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Ethnic Differences in Weight Gain and Diabetes Risk: The Multiethnic Cohort

Yukiko Morimoto¹, Susan M. Schembre¹, Astrid Steinbrecher¹, Eva Erber¹, Ian Pagano¹, Andrew Grandinetti², Laurence N. Kolonel¹, and Gertraud Maskarinec¹

¹Cancer Research Center, University of Hawaii, Honolulu, Hawaii, U.S.A.

²John A. Burns School of Medicine, University of Hawaii, Honolulu, Hawaii, U.S.A.

Abstract

Aim—To improve our understanding of excess body weight and risk for diabetes type 2, we examined the influence of weight change in the Hawaii component of the Multiethnic Cohort with 78,006 Caucasians, Japanese Americans, and Native Hawaiians.

Methods—Participants aged 58.5±9.2 years completed a questionnaire at cohort entry (Qx1) that included weight at age 21 and a follow-up questionnaire 5 years later (Qx2). After 14 years of follow-up, 8,892 incident diabetes cases were identified through self-report or linkages to the major health plans in Hawaii. We applied Cox regression, stratified by age and adjusted for confounders, to estimate hazard ratios (HR).

Results—The mean weight gain from age 21 to Qx1 was 10.5 ± 11.0 kg and 0.8 ± 5.6 kg between Qx1 and Qx2. Diabetes risk showed a significant dose-response relation with weight gain since age 21 ($p < 0.0001$). The respective HRs for a weight gain of 5–10 kg and of ≥ 25 kg were 1.8 (95% CI: 1.7–2.0) and 7.7 (95% CI: 7.1–8.4), while weight loss of more than 5 kg significantly reduced risk (HR = 0.7; 95% CI: 0.6–0.9). The association of weight loss and reduced diabetes risk were strongest for Caucasians, intermediate for Japanese Americans, and weakest for Native Hawaiians. On the other hand, the absolute risk of developing diabetes was higher for Japanese Americans and Native Hawaiians than for Caucasians at all BMI levels. Weight change between Qx1 and Qx2 conferred a smaller risk.

Conclusion—These findings support current public health recommendations for weight control, in particular among ethnic groups at high risk for diabetes.

Keywords

Type 2 diabetes; BMI; obesity; weight gain, ethnicity; prospective studies

The global burden of diabetes continues to rise, in particular among ethnic groups other than Caucasian [1–3]. Native Hawaiians suffer from extremely high rates of obesity and diabetes, but, despite their relatively low body weight, persons with Japanese ancestry are also disproportionately affected by diabetes [4]. Among the more than 44,000 Japanese Americans, 14,000 Native Hawaiians, and 35,000 Caucasians