

# Prevalence of Glucose Intolerance Among Native Hawaiians in Two Rural Communities

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RESEARCH (NHHR) PROJECT

**OBJECTIVE** — To estimate prevalence of type 2 diabetes and impaired glucose tolerance (IGT) among a population of native Hawaiians in two rural communities.

**RESEARCH DESIGN AND METHODS** — Prevalence of glucose intolerance was assessed in two rural communities by history (confirmed by record review) or with a 75-g oral glucose tolerance test according to World Health Organization criteria. Anthropometric and demographic data were also obtained. A short survey was used to estimate the prevalence of known diabetes among nonparticipants. Prevalence rates were adjusted using the standard world population of Segi.

**RESULTS** — A total of 574 native Hawaiians age  $\geq 30$  years participated. The crude prevalence of IGT and type 2 diabetes were 15.5 and 20.4%, respectively. Only IGT prevalence was significantly higher ( $P = 0.03$ ) among women (18.7%) than among men (10.9%). Prevalence of glucose intolerance was significantly associated with BMI, waist circumference, and waist-to-hip ratio (WHR). After adjusting for age and BMI, waist circumference and WHR were significantly and independently associated with type 2 diabetes prevalence only among women. Prevalence of type 2 diabetes was not significantly associated with the percentage of Hawaiian ancestry after adjusting for age.

**CONCLUSIONS** — This study observed a high prevalence of glucose intolerance associated with being overweight among native Hawaiians. Age-adjusted type 2 diabetes prevalence was four times higher than among the U.S. National Health and Nutrition Examination Survey (NHANES) II population. Prevalence was high despite high rates of admixture with other ethnic groups of Hawaii, suggesting that these other Asian and Pacific Island populations share similar susceptibility to type 2 diabetes risk.

Native Hawaiians, the indigenous peoples of Hawaii, have been reported to have an increased prevalence of type 2 diabetes compared with other ethnic groups living in Hawaii (1–3). In 1963, Sloan (1) first reported an age-adjusted rate of 48.8 per 1,000 among gainfully

employed full-Hawaiians age  $\geq 14$  years, six times the rate among Caucasians participating in that study. Age-adjusted prevalence among part-Hawaiians was lower (26.6 per 1,000), but still four times higher than among Caucasians. Diagnosis of diabetes was based on a blood glucose level of

$\geq 130$  mg/dl, determined 2–2.5 h after a 50-g glucose meal. Curb et al. (3) observed crude diabetes prevalence rates of 10% for men and 12% for women with a 50% Hawaiian ancestry. Because diabetes was determined by medical history or presence of glycosuria, it is likely that the condition was underdiagnosed.

None of the earlier studies of diabetes prevalence among native Hawaiians applied recommended World Health Organization (WHO) criteria for glucose intolerance. The Native Hawaiian Health Research (NHHR) Project is the first population-based research project to apply WHO criteria in the estimation of glucose intolerance (impaired glucose tolerance [IGT] or type 2 diabetes) prevalence among native Hawaiians. We report the estimated prevalence of glucose intolerance among native Hawaiians participating in the NHHR Project.

**RESEARCH DESIGN AND METHODS** — The study methods of the NHHR Project have been described previously (4) and are summarized here. The NHHR Project was conducted in partnership with existing native Hawaiian health care organizations in the communities of North Kohala, on the island of Hawaii, and Waimea/Kehaha, on the island of Kauai. A door-to-door census was conducted in each of these rural communities to identify all persons eligible for screening. Criteria for participation included the following: 1) native Hawaiian ancestry (the native Polynesian population of Hawaii), 2) resident of the census communities, and 3) nonpregnant adult  $\geq 30$  years of age. Any North Kohala residents reporting some Hawaiian ancestry were eligible to participate. A total of  $\sim 1,100$  native Hawaiian adults were identified in the combined communities, of whom 574 ( $\sim 53\%$ ) completed the full interview and clinical examination. Native Hawaiian ancestry and percentage ancestry were determined by self-report. Of the nonparticipants, 60% responded to a limited survey that was conducted to estimate the prevalence of known diabetes and assess selection bias among the study population.

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**Abbreviations:** IGT, impaired glucose tolerance; NHANES, National Health and Nutrition Examination Survey; NHHR, Native Hawaiian Health Research; POR, prevalence odds ratio; TGI, total glucose intolerance; WHO, World Health Organization; WHR, waist-to-hip ratio.

