0±4.4	251	251	21.5±4.0	251	251	21.5±4.0		
Overweight (BMI ≥25–29.9kg/m ²)	767	144	19 (16 to 22)	264	65	25 (20 to 30)	252	59	23 (18 to 29)	251	20	8 (5 to 12)	251	20	8 (5 to 12)		
Male	356	67	19 (15 to 23)	112	32	29 (20 to 38)	128	29	23 (16 to 31)	116	6	5 (2 to 11)	116	6	5 (2 to 11)		
Female	411	77	19 (15 to 23)	152	33	22 (15 to 29)	124	30	24 (17 to 33)	135	14	10 (6 to 17)	135	14	10 (6 to 17)		
Obesity (BMI ≥30kg/m ²)	767	82	11 (9 to 13)	264	59	22 (18 to 28)	252	16	6 (4 to 10)	251	7	3 (1 to 6)	251	7	3 (1 to 6)		
Male	356	20	6 (3 to 9)	112	15	13 (8 to 21)	128	3	2 (0.5 to 7)	116	2	2 (0.2 to 6)	116	2	2 (0.2 to 6)		
Female	411	62	15 (12 to 19)	152	44	29 (22 to 37)	124	13	10 (6 to 17)	135	5	4 (1 to 8)	135	5	4 (1 to 8)		
Mean (SD) WHR	758	758	0.91±0.09	264	264	0.88±0.12	250	250	0.94±0.08	244	244	0.90±0.06	244	244	0.90±0.06		
Central obesity (WHR, M≥0.9/F≥0.85)	758	514	68 (64 to 71)	264	138	52 (46 to 58)	250	225	90 (86 to 93)	244	151	62 (56 to 68)	244	151	62 (56 to 68)		
Male	351	218	62 (57 to 67)	112	50	45 (35 to 54)	128	125	98 (93 to 100)	111	43	39 (30 to 48)	111	43	39 (30 to 48)		
Female	407	296	73 (68 to 77)	152	88	58 (50 to 66)	122	100	82 (74 to 88)	133	108	81 (74 to 87)	133	108	81 (74 to 87)		
Mean (SD) SBP (mm Hg)	738	738	123±17.5	264	264	125.7±19.8	222	222	126.7±16.8	252	252	116.8±13.3	252	252	116.8±13.3		
Mean (SD) DBP (mm Hg)	738	738	75.3±10.9	264	264	77±12.4	222	222	78.4±9.7	252	252	70.7±8.5	252	252	70.7±8.5		
Prehypertension**	738	339	46 (42 to 50)	264	120	46 (39 to 52)	222	123	55 (42 to 62)	252	96	38 (32 to 44)	252	96	38 (32 to 44)		
Male	344	189	55 (50 to 60)	112	65	58 (48 to 67)	115	67	58 (49 to 67)	117	57	49 (39 to 58)	117	57	49 (39 to 58)		
Female	394	150	38 (33 to 43)	152	55	36 (29 to 44)	107	56	52 (42 to 62)	135	39	29 (21 to 37)	135	39	29 (21 to 37)		
Hypertension (≥140/90mm Hg)	738	118	16 (13 to 19)	264	58	22 (17 to 28)	222	48	22 (16 to 28)	252	12	5 (3 to 8)	252	12	5 (3 to 8)		

Continued

Table 4 Continued

NCD risk factors	Overall		West Hiri		Asaro		Karkar Island		p Value*				
	N	n	% (95% CI)	N	n	% (95% CI)	N	n		% (95% CI)			
Male	344	65	19 (15 to 23)	112	32	29 (20 to 38)	115	28	24 (17 to 33)	117	5	4 (1 to 10)	<0.001
Female	394	53	13 (10 to 17)	152	26	17 (14 to 24)	107	20	19 (12 to 27)	135	7	5 (2 to 10)	<0.001
Mean (SD) cholesterol (mmol/L)	708		4.6±1.8	258		5.0±1.8	218		4.7±1.7	232		4.2±1.7	<0.001
Elevated cholesterol (>6.2 mmol/L)	708	123	17 (15 to 20)	258	61	24 (19 to 29)	218	35	16 (11 to 22)	232	27	12 (8 to 17)	0.002
Male	321	50	16 (12 to 20)	108	22	20 (13 to 29)	108	18	17 (10 to 25)	105	10	10 (5 to 17)	0.086
Female	387	73	19 (15 to 23)	150	39	26 (19 to 34)	110	17	15 (9 to 24)	127	17	13 (8 to 21)	0.016
Mean (SD) HDL-C (mmol/L)	709		1.2±0.6	258		1.3±0.5	218		1.1±0.5	233		1.0±0.6	<0.001
Low HDL-C††	709	388	55 (51 to 58)	258	116	45 (39 to 51)	218	127	58 (51 to 65)	233	145	62 (56 to 68)	<0.001
Male	322	142	44 (39 to 50)	108	33	31 (22 to 40)	108	49	45 (36 to 55)	106	60	57 (47 to 66)	0.001
Female	387	246	64 (59 to 68)	150	83	55 (47 to 63)	110	78	71 (61 to 79)	127	85	67 (58 to 75)	0.023
Mean (SD) HbA1c	712		5.4±0.8	253		5.7±1.2	220		5.3±0.3	239		5.2±0.4	<0.001
Prediabetes HbA1c (≥5.7%–6.4%)	712	107	15 (13 to 18)	253	65	26 (20 to 32)	220	25	11 (8 to 16)	239	17	7 (4 to 11)	<0.001
Male	323	41	13 (9 to 17)	107	20	19 (12 to 27)	109	13	12 (7 to 20)	107	8	7 (3 to 14)	0.052
Female	386	66	17 (13 to 21)	146	45	31 (23 to 39)	111	12	11 (6 to 18)	132	9	7 (3 to 13)	<0.001
DMT2 HbA1c (≥6.5%)	712	24	3 (2 to 5)	253	22	9 (6 to 13)	220	0	0 (0 to 2)	239	2	1 (0 to 3)	<0.001
Male	323	8	2 (1 to 5)	107	8	7 (3 to 14)	109	0	0 (0 to 3)	107	0	0 (0 to 3)	<0.001
Female	386	16	4 (2 to 7)	146	14	10 (5 to 16)	111	0	0 (0 to 3)	132	2	2 (0.2 to 5)	<0.001

