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Prevalence and predictors of prediabetes and diabetes among adults in Palau: population-based national STEPS survey

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ABSTRACT

We aimed to investigate the prevalence and predictors of diabetes and prediabetes among adults in Palau. We used data of 1915 adults, aged 25 to 64 years, who participated in the World Health Organization's (WHO) STEPwise Approach to Risk Factor Surveillance (STEPS) study in Palau. Information on behavioral risk factors of NCDs and physical and biochemical measurements were obtained using standard methods of the WHO. The diagnosis of diabetes and prediabetes was based on the recent American Diabetes Association criteria. Predictors of the prevalence of diabetes and prediabetes were identified using multinomial logistic regression analysis. The overall age-standardized prevalence of prediabetes and diabetes were 40.4% (43.6% for men, 37.4% for women) and 17.7% (18.6% for men, 17% for women), respectively. Old age, overall obesity (high BMI), central obesity (large waist circumference or waist-hip ratio), hypertension and hypertriglyceridemia were significant predictors of prediabetes and/or diabetes. Diabetes occurred at a younger age in "obese" individuals than that of their "non-obese" counterparts. We confirmed that prediabetes and diabetes are highly prevalent in Palau affecting 40% and 18% adults, respectively. Introducing public health interventions to reduce and prevent obesity as early as possible could prove useful to curb the problem.

Key Words: prevalence, diabetes, prediabetes, predictors, Palau

INTRODUCTION

Diabetes is one of the most common chronic diseases affecting the lives of many people around the world.[1,2] In 2015, the International Diabetes Federation (IDF) has estimated that

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415 million adults to have had diabetes, and 318 million others with prediabetes to have been at high risk of developing the disease in the future.[3] Western Pacific Region has substantially more adults with diabetes (153 million) than any other region.[3]

Palau, a Micronesian island country in the Pacific region, is known to have a high burden of non-communicable diseases (NCD) including diabetes. IDF estimates for 2015 put the country's age-adjusted prevalence of diabetes among adults aged 20–79 years at 20.9%.[3] Although the country has recognized the seriousness of the situation by declaring a state of health emergency on NCD in 2011,[4] nationwide epidemiological studies to investigate the prevalence of diabetes had been lacking. In fact, the aforementioned IDF estimate was extrapolated based on data from other countries with similar demographic profile.[3]

The Ministry of Health of Palau, in collaboration with the World Health Organization (WHO), conducted a nationwide NCD risk factor surveillance between 2011 and 2013. We utilized the data from that survey to estimate prevalence of prediabetes and diabetes in Palau. We also assessed the association of several demographic, lifestyle, anthropometric, and clinical factors with the prevalence of prediabetes and diabetes to generate information that can be utilized for prevention activities.

METHODS AND MATERIALS

Study setting and subjects

Between September 2011 and June 2013, a nation-wide, community-based, cross-sectional survey targeting adults aged 25–64 years was conducted in Palau. A total of 2226 non-pregnant adults participated in the survey. After excluding participants aged <25 or >64 (n=10) and those with missing values for age, anthropometric measurements, blood pressure, and fasting blood glucose (n=301), data of 1915 participants were considered for the current analysis.

Measurement and classification of variables

Information on demographic and behavioral risk factors of NCD was obtained using a STEPS questionnaire adapted for Palau. Physical and biochemical measurements were taken following the WHO standards. Details about the procedures of the measurements are reported elsewhere.[5]

Participants were told to fast for at least 8 hours before examination. Capillary whole blood samples were drawn from the fingertip of each participant to determine fasting blood glucose (FBG) and lipid profile (total cholesterol and triglycerides) on portable devices: Accu-Chek Performa and Accutrend Plus system (Roche Diagnostics) for FBG and lipid profiles, respectively. We classified participants into three categories of glycemic status as normoglycemic (FBG=5.6 mmol/L or less), prediabetes (FBG=5.6–6.9 mmol/L) and diabetes (FBG=7 mmol/L or above).[6]