**Table 1—Age-specific, crude, and age-standardized prevalence of type 2 diabetes among native Hawaiians in two rural communities, NHHR Project, 1993–1996 (n = 574)**

Age-group (years)	Women			Men			Women and men combined		
	All	Type 2 diabetes	Prevalence (%)	All	Type 2 diabetes	Prevalence (%)	All	Type 2 diabetes	Prevalence (%)
30–34	50	3	6.1	29	5	17.2	79	8	10.1
35–39	58	4	6.9	46	3	6.5	104	7	6.7
40–44	62	7	11.3	29	4	13.8	91	11	12.1
45–49	40	10	25.0	35	5	14.3	75	15	20.0
50–54	47	15	31.9	30	7	23.3	77	22	28.6
55–59	19	9	47.4	22	7	31.8	41	16	39.0
60–64	24	10	41.7	11	4	36.4	35	14	40.0
65–69	17	3	17.6	14	6	42.9	31	9	29.0
70–74	18	8	44.4	7	1	14.3	25	9	36.0
≥75	8	1	12.5	8	5	62.5	16	6	37.5
Total	343	70	20.4	231	47	20.4	574	117	20.4
Age-standardized prevalence ≥30 years*			22.2 (17.9–26.6)			22.3 (16.9–27.7)			22.4 (19.0–25.8)
Age-standardized prevalence 30–64 years*			22.2 (17.2–26.6)			18.9 (14.2–23.7)			20.4 (15.6–25.1)

Data are n or %. \*Standardized to the standard world population of Segi (data in parentheses are 95% CIs, computed using normal approximation for calculation of variances).

Blood samples were collected from all participants after an overnight fast of 10–12 h. Individuals not taking insulin or oral diabetic medication underwent a 2-h, 75-g oral glucose tolerance test (OGTT) and were classified according to WHO criteria (5). All plasma glucose levels were assayed in the NHHR laboratory using the glucose oxidase method on a YSI autoanalyzer (Yellow Springs, OH). Medical history of diabetes was confirmed by a record review conducted at the offices of participants' primary care physicians.

Individuals were measured for weight, height, and waist and hip circumference using standardized protocols (6). Specifically, waist circumference was measured with the participant in a standing position with a measuring tape placed horizontally at the participant's natural waist. Hip circumference was also determined in the standing position with a measuring tape placed horizontally at the maximal protrusion of the gluteal muscles (6). BMI was calculated as the weight in kilograms divided by the square of the height in meters. Being overweight was defined as having a BMI ≥27.3 kg/m<sup>2</sup> or 27.8 kg/m<sup>2</sup> for women and men, respectively (7). The waist-to-hip ratio (WHR) was expressed as the ratio of waist-to-hip circumference in centimeters. Central adiposity was defined as a WHR ≥0.9 and 0.8 for men and women, respectively (8).

**Statistical analysis**

The standard world population of Segi (9) was used to calculate age-standardized prevalence using the direct method for glucose intolerance. Standardized estimates for diabetes were calculated using weights for 5-year age-groupings among participants age <65 years for comparison with other populations standardized in a similar fashion (10). Standardized rates were again calculated after including participants age ≥65 years. Because the number of cases of type 2 diabetes and IGT were >10 in each case, the normal approximation was used for the calculation of confidence limits for all summary prevalence rates (10). Crude and age-adjusted prevalence odds ratios (PORs) were calculated using multiple logistic regression to estimate the association among total glucose intolerance (TGI; defined as IGT and type 2 diabetes combined), obesity, central adiposity, and percentage of Hawaiian ancestry. The likelihood ratio  $\chi^2$  test (11) was used to evaluate multiplicative interaction between BMI and WHR. Logistic regression was performed using JMP and SAS statistical software from SAS Institute (Cary, NC).