*p Values were obtained by Pearson's χ^2 test and Fisher's exact test where appropriate for categorical variables and one-way ANOVA for continuous variables, †Current tobacco smoking on a daily basis, ‡Consumption of alcohol within last 30 days. §Chewed betel nut within last 30 days, ¶Vigorous physical activity <75 min and moderate physical activity <150 min/week, **Prehypertension=SBP>120–139.9 mm Hg and/or DBP 80–89 mm Hg, ††Low HDL-C=<1 mmol/L men and ≤1.3 mmol/L women. ANOVA, analysis of variance; BMI, body mass index; DBP, diastolic blood pressure; DMT2, diabetes mellitus type 2; HbA1c, haemoglobin A1c; HDL-C, high-density lipoprotein-cholesterol; iHDSS, integrated Health and Demographic Surveillance Sites; NCD, non-communicable disease; SBP, systolic blood pressure; WHR, waist-to-hip ratio.

Our results showed a higher prevalence of overweight and obesity in periurban West Hiri relative to rural Asaro and Karkar Island. Norgan in 1995 reported overweight and obesity prevalence in Karkar and Lufa communities was less than 10%,⁷⁵ which is lower than our findings. In addition, the overall obesity prevalence (11%) in our study is higher than that reported in the PNG STEPS survey.³⁶ Although the West Hiri obesity rates (22%) are comparable to that reported for Port Moresby residents (21%), it is lower than that in some neighbouring Pacific Islands.^{35 57} Despite the low prevalence of obesity, especially in Asaro and Karkar Island, our results showed very high prevalence of central obesity (waist-to-hip ratio) across all sites, but more so in Asaro. Central obesity, based on waist-to-hip ratio, has been reported to substantially increase the risk of CVDs and is a preferred measure of obesity for predicting CVD and all-cause deaths.^{76 77} The high prevalence of central obesity in Asaro indicates a different propensity for fat distribution to West Hiri. This finding further indicates the standard BMI thresholds may not be suitable for use in PNG, as has also been suggested for other ethnic groups in the Asia Pacific region.⁴⁶ Some countries have introduced taxes on unhealthy food and beverages to reduce their consumption.⁷⁸ Health promotion via media, education in schools and workplaces as that in New Zealand⁷⁹ may also help reduce overweight and obesity prevalence. PNG may need to consider adopting such initiatives to help reduce and control the availability and sales of high sugar, salt and fat content foods in the country.

Other CVD risk factors, such as elevated BP and hyperlipidaemia, were higher across the three sites in our study compared with the earlier PNG STEPS survey. High rates of prehypertension (55%) in the Asaro population are concerning as studies conducted between the 1950s and 1980s in the highlands population showed low levels of elevated BP.^{80–82} According to previous studies in Asaro, the prevalence of hypertension was^{14 83} lower than our findings (22%). Similarly, in the 1960s–1980s hypertension was absent or very low in Karkar as elsewhere in the country.^{14 84–86} However, our results showed increased prevalence of both prehypertension (38%) and hypertension (5%) among the Karkar population. Over the last two decades, hypertension has been recorded at very high levels in other parts of the country, such as the Purari Delta, Manus and urban Port Moresby.^{13 29}

Inter-regional differences in NCD risks have been previously observed for hypercholesterolaemia. Some parts of the country inclusive of Asaro and rural Central Province recorded zero or low prevalence of hypercholesterolaemia from the late 1980s to early 1990s,^{17 87 88} yet very high in certain populations such as urban Port Moresby and group of male miners in Bougainville.^{17 23 89} The prevalence of hypercholesterolaemia (24%) in our periurban West Hiri population was slightly lower than that of urban Port Moresby, although a lower cut-off (≥ 5.2 mmol/L) was used in the latter study. Our results combined with these previous studies suggest an urgent need for interventions

to control CVD risk factors across all populations of PNG. In addition to WHO's 'best buys',⁶¹ and a country appropriate adaptation of the Green Prescription,⁹⁰ enabling health education programmes to promote activity and healthy lifestyle in schools and communities would be beneficial for PNG.

