Prevalence of Diabetes and Glucose Intolerance in an Ethnically Diverse Rural Community of Hawaii

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Background: We report the prevalence of diabetes in a rural, multiethnic community in Hawaii, of predominantly Asian and Native Hawaiian ancestry, by using 1997 World Health Organization diagnostic criteria applied to a two-hour oral glucose tolerance test.

Methods: This cross-sectional survey included 1452 men and nonpregnant women who were >18 years of age. Blood was drawn in the fasting and postchallenge states. Individuals under pharmacologic treatment for diabetes were excluded. Information obtained included demographics, medical history, dietary intake, physical activity, and anthropometric measurements.

Results: Prevalence of diabetes was approximately three-fold higher among Asian and Native Hawaiian ancestry groups than among Caucasians, even after adjusting for other risk factors. Furthermore, diabetes prevalence was similar among all non-Caucasian ethnic groups despite significant differences in body mass indices.

Conclusions: These findings indicate that earlier reports of high prevalence of diagnosed diabetes among Asians and Hawaiian ethnic groups were not due to detection bias, since our study revealed similar prevalence of previously unrecognized diabetes. Furthermore, similar prevalence among these groups was observed despite significant differences in body mass indices, diet, and physical activity. This apparent paradox may reflect limitations in the measurement of these risk factors; differences in the impact of these risk factors on diabetes risk in different ethnic groups; or ethnic differences in lifestyle, biochemical, or genetic factors that were not examined in this study. (*Ethn Dis*. 2007;17:250–255)

Key Words: Diabetes, Glucose, Hawaii

Introduction

The metabolic syndrome refers to a cluster of metabolic risk factors for coronary heart disease that includes abdominal obesity, atherogenic dyslipidemia, elevated blood pressure, and glucose intolerance. We previously observed a high prevalence of metabolic syndrome in a multiethnic population in Hawaii[1] by using criteria recommended by the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (ATP III).[2] However, these criteria are likely to underestimate the prevalence of glucose intolerance since they rely on fasting plasma glucose levels, which have a relatively poor sensitivity in the detection of type 2 diabetes and impaired glucose tolerance compared to the oral glucose challenge test (OGTT).[3]

Most of Hawaii's population is of Asian and Pacific Islander ancestry – populations that have been reported to be at higher risk for type 2 diabetes.[4–9] For example, the Hawaii Behavioral Risk Factor Surveillance System (BRFSS) has reported a high prevalence of diabetes in people of Chinese, Japanese, Filipino, and Hawaiian ancestries (http://www.hawaii.gov/health/statistics/brfss/). However, BRFSS data included only cases with prior diagnoses of diabetes and, therefore, are subject to significant biases due to potential disparities in healthcare access and lack of a standardized diagnostic criterion. To date, only one community-based study has been conducted in Hawaii that applied standardized World Health Organization (WHO) diagnostic criteria to estimate the prevalence of type 2 diabetes in Native Hawaiians[10] but did not include participants of Asian and European ethnic ancestries. Therefore, we report here the prevalence of diabetes, according to the current WHO diagnostic criteria,[11] in a multiethnic Hawaii population.

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Methods

The methods of the Kōhala Health Research Project have been described previously.[12] In brief, the survey was cross-sectional in design and was conducted between 1997 and 2000. All men and nonpregnant women ≥18 years of age who were residing in North Kōhala, Hawaii, were invited to participate. Estimates based on census data place the number of eligible residents at ≈3500 adults. Participants were solicited via telephone with a cross-reference directory. Community sup-

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port for the research project was fostered through local public television announcements, flyers posted at community centers and stores, and presentations given to community organizations.