**RESULTS** — Both communities, North Kohala and West Kauai, had similar prevalence rates of type 2 diabetes (21.2 and 19.2%, respectively; previously known and newly detected diabetes combined), and TGI (35.7 and 36.5%, respectively) was

similar. The age-adjusted prevalence of diabetes among both communities combined was 20.41% (95% CI 16.14–24.61). Diabetes was increasingly prevalent with advancing age, peaking at 37.5% among participants age ≥75 years (Table 1). However, prevalence of IGT appeared to be relatively constant across age-groups (Table 2) and was less common than type 2 diabetes (IGT/TGI ratio = 0.43). Less than half of the participants with diabetes (44%) had a previous history. An additional 15.5% were classified as IGT for a combined TGI prevalence of 36.0%. The crude prevalence of known diabetes was 8.9%. A review of available medical records included 31 participants reporting a previous diagnosis of type 2 diabetes. The diagnoses were confirmed in all 31 participants. The prevalence of known diabetes among Hawaiians who responded to the short nonparticipant survey was higher (15.4%) than among participants, a difference that was of marginal statistical significance after adjusting for age using logistic regression (POR = 1.30 [95% CI 0.98–1.78]).

Age-standardized prevalence (Table 1) for men and women age ≥30 years was 20.4% (95% CI 17.1–23.6). Prevalence of type 2 diabetes was virtually identical among men (20.4% [95% CI 15.2–25.5]) and women (20.4% [95% CI 16.1–24.6]) age ≥30 years, but women in the study were observed to have a significantly higher

**Table 2—Age-specific, crude, and age-standardized prevalence of IGT among native Hawaiians, NHHR Project, 1993–1996 (574)**

Age-group (years)	Women			Men			Women and men combined		
	All	IGT	Prevalence (%)	All	IGT	Prevalence (%)	All	IGT	Prevalence (%)
30–34	50	6	12.2	29	4	13.8	79	10	12.7
35–39	58	7	12.1	46	6	13.0	104	13	12.5
40–44	62	17	27.4	29	2	6.9	91	19	20.9
45–49	40	7	17.5	35	1	2.9	75	8	10.7
50–54	47	10	21.3	30	1	3.3	77	11	14.3
55–59	19	3	15.8	22	3	13.6	41	6	14.6
60–64	24	4	16.7	11	2	18.2	35	6	17.1
65–69	17	6	35.3	14	1	7.1	31	7	22.6
70–74	18	4	22.2	7	3	42.9	25	7	28.0
≥75	8	0	0.0	8	2	25.0	16	2	12.5
Total	343	64	18.7	231	25	10.8	574	89	15.5
Age-standardized prevalence, ≥30 years*			18.2 (14.1–22.2)			11.8 (7.5–16.1)			15.6 (12.5–18.4)
Age-standardized prevalence, 30–64 years			17.6 (16.0–19.2)			9.8 (8.2–11.4)			14.6 (13.0–16.2)

Data are *n* or %. \*Standardized to the standard world population of Segi (data in parentheses are 95% CIs, computed using normal approximation for calculation of variances).

prevalence of IGT than men (18.7% [95% CI 14.1–22.2] among women versus 10.8% [95% CI 6.8–15.0] among men,  $P = 0.03$ ). Among men and women age 30–64 years, age-standardized type 2 diabetes prevalence (18.9 vs. 21.9%, respectively,  $P = 0.47$ ) did not differ significantly. The higher age-standardized IGT prevalence (Table 2) among women (18.2% [95% CI 14.1–22.2]) compared with men (11.8% [95% CI 7.5–16.1]) was only marginally significant ( $P = 0.06$ ); however, the prevalence of TGI was significantly higher among women than men after adjusting for age (34.9 vs. 29.3%, respectively,  $P = 0.01$ ).

Prevalence of type 2 diabetes was significantly higher among Full Hawaiians compared with Part-Hawaiians (34.1 vs. 19.3%,  $POR = 2.16$  [95% CI 1.12–4.18]). After adjusting for age, the  $POR$  was attenuated and was no longer statistically significant ( $POR = 1.53$  [95% CI 0.76–3.07]). Likewise, a marginally significant higher type 2 diabetes prevalence among participants reporting 50% or more Hawaiian ancestry (23.3%), compared with those less than 50% (17.1%;  $POR = 1.47$  [95% CI 0.97–2.24]), was attenuated after adjustment for age ( $POR = 1.1$  [95% CI 0.88–1.37]).

Being overweight was highly prevalent in the study population (66.5% [95% CI 61.1–71.2]), and increased body weight was strongly associated with glucose intolerance (Table 3). The associations between

BMI and glucose intolerance were similar in both men and women ( $POR = 1.36$  vs. 1.48 for men and women, respectively). The correlation between BMI and measures of centrality was higher among men ( $r = 0.41$ ) than among women ( $r = 0.28$ ). Neither waist circumference nor WHR were significantly associated with TGI among men after controlling for the effects of BMI; however, among women, both markers for fat distribution were significantly associated with TGI independently of BMI.