Body mass index (BMI) in kg/m^2 was classified into three groups: <18.5 or 18.5–24.9 (underweight/normal), 25.0–29.9 (overweight) and ≥30.0 (obese).[7] We merged 'underweight' and 'normal' together as the number of underweight individuals was too small to constitute a standalone BMI group. Abdominal obesity was defined as having waist circumference (WC) of ≥94 cm for men or ≥80 cm for women, and large waist-hip ratio (WHR) was defined as having WHR of ≥0.90 for men or ≥0.85 for women.[7] Blood pressure (BP) in mmHg was categorized into three groups: normal (systolic BP<120 and diastolic BP<80), pre-hypertension (systolic BP=120–139 or diastolic BP=80–89) and hypertension (systolic BP≥140 or diastolic BP≥90).[8]

Statistical analyses

We classified age (years) into 5 groups (25–29, 30–39, 40–49, 50–59 and 60–64), and age-specific prevalence of diabetes and prediabetes was calculated stratified by sex. The overall prevalence of diabetes and prediabetes was calculated by standardizing the data according to the age and sex distribution of the 2010 national population estimates for Palau,[9] using the direct method.

Chi-squared test, analysis of variance, or nonparametric median comparison test, as deemed necessary, was used to compare the characteristics of participants across the three categories of glycemic status. Odds ratios (OR) and 95% confidence intervals (CI) were estimated by multinomial logistic regression using the normoglycemic group a reference. The following variables which showed significant associations with the glycemic status at $P<0.25$ in the bivariate analyses were included in the multivariate models to assess their associations with prediabetes and diabetes: age (categorical), ethnicity (non-Palauan/Palauan), education status (primary school or lower, secondary school, or college and above), current betel nut chewing (yes/no), ever smoked (yes/no); BMI, WC, WHR, and BP (all categorical), total cholesterol and triglycerides (both continuous and log-transformed). Anthropometric variables (BMI, WC, and WHR) were not included for adjustment when each of them was in the multivariate model. Presence of a trend in the association between categorical variables with prediabetes and diabetes was assessed by assigning ordinal numbers to each level of the categorical variables, and treating them as continuous data in the multivariate model. IBM SPSS Statistics for Windows software, Version 22 (IBM Corp, Armonk, NY, USA) or OpenEpi software[10] was used for the analyses. All tests were two-sided with significance level set at $P<0.05$.

Ethics approval

The survey was approved by the WHO and Institutional Review Board of the Ministry of Health, Republic of Palau. Written informed consent was obtained from all of the participants. Data analysis of this study is a part of a joint research between Palau and Japan, which was approved by the Bioethics Review Committee of Nagoya University School of Medicine (approval number: 2012-0103) and Institutional Review Board of the Ministry of Health, Republic of Palau.

RESULTS

Demographic and lifestyle characteristics

About 47.5% of our study participants were men. The mean age and standard deviation (SD) was 45.3 (10.4). Palauan constituted about 74.8% of the study subjects, and majority (83.5%) had attended secondary school or above. Almost half (47.9%) of the participants reported to have ever smoked cigarette in their lifetime, and 58.4% others have reported current betel nut chewing practice. Three out of four study participants were overweight or obese and the mean (SD) for BMI was 29.8 (6.6) kg/m^2.

Prevalence and predictors of prediabetes and diabetes

The overall crude prevalence of prediabetes was 40.8% (43.3% for men, 38.6% for women), while that of diabetes was 19.8% (20.5% for men, 19.3% for women). Age-standardized prevalence of prediabetes and diabetes were 40.4% (43.6% for men, 37.4% for women) and 17.7% (18.6% for men, 17% for women), respectively. The prevalence of diabetes consistently increased with age in both sexes (Table 1). Subjects with diabetes were generally older, and more likely to be betel nut chewers, obese, hypertensive and with unfavorable lipid profiles than

Table 1 Prevalence (95% CI) of prediabetes and diabetes among adults in Palau, 2011–2013