Medical History and Clinical Data

A medical history was obtained from each participant that included history of diabetes and diabetic medication use. The health screening examination took approximately two to three hours. Blood was drawn in the fasting state and after a two-hour, 75-g OGTT. Participants fasted (with the exception of water) for 10–14 hours before the appointment. Those under pharmacologic treatment for diabetes were excluded from the OGTT. Participants were classified according to the 1998 WHO criteria for diabetes and abnormalities of glucose regulation.[13] In brief, participants were classified as having impaired fasting glucose (IFG), impaired glucose tolerance (IGT), or type 2 diabetes mellitus (T2DM). The 1998 WHO criteria group patients with either IFG or IGT into a larger category termed impaired glucose regulation (IGR). All other participants were considered to have normal glucose tolerance. For some analyses, T2DM, IFG, and IGT were treated as a combined category of total glucose intolerance (TGI).

Anthropometric Measurements

Weight, height, and waist-hip circumferences, taken in the standing position, were obtained from each participant using standardized protocols.[14] All measurements were performed in triplicate and averaged for the final estimates. Body mass index (BMI) was assessed by dividing the weight in kilograms by the square of height in meters (kg/m^2).[15] Waist:hip ratios (WHR) were measured by dividing the hip measurement by the waist measurement and used as a measure of central adiposity.[16]

Physical Activity

The average energy expenditure from leisure and occupational activity for the past month and past year were estimated by using the Pima Indian Physical Activity Questionnaire,[17] adapted to include activities unique to Hawaii customs. The participants reported their participation in 37 leisure time activities. Metabolic equivalents (METS) were calculated by using standardized estimates of energy expenditure as recommended by the American Colleges of Sports Medicine Compendium for Physical Activity.[18] When used as a continuous variable, data were transformed by taking the natural logarithm to stabilize the variance. The 75th percentile (50 METS) was used to dichotomize the data and classify participants with regard to an active vs nonactive lifestyle.

Population

Of the estimated 3500 eligible adults residing in Kōhala during the study period, >1500 individuals participated in at least a portion of the survey. A total of 1452 participants completed the entire three- to four-hour examination and interview. Ethnic ancestry was determined by self-report. The three largest non-mixed ethnic groups were Caucasians (n=291), Japanese Americans (n=203), and Filipino Americans (n=193). Only 10 Hawaiians reported 100% Hawaiian ancestry; the remainder, categorized as mixed with native Hawaiian ancestry (n=510), were defined as any participant who had ancestors residing in the islands of Hawaii before the initial Western contact in 1778. A fifth group was composed of people of mixed-ethnic ancestry but with no Hawaiian ancestry (n=255).

Statistical Analysis

Chi-square analysis was used to compare simple cross-tabulations between two categorical variables, such as T2DM and ethnic group. Crude and adjusted relative risks were estimated by using modified Poisson regression with Proc GENMOD in the SAS statistical package (SAS Institute, Gary, Ind). Although odds ratios estimated by logistic regression are often used to estimate the relative risk for dichotomous outcomes, when the outcome is common, as with diabetes prevalence, the odds ratio may overestimate the relative risk. Poisson regression, however, provides direct estimates of relative risk and is more appropriate when the event is in question, T2DM in this case, is not rare (>10%). Modified Poisson regression has the additional advantage of providing more robust standard errors for estimation of confidence intervals[19] for hypothesis testing.

The effects of other widely recognized risk factors were included in a forward stepwise fashion to adjust for spurious associations that may have been introduced by ethnic variance in the distribution of these potentially confounding variables. Selection of these variables was based on both physiologic and statistical considerations.

RESULTS

Table 1 summarizes comparisons of distributions of known T2DM risk factors in the main ethnic groups making up the Kōhala Health Research study population, with Caucasian ancestry participants as a reference group. Mean BMI was significantly higher among Native Hawaiians and people of mixed-ethnic ancestry compared to Caucasians. Japanese and Filipinos did not differ significantly from Caucasians.