The relationship among TGI prevalence, central adiposity, and obesity is illustrated in Fig. 1. Prevalence was uniformly higher among obese men regardless of the centrality of fat distribution. However, rates were increased markedly among obese and

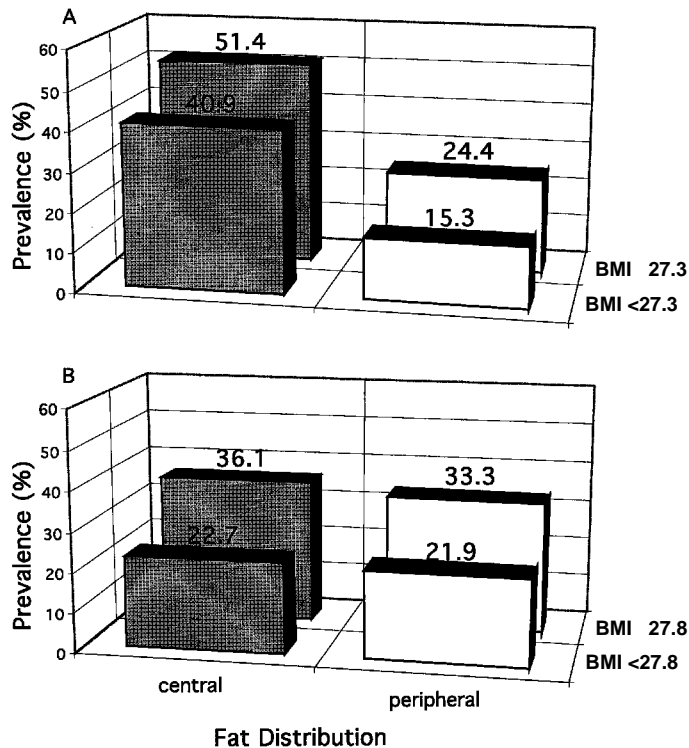
nonobese women with a high centrality. While central adiposity and obesity had independent associations with TGI, there was no statistical evidence for multiplicative interaction between BMI and WHR among women (likelihood ratio  $\chi^2 = 1.81$ ,  $P > 0.05$ ).

**CONCLUSIONS** — Age-adjusted prevalence rates among rural native Hawaiians age 30–64 years who participated in the NHHR Project are the highest reported for any Polynesian or part-Polynesian population standardized using the standard world population of Segi (12–15). Comparison with global estimates of standardized prevalence rates reported by King et al. (10) reveals that the prevalence among

**Table 3—Univariate analysis of associations between TGI and selected anthropometric measurements among native Hawaiians living in two rural communities in Hawaii, 1993–1996**

	Unit increase	Unadjusted	Age-adjusted	Age, BMI-adjusted
<b>Men</b>				
BMI	5 kg/m <sup>2</sup>	1.36 (1.08–1.72)	1.54 (1.19–1.99)	—
WHR	0.1	1.37 (0.84–2.22)	1.28 (0.77–2.15)	0.86 (0.48–1.53)
WC	10 cm	1.27 (1.03–1.56)	1.34 (1.08–1.67)	0.88 (0.57–1.36)
<b>Women</b>				
BMI	5 kg/m <sup>2</sup>	1.48 (1.26–1.74)	1.57 (1.33–1.87)	—
WHR	0.1	3.38 (2.31–4.95)	3.14 (2.12–4.64)	2.61 (1.74–3.92)
WC	10 cm	1.68 (1.43–1.98)	1.70 (1.44–2.02)	1.78 (1.31–2.42)

Data are  $POR$  (95% CI). TGI included individuals with either IGT or type 2 diabetes. WC, waist circumference.



**Figure 1**—Prevalence of glucose intolerance (IGT type 2 diabetes) in relation to body fat distribution and being overweight among Hawaiian women (A) and men (B) in two rural communities.

Hawaiians in this study is among the highest reported among any population with the exception of the Pima and Nauruan populations. Volunteer bias because of low participation rates in this study (53%) may have altered prevalence estimates. However, despite apparently large differences in participation rates between the two communities (56 vs. 42% for North Kohala and West Kauai, respectively), the communities did not differ significantly in prevalence of glucose intolerance. Furthermore, the prevalence of known diabetes in the unexamined who responded to the short survey was higher than among the examined NHHR participants. This suggests that if selection bias occurred in the study population, it would have resulted in an underestimate of glucose intolerance prevalence.