Previous studies have reported a variable prevalence of DMT2 in parts of PNG. According to studies conducted in the 1980s–1990s, DMT2 was absent or existed at very low prevalence in many parts of PNG including Karkar Island and Asaro communities.^{33 34 54} DMT2 prevalences in these communities have remained low over a long period of time and our findings are consistent with the earlier studies; however, prediabetes data from our study may suggest this is changing. Indeed, studies conducted in Koki, in urban Port Moresby, Wanigela village in Central Province and residents of Port Moresby between the 1970s and 2000 reported very high prevalences of DMT2.^{16 18 31 32} Based on genetics and longer exposure to modernisation, it is not surprising that West Hiri population had a higher prevalence of both prediabetes (26%) and DMT2 (9%) than Asaro and Karkar. Together with previous studies, our findings indicate limited change in DMT2 in recent history but continued marked disparity between populations, although the percentage of adults with elevated HbA1c across sites should be of significant concern. Control measures should include restrictions on imported high-sugar and fat content foods as well as the use of mass media and other education and public awareness raising activities.

STRENGTHS AND LIMITATIONS

The study had a number of strengths and limitations. Strengths include an up-to-date prevalence of NCD risk factors in three sites at different stages of social and economic development; and the collection of NCD risk factor data during the early stages of a huge gas development project which provides a baseline for future longitudinal studies to monitor NCDs and risk factors. The limitations are as follows: First, this was a cross-sectional study and provides a snapshot of the risk and disease burden at a particular moment in time. Second, the study was conducted in only three locations across PNG and is therefore not nationally representative. Third, the full sample size was not achieved and younger people were undersampled, which could have led to an overestimation of NCD risk factor burden. Fourth, the study relied on the participants' self-report for some measures, possibly resulting in recall bias (eg, self-reported 7-day food consumption). Fifth, biological samples were not collected from all participants therefore interpretation of results was limited only to those with biological samples.

CONCLUSION

Although not nationally representative, our study is suggestive of a socioeconomic and nutrition transition being under way in all three sites, especially in periurban

West Hiri, which had a higher NCD risk factor burden compared with the rural sites. However, some risk factors were common across sites, suggesting these populations are at heightened risk of developing CVDs. Few participants had received an NCD diagnosis despite the high prevalence of NCD risk factors, suggesting that current NCD screening and prevention as well as treatment services are inadequate in the sites taking part in this study. Training on NCDs and their risk factors as well as appropriate lifestyle interventions need to be incorporated into existing health training curriculum. Such training would facilitate appropriate screening, monitoring and control of NCDs at the primary healthcare setting. In addition, facilities need to be provided with the basic equipment/tools for screening. This calls for an urgent need to mobilise appropriate and multisectoral preventive interventions and upskill health services. Regular monitoring of these populations would provide up-to-date information and feedback on the effectiveness of any interventions for the emerging NCD epidemic in PNG.

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Acknowledgements The authors wish to thank all research participants, Provincial Government, church health authorities and community representatives in the respective sites. The authors are grateful to the dedicated NCD Study field and laboratory staff members. The authors also acknowledge the PNGIMR for providing the administrative and technical support to conduct this study. Lastly, we acknowledge the financial support via an unrestricted grant provided by PNG ExxonMobil to conduct this survey in the three sites. The governance and management of the study was completely independent from the funders.

Contributors RS, CB, IR, GM, AM, MU, IHK, JP, GV, HG, SP and PR were responsible for study design. PR, JP, GV, HG and SP helped conduct the study and were responsible for data collection. PR conducted the data analysis and was responsible for drafting the manuscript. JP, RS, CB, AM, MU, HG, BO and BM critically revised the manuscript. The final draft was approved by all authors.

Competing interests None declared.

Patient consent All study participants signed a consent form prior to being recruited into the study.

Ethics approval PNG Institute of Medical Research Institutional Review Board and PNG Medical Research Advisory Committee.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Requests for data access should be directed to the corresponding author and will be granted subject to approval by the Medical Research Advisory Council of Papua New Guinea.

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Title:

Prevalence of non-communicable disease risk factors in three sites across Papua New Guinea: a cross-sectional study

Date:

2017-03-01

Citation:

Rarau, P., Vengiau, G., Gouda, H., Phuanukoonon, S., Kevau, I. H., Bullen, C., Scragg, R., Riley, I., Marks, G., Umezaki, M., Morita, A., Oldenburg, B., McPake, B. & Pulford, J. (2017). Prevalence of non-communicable disease risk factors in three sites across Papua New Guinea: a cross-sectional study. *BMJ GLOBAL HEALTH*, 2 (2), <https://doi.org/10.1136/bmjgh-2016-000221>.

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