Age group	Prediabetes			Diabetes		
	Men	Women	All	Men	Women	All
25–29	31.6 (22.2–42.7)	24.7 (16.8–34.8)	28.0 (21.6–35.3)	7.9 (3.7–16.2)	7.1 (3.3–14.6)	7.5 (4.3–12.6)
30–39	49.0 (42.3–55.8)	31.8 (26.0–38.3)	40.2 (35.6–44.9)	12.1 (8.4–17.3)	11.1 (7.5–15.9)	11.6 (8.9–14.9)
40–49	42.5 (36.9–48.3)	43.5 (38.3–48.9)	43.0 (39.2–47.0)	22.5 (18.0–27.7)	17.2 (13.5–21.6)	19.6 (16.7–22.9)
50–59	45.6 (39.7–51.7)	43.2 (37.4–49.1)	44.4 (40.2–48.6)	24.5 (19.7–30.1)	25.8 (21.0–31.3)	25.2 (21.7–29.1)
60–64	35.8 (26.2–46.7)	37.0 (28.5–46.9)	36.5 (29.8–43.7)	33.3 (24.0–44.2)	37.0 (28.2–46.8)	35.4 (28.8–42.6)
25–64[a]	43.3 (40.2–46.6)	38.6 (35.7–41.7)	40.8 (38.7–43.1)	20.5 (18.0–23.2)	19.3 (17.0–21.9)	19.8 (18.1–21.7)
25–64[b]	43.6 (41.5–43.2)	37.4 (36.6–38.3)	40.4 (39.5–41.3)	18.6 (17.9–19.3)	17.0 (16.3–17.6)	17.7 (17.1–18.4)

Abbreviations: CI: confidence interval.
Data are presented as % (95% CI).
[a] Crude prevalence
[b] Age-standardized prevalence after direct standardization using the Palauan national population data (2010) as the standard population.

Table 2 Characteristics of study participants by glycemic status, Palau, 2011–2013

Characteristics	NG (n=752)	Prediabetes (n=782)	Diabetes (n=381)	*P*-value[a]
Demographic				
Age, years	42.7 (10.5)	45.7 (9.9)	49.4 (9.5)	<0.0001
Female	56.2	49.6	51.1	0.041
Native Palauan	73.4	71.3	85.0	<0.0001
Low education level[b]	14.2	16.6	17.5	0.037
Lifestyle related				
Ever smoker	45.6	48.5	51.3	0.176
Current betel nut chewer	59.2	53.5	67.5	<0.0001
Ever consumed alcohol	70.9	73.6	72.4	0.458
Metabolic				
Body mass index, kg/m^2	28.6 (6.52)	30.0 (6.39)	31.8 (6.74)	<0.0001
Waist circumference, cm	94.0 (15.6)	96.8 (14.7)	101.8 (13.9)	<0.0001
Waist-hip ratio	0.92 (0.08)	0.93 (0.07)	0.96 (0.07)	<0.0001
Systolic blood pressure, mmHg	135.5 (21.5)	139.3 (21.6)	148.3 (22.8)	<0.0001
Diastolic blood pressure, mmHg	83.2 (13.0)	85.3 (11.9)	88.1 (12.1)	<0.0001
Hypertensive	26.6	32.5	44.7	<0.0001
Total cholesterol, mmol/L[c]	4.13 (3.9)	4.28 (1.01)	4.26 (1.07)	0.070
Triglycerides, mmol/L[c]	1.36 (1.08)	1.59 (1.15)	2.03 (1.67)	<0.0001

Abbreviations: NG, normoglycemic. Data are presented as mean (SD) and percentage for continuous and categorical variables, respectively unless specified otherwise.
[a] Based on analysis of variance or chi-squared test for continuous and categorical variables, respectively.
[b] Primary school or lower levels.
[c] Median (inter-quartile range) and *P*-values obtained using nonparametric median comparison test

those without the disease (Table 2).

Age was positively and significantly associated with both prediabetes and diabetes in women and with only diabetes in men (*P* for trend <0.01 in all). Moreover, hypertension (in women only) and hypertriglyceridemia (both in men and women) were significantly associated with diabetes. The association of hypertriglyceridemia with diabetes was stronger in women than in men (Table 3).