Total fat and saturated fat intakes, but not percentage of calories from fat, were significantly higher among Native Hawaiians compared to Caucasians. Total and saturated fat intakes were significantly lower in Japanese and Filipinos than for Caucasians, but only

Table 1. Means and standard deviations of selected population characteristics by ethnic group, comparing Caucasians to all other Asian/Pacific Island ancestry groups among participants using analysis of variance (*N*=1452)

	Caucasian	Filipino	Hawaiian	Japanese	Other/Mixed
n	295	186	526	190	255
Gender (men/women)	148/147	72/114	234/292	93/97	118/137
Age	49.4 (12.4)	53.7 (16.2)*	44.1 (14.6)†	59.6 (16.4)†	47.4 (16.5)
Past week leisure time activity (METS)	49.8 (94.9)	28.4 (30.5)†	69 (460.7)	33.9 (37.9)*	50.3 (90.8)
Total dietary energy intake (kcal)	2267.6 (848.6)	2376.8 (1008.6)	2720 (1222.8)†	2122.6 (756.1)	2423.3 (1083.2)
Dietary fiber intake (g)	24.8 (11.2)	20.5 (9.9)†	21.4 (12.2)†	19.5 (9.9)†	21 (11.1)†
Total fat intake (g)	86.3 (37.2)	77.7 (43.9)	101.8 (54.7)†	72.9 (32.9)†	94.2 (49.1)
Saturated fat intake (g)	25.7 (11.8)	23 (13.7)	30.5 (16.9)†	20.6 (9.2)†	28.2 (15.9)
Carbohydrate intake (g)	287.0 (118.3)	329.9 (128.7)†	345.3 (153.8)†	289.4 (108.8)	300.3 (136.4)
Percent calories from fat	32.9 (7.5)	31.4 (7.5)	33.3 (7.1)	32.3 (7.3)	32.5 (7.1)
Percent calories from saturated fat	9.7 (2.6)	9.3 (2.6)†	9.9 (2.4)	9.4 (2.7)	9.6 (2.5)
Percent calories from carbohydrates	51.7 (9.0)	53.9 (8.4)	51.4 (8.6)	52.9 (9.1)	52.2 (8.9)
Body mass index (kg/m^2)	25.5 (5.3)	26.1 (5.8)	31.3 (8.8)†	25.7 (4.2)	27.5 (5.5)†
Waist circumference (cm)	88.7 (13.4)	88.7 (12.3)	97.6 (16.5)†	88.5 (13.0)	91.6 (13.7)*
Waist (cm)/hip (cm)	.924 (.07)	.944 (.07)†	.944 (.07)†	.945 (.06)†	.940 (.08)*

* $P<.05$; † $P<.01$.

Filipinos had a lower intake as percentage of total calories. Carbohydrate intake was significantly higher among Hawaiians and Filipinos than among Caucasians, but percentage of calories from carbohydrates was significantly higher only for Filipinos. Dietary fiber intake was significantly lower among all non-Caucasian ethnic groups compared to Caucasians. Thus, higher intakes of total fat, saturated fat and carbohydrate among Hawaiians were related to their higher total food consumption.

Prevalence of each category of glucose intolerance by ethnic groups is summarized in Table 2. The total prevalence of T2DM was 15.70%, and another 17.15% met the criteria for IGR. We observed similar prevalence of T2DM and TGI among men and women (data not shown); however, women were observed to have significantly higher prevalence of IGT (14.89%) than men (9.77%). All non-Caucasian ethnic groups had a similarly high prevalence of diabetes (>15%), while diabetes prevalence was lowest among Caucasians (4.41%). Prevalence of impaired glucose regulation was highest among Japanese (26.84%) and Filipino (22.04%) participants; however, the lowest prevalence of IFG was observed among those of Japanese ancestry (2.63%), despite a high prevalence of IGT and T2DM. Overall, diabetes prevalence was similarly high among all non-Caucasian participants, all of which were significantly higher than that observed in Caucasian participants (Table 2).

Tables 3 summarizes the risk ratios for total glucose intolerance for each ethnic group compared to Caucasians. Prevalence risk ratios indicate a significant increase in prevalence among all ethnic groups in comparison to Caucasians, which was roughly doubled in all groups with the exception of those of mixed-ethnic ancestry, which was associated with a 46% increase in prevalence. After adjusting for age, BMI, WHR, gender, and dietary factors, the risk ratios attenuated slightly but were significant for all ethnic groups except for the mixed-ethnic ancestry group.