The prevalence of being overweight (BMI >27.8 for men, >27.3 for women) was over twice as high compared with a prevalence of 26% reported for the U.S. population (16), and we observed a strong association between glucose intolerance and increased body weight. However, the high prevalence of being overweight alone may not fully account for the fourfold increase in age-adjusted type 2 diabetes

prevalence compared with non-Hispanic whites enrolled in the National Health and Nutrition Examination Survey (NHANES) II study (10,17). Similarly, as many other studies have reported (18–22), we observed an independent association between central adiposity and glucose intolerance; however, this association was only observed among the women in this study. Lack of association between central adiposity with TGI among men may be explained by the higher correlation between BMI and measures of centrality ( $r = 0.41$ ) when compared with women ( $r = 0.28$ ). As men gain weight, central adiposity also tends to increase, so it is difficult for a statistical model to separate the independent effects of each on glucose intolerance.

The high prevalence reported here is even more remarkable considering that <8% of the participants in this study were Full Hawaiian. Furthermore, unlike other indigenous populations such as Native Americans, where mixed ancestry is associated with reduced risk (23,24), the association between higher percentage of Hawaiian ancestry was not significant once differences in age were considered. There are two possible explanations why type 2 dia-

betes prevalence was not significantly associated with increasing percentage of Hawaiian ancestry. We relied on self-report to classify individuals' percentage ancestry. Misclassification may have been severe, and even though it would be expected to be nondifferential with regard to glucose tolerance status, the resulting bias would be expected to attenuate the observed odds ratio (25). Another possible explanation for the lack of association with percentage of Hawaiian ancestry may be the multi-ethnic nature of this population. Unlike other indigenous populations, where admixture tends to be with the majority ethnic group, Hawaiians often report multiple ethnic groups among their ancestry. Over 50% of NHHR participants reported two or more ancestral ethnic groups besides Hawaiian. Many of these ethnic groups, namely Chinese, Japanese, and Filipinos, have been reported to have similar, high prevalence of diagnosed type 2 diabetes in Hawaii (26). Thus, less protection would be observed among Part-Hawaiians than might occur if admixture occurred with a relatively homogeneous population with clearly lower risk for glucose intolerance.

Other studies that reported lower type 2 diabetes prevalence among other Polynesian populations have typically been conducted among communities that are more isolated geographically and economically, and to varying degrees, were less westernized, or in which westernization was a relatively recent phenomenon. Despite the rural location in which the NHHR participants resided, when compared with other rural Polynesian island communities, the lifestyle of the study population is highly westernized, with relatively high income levels and ready access to automobiles, television, fast food, and other artifacts of urban American culture. Most of these other studies were completed before 1980, and many of these populations have undoubtedly undergone further changes in lifestyle that may contribute to increased type 2 diabetes prevalence. A more recent 1991 survey of adults age 30–50 years in New Caledonia (27) reported rates among urban-living Polynesians that approach rates observed in this study. Another recent report comparing prevalence rates among three separate communities in Western Samoa (28) confirmed that type 2 diabetes prevalence had increased significantly after 13 years of follow-up. Dowe et al. (29) proposed that a high ratio of IGT to TGI may be related to increasing prevalence among a population.

The low IGT/TGI ratio observed in this study suggests that prevalence rates have peaked among Hawaiians, but other Polynesian populations exhibit high IGT/TGI ratios (29). Thus, as economy and lifestyle continue to change among these Pacific Island populations, concurrent increases in prevalence approaching or exceeding that observed among Hawaiians will impose a significant public health burden on these populations.

The observations of this study also have important implications beyond the Pacific basin. Asian and Pacific Island Americans are the fastest-growing minority in the U.S. and their numbers are predicted to quadruple by the year 2038 (30). Within this group, native Hawaiians comprise nearly 60% of the estimated 365,000 Pacific Islanders and represent the single largest ethnic group of Pacific Island origin in the U.S. (30). Thus, it is highly likely that the high prevalence of diabetes among the ethnically heterogeneous population of Hawaiians may represent a future scenario for an increasingly multi-ethnic U.S. population.

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