When the three anthropometric measurements were analyzed one at a time, BMI was positively and significantly associated with prediabetes and diabetes in both sexes (*P* for trend <0.01), whereas abdominal obesity was significantly associated with only diabetes in women and with both prediabetes and diabetes in men (*P*<0.01 for all), and having large WHR was strongly associated with only diabetes in women (*P*<0.01). The abdominal obesity-diabetes association was

Table 3 Predictors of prediabetes and diabetes mellitus among adults in Palau, 2011–2013

Predictors	Men		Women	
	Prediabetes	Diabetes	Prediabetes	Diabetes
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Age (years)				
25–29	reference	reference	reference	reference
30–39	2.61 (1.38–4.93)	1.63 (0.59–4.55)	1.51 (0.80–2.84)	1.71 (0.59–5.01)
40–49	2.43 (1.29–4.55)	2.71 (1.03–7.13)	2.71 (1.46–5.02)	2.93 (1.04–8.25)
50–59	3.04 (1.60–5.78)	3.73 (1.41–9.85)	3.54 (1.85–6.76)	5.46 (1.92–15.53)
60–64	2.23 (0.99–5.04)	5.04 (1.70–14.97)	3.64 (1.64–8.10)	8.81 (2.81–27.60)
P for trend	0.051	<0.001	<0.001	<0.001
BMI				
Normal/underweight	reference	reference	reference	reference
Overweight	1.07 (0.71–1.62)	1.63 (0.87–3.04)	1.25 (0.81–1.93)	1.07 (0.56–2.03)
Obese	1.98 (1.27–3.09)	3.12 (1.65–5.90)	1.97 (1.27–3.06)	2.44 (1.32–4.51)
P for trend	0.002	<0.001	0.001	<0.001
Waist circumference				
Normal	reference	reference	reference	reference
Abdominal Obesity	1.63 (1.15–2.31)	2.39 (1.49–3.82)	1.50 (0.96–2.35)	5.00 (1.87–13.31)
Waist-Hip ratio				
Normal	reference	reference	reference	reference
Large	1.19 (0.79–1.80)	1.81 (0.95–3.48)	1.31 (0.88–1.95)	2.82 (1.37–5.81)
Blood pressure				
Normal	reference	reference	reference	reference
Pre-Hypertension	0.83 (0.48–1.42)	1.50 (0.58–3.88)	1.32 (0.87–1.98)	1.68 (0.86–3.26)
Hypertension	0.96 (0.54–1.71)	1.93 (0.73–5.09)	1.33 (0.82–2.15)	2.49 (1.23–5.06)
P for trend	0.735	0.150	0.289	0.005
Triglycerides	1.45 (0.85–2.48)	5.65 (2.23–14.34)	1.72 (0.80–3.68)	12.78 (5.05–32.28)

Abbreviations: OR, odds ratio; CI, confidence interval; BMI, body mass index.
[a] Adjusted for educational status (primary school or lower, secondary school, or college and above), ethnicity (non-Palauan/Palauan), current betel nut chewing practice (yes/no), ever smoked (yes/no), log-transformed serum total cholesterol (mmol/L) and mutually adjusted (anthropometric variables were not included for adjustment when each of them were in the model).
[b] Waist circumference: ≥94 cm for men and ≥80 cm for women.
[c] High waist-hip ratio: ≥0.90 for men and ≥0.85 for women.

almost twice as strong in women as in men (Table 3). When the measurements were mutually adjusted for each other, BMI remained to be a significant predictor of prediabetes in both sexes ($P<0.05$), and marginally significant predictor of diabetes in men ($P=0.065$) but not in women. In contrast, WC and WHR showed significant ($P=0.014$) and marginally significant ($P=0.063$) associations with diabetes in women, respectively. (Data not shown)

As shown in Table 4, the odds of diabetes (in both men and women) and prediabetes (in women) tended to increase with age irrespective of their obesity status. The significant age-diabetes association in "obese" individuals occurred at a younger age (40–49 years in women and 50–59 years in men) than that of their "non-obese" counterparts (60–64 years in both men and women). Moreover, obesity tended to increase the odds of diabetes in women more than it did in men in the same age group.

Table 4 Multivariable adjusted[a] OR (95% CI) of prediabetes and diabetes according to obesity status by age, Palau, 2011–2013

Age (years)	Men		Women	
	Prediabetes	Diabetes	Prediabetes	Diabetes
Obese				
25–29	reference	reference	reference	reference
30–39	1.98 (0.72–5.41)	2.86 (0.67–12.17)	1.36 (0.48–3.80)	2.87 (0.56–14.72)
40–49	1.37 (0.52–3.61)	2.83 (0.70–11.41)	2.63 (0.97–7.16)	5.52 (1.11–27.36)
50–59	2.95 (1.10–7.92)	4.25 (1.03–17.48)	3.99 (1.38–11.59)	14.24 (2.78–73.04)
60–64	2.06 (0.54–7.82)	4.91 (0.92–26.23)	3.81 (1.11–13.12)	13.24 (2.27–77.28)
P for trend	0.077	0.040	<0.001	<0.001
Non-Obese				
25–29	reference	reference	reference	reference
30–39	3.20 (1.37–7.47)	0.66 (0.14–3.18)	1.69 (0.76–3.79)	1.06 (0.24–4.64)
40–49	3.49 (1.50–8.10)	2.12 (0.53–8.45)	2.91 (1.32–6.42)	1.61 (0.39–6.53)
50–59	2.95 (1.24–7.02)	3.04 (0.77–12.09)	3.50 (1.53–7.99)	2.09 (0.52–8.48)
60–64	2.19 (0.77–6.25)	4.49 (1.02–19.74)	3.67 (1.28–10.54)	6.28 (1.37–28.71)
P for trend	0.339	0.001	0.001	0.001

Abbreviations: OR, odds ratio; CI, confidence interval

[a] Adjusted for educational status (primary school or lower, secondary school, or college and above), ethnicity (non-Palauan/Palauan), current betel nut chewing practice (yes/no), ever smoked (yes/no), waist circumference (normal/abdominal obesity), waist-hip ratio (normal/large), blood pressure (normal, pre-hypertension, hypertension), log-transformed serum total cholesterol (mmol/L), and log-transformed serum triglycerides (mmol/L).

DISCUSSION

Our analysis has shown that prediabetes and diabetes are highly prevalent in Palau: close to 18% of adults aged 25–64 years in the country already have diabetes and about 40% others with prediabetes may be at high risk of developing the disease. Age, obesity, hypertension and hypertriglyceridemia were significantly associated with the prevalence of prediabetes and/or diabetes.

The prevalence of diabetes in our study population is slightly lower than IDF's estimate[3] for 2015 (20.9%). But it is higher than that of a report from a similar study in Nauru[11] – 17.7% vs 13.7% –, while it is almost similar with that of Pacific islanders living in the United States[12] –17.7% vs 18.3%. On the other hand, the prevalence of prediabetes in our study subjects (40.4%) is much higher than what was reported from studies in Nauru (6%)[11] and American Samoa (22.4%).[13] The prevalence of diabetes and prediabetes in our study is also higher than what has been recently reported in studies conducted in Bangladesh (9.7% for diabetes and 22.4% for prediabetes)[14] and Vietnam (6% for diabetes and 13.5% for prediabetes).[15]

Changes in the lifestyles may be to blame for the high prevalence of diabetes in Palau and other Pacific island countries. In the old days, Pacific islanders used to be active, and their diets used to consist primarily of low-fat and high-fiber foods. These days, access to technologies have led most islanders to have sedentary lifestyles, and their diets are high in calories, salt, fat, and refined foods.[4,16] Indeed, the identification of measures of obesity and hypertriglyceridemia as significant predictors of diabetes and prediabetes in our study population suggest that excess body fat may be important risk factor for diabetes and prediabetes in Palau, which is in line with findings of previous studies.[11-13,17]

Our study is the first study to report about the prevalence of prediabetes and diabetes among Palauan adults based on a representative national survey. The findings of this study could prove useful to assess the burden of diabetes in Palau and help policy makers design relevant policies and appropriately allocate resources for prevention and control of the disease.[2]

Almost one in five adults in Palau has diabetes. But it is worth noting that this figure may just

be the 'tip of the iceberg' of the problem. Indeed, our analysis has also revealed that additional 40% of the adult population have prediabetes, and it may be a matter of time before significant proportion of those people with prediabetes develop overt diabetes.[18] This will add extra burden to the Palauan health sector which spends 55% of its annual budget on managing NCD.[4]

The prevalence of prediabetes is slightly higher in men than in women in the present study. Our finding is corroborated by previous studies which reported lower fasting plasma glucose in women.[19,20] However, it is noteworthy that prediabetes also constitutes impaired glucose tolerance in addition to impaired fasting glycemia,[21,22] and our finding may be an underestimation of what may be the true prevalence of prediabetes in men and women in Palau. Similar studies in the future may consider including oral glucose tolerance test to assess the full extent of the problem.

Consistent with previous reports,[11,14,15] the prevalence of diabetes increased with age both in men and women in our study. But the onset of significant age-diabetes association was at a younger age for obese than for non-obese individuals, especially in women. This indicates that if lifestyle interventions to reduce weight and maintain it healthy are started as early as possible, early onset of diabetes could be prevented among Palauan adults.

Measures of overall obesity (BMI) in men and central obesity (mainly WC) in women appeared to be the best predictors of diabetes. Different findings had been reported in previous studies as to whether overall obesity or central obesity is better at conferring risk of diabetes. For instance, both central obesity (WC) and overall obesity (BMI) emerged as significant predictors of diabetes among Korean women,[23] while measures of central obesity had stronger association with diabetes than BMI in Korean men[23] and multiethnic Asian men and women.[24,25] Ethnic disparities in body composition had been mentioned as possible explanation for the discrepancy observed in different populations.[26,27] However, we used the conventional cut-off points of the anthropometric measurements for Europeans, and those thresholds may have differential sensitivity to predict diabetes among Palauan adults. Pacific Islanders are said to have less body fat and higher muscle mass than Europeans.[28,29] Further studies are warranted to assess the discriminatory ability and the optimal cut-off points of the different anthropometric measures in predicting the risk of diabetes among Palauan adults.

Hypertension (in women) and hypertriglyceridemia (in both sexes) were positively associated with diabetes. In addition, the association of hypertriglyceridemia with diabetes was stronger in women than in men. Previous studies had similarly reported increased frequency of hypertension[19,20] and hypertriglyceridemia[30] in women than in men with diabetes. Our findings also corroborate the sex differences in the clustering of metabolic syndrome components reported in previous studies.[31-33] As the coexistence of hypertension and hypertriglyceridemia with diabetes can have more deleterious cardiovascular effects, particularly in women,[20] individuals with one of the components of metabolic syndrome should be screened for having other comorbid conditions as well.

There are some limitations which need to be considered when interpreting our findings. First, there was no data on detailed dietary history including consumptions of fruit and vegetables and alcohol, and levels of physical activity. Residual confounding by those unmeasured variables is, therefore, possible. Second, using only FBG may have underestimated the prevalence of prediabetes in this population as FBG may miss to detect those with isolated impaired glucose toleran.[22] Third, the cross-sectional nature of our study precludes to assess cause and effect relationships.

In summary, we found that prediabetes and diabetes are highly prevalent among adults in Palau, with slight male preponderance for prediabetes. Older age, overall obesity (BMI), central obesity (large WC or WHR), hypertension and hypertriglyceridemia were identified as significant predictors of prediabetes and/or diabetes. In addition to introducing public health interventions to reduce and prevent obesity as early as possible, readopting healthy lifestyles should be promoted

among all adults in Palau.

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