Ethnic differences in T2DM prevalence were even more pronounced and

Table 2. Prevalence (%) of glucose intolerance in a multiethnic population in Kohala, Hawaii, 1997–2000

Ethnic Ancestry	*n*	Impaired Fasting Glucose (IFG)	Impaired Glucose Tolerance (IGT)	Impaired Glucose Regulation (IFG+IGT)	Newly Diagnosed Diabetes	Past History of Diabetes	Total with Diabetes	Total Glucose Intolerance
Caucasian	295	11 (3.73%)	29 (9.83%)	40 (13.56%)	9 (3.05%)	4 (1.36%)	13 (4.41%)	53 (17.97%)
Filipino	186	12 (6.45%)	29 (15.59%)	41 (22.04%)	17 (9.14%)	19 (10.22%)	36 (19.35%)	77 (41.4%)
Hawaiian/ part-Hawaiian	526	32 (6.08%)	53 (10.08%)	85 (16.16%)	44 (8.37%)	56 (10.65%)	100 (19.01%)	185 (35.17%)
Japanese	190	5 (2.63%)	46 (24.21%)	51 (26.84%)	19 (10.00%)	21 (11.05%)	40 (21.05%)	91 (47.89%)
Other/mixed non-Hawaiian	255	7 (2.75%)	25 (9.80%)	32 (12.55%)	15 (5.88%)	24 (9.41%)	39 (15.29%)	71 (27.84%)
Total	1452	67 (4.61%)	182 (12.53%)	249 (17.15%)	104 (7.16%)	124 (8.54%)	228 (15.70%)	477 (32.85%)

Table 3. Crude and adjusted prevalence ratios for total glucose intolerance estimated by Poisson regression by using generalized linear models,* comparing Caucasian participants to participants of all other ethnic ancestry categories

	Model 1	Model 2	Model 3	Model 4	Model 5
Caucasian	-	-	-	-	-
Filipino	2.24 (1.58–3.19)	1.87 (1.31–2.67)	1.86 (1.30–2.64)	1.76 (1.24–2.51)	1.68 (1.17–2.40)
Hawaiian/part-Hawaiian	1.94 (1.43–2.63)	2.19 (1.61–2.97)	1.82 (1.32–2.49)	1.69 (1.23–2.32)	1.66 (1.21–2.28)
Japanese	2.67 (1.90–3.74)	1.86 (1.32–2.63)	1.88 (1.33–2.65)	1.82 (1.29–2.58)	1.79 (1.26–2.53)
Other/mixed non-Hawaiian	1.46 (1.02–2.10)	1.46 (1.02–2.09)	1.37 (0.95–1.96)	1.27 (0.88–1.83)	1.23 (0.86–1.78)

* Model 1: unadjusted; model 2: adjusted for age; model 3: adjusted for age, body mass index; model 4: adjusted for age, body mass index, waist:hip ratio; model 5: adjusted for age, body mass index, waist:hip ratio, gender, total caloric intake, dietary fiber intake, carbohydrate intake.

were also significantly higher among all non-Caucasian ethnic groups compared to Caucasians. Risk ratios indicate an increase in risk of 3.5- to nearly 5-fold compared to Caucasians (Table 4). Even after adjusting for potential confounding variables, risk ratios remained significant and were only slightly attenuated, with approximately a three-fold increase in the prevalence of diabetes. Furthermore, when age-adjusted T2DM prevalence was compared only in normal-weight individuals (BMI <25 kg/m^2; data not shown), statistically significant risk ratios from 3.5 to 5 were still observed in all non-Caucasian ethnic groups relative to Caucasians. For all analyses based on either T2DM or TGI, no significant differences were seen between the non-Caucasian ancestry categories.

DISCUSSION

After adjusting for age, BMI, WHR, gender, level of leisure time physical activity, dietary fiber, carbohydrate, and energy intake, the prevalence of T2DM and TGI among Hawaiians, Filipinos, and Japanese was significantly higher than among Caucasians. Furthermore, with the exception of the Caucasian group, T2DM prevalence was similar among all ethnic groups despite significant differences in BMI. These findings suggest that either BMI does not serve as an equally valid proxy for body fat across different ethnic groups or that body fat plays a very different role in altering diabetes risk in different ethnic groups. The increased prevalence of diabetes among people of Asian ancestries (Japanese and Filipino) may reflect differences in body fat percentages that are not captured by BMI estimates.[20–22] Likewise, differences in the abdominal fat deposition may be the primary risk factor among these groups – a fat depot that is poorly estimated by either BMI or WHR. Boyko et al demonstrated that intra-abdominal visceral fat assessed by computed tomographic scanning methods was a better predictor of diabetes risk than anthropometric measures of adiposity.[23] Waist:hip circumference ratios have been reported to account for only ≈50% of the variance of abdominal visceral fat.[24]

Alternatively, other factors, such as differences in diet and physical activity, may account for the ethnic disparities in the prevalence of T2DM and glucose intolerance. We observed ethnic differences in several dietary factors and level of leisure time physical activity. Although inclusion of these variables in multiple regression models did not explain the ethnic disparity in the primary outcomes, health-related behaviors, such as these are difficult to measure accurately and precisely by self-report. Therefore, recall bias re-

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Table 4. Crude and adjusted prevalence ratios for type 2 diabetes estimated by Poisson regression using generalized linear models,* comparing Caucasian participants to participants of all other ethnic ancestry categories

	Model 1	Model 2	Model 3	Model 4	Model 5
Caucasian	-	-	-	-	-
Filipino	4.78 (2.56–8.93)	2.97 (1.57–5.60)	3.02 (1.60–5.70)	2.92 (1.55–5.50)	2.9 (1.54–5.47)
Hawaiian/part-Hawaiian	4.39 (2.33–8.28)	3.42 (1.81–6.48)	3.41 (1.8–6.44)	3.17 (1.67–6.00)	3.11 (1.64–5.92)
Japanese	4.28 (2.40–7.63)	4.93 (2.76–8.79)	3.85 (2.13–6.96)	3.43 (1.90–6.19)	3.41 (1.89–6.16)
Other/mixed non-Hawaiian	3.47 (1.85–6.50)	3.38 (1.81–6.34)	3.12 (1.66–5.85)	2.86 (1.52–5.39)	2.83 (1.50–5.34)

* Model 1: unadjusted; model 2: adjusted for age; model 3: adjusted for age, body mass index; model 4: adjusted for age, body mass index, waist:hip ratio; model 5: adjusted for age, body mass index, waist:hip ratio, gender, total caloric intake, dietary fiber intake, carbohydrate intake.

garding these behaviors would be expected to underestimate the impact of these factors on explaining the ethnic disparities in glucose intolerance observed in this study.

Finally, the high prevalence in participants of Japanese and Filipino ancestry despite relatively low body mass indices, may reflect a difference in the relative roles of insulin resistance versus insulin secretion in response to a glucose load. Type 2 diabetes mellitus (T2DM) in nonobese Japanese is preceded by decreased insulin secretion.[25] Kosaka proposed a subtype of T2DM marked by impaired insulin secretion that occurs in nonobese individuals as observed in Japanese, Korean, and Vietnamese populations.[8,25,26] This inability of pancreatic β-cells to secrete sufficient insulin has been well described in the Japanese[27,28] and would result in increased risk for T2DM at lower levels of obesity-related insulin resistance.

In conclusion, ethnic differences in BMI and WHR did not account for the ethnic variation in the prevalence of diabetes and total glucose intolerance. Furthermore, the significant ethnic differences observed in diabetes risk among the normal-weight participants suggest ethnic differences in adiposity that cannot explain the ethnic disparities in glucose tolerance. Ethnic variance in diet and level of physical activity also did not explain these ethnic disparities, but the inherent error in measuring lifestyle characteristics may have resulted in underestimation of their effects in models including these variables. Finally, ethnicity may be associated with other culturally determined lifestyle factors, other biochemical factors, or even genetic factors that were not examined in this study, which may predispose these ethnic populations to a higher risk for total glucose intolerance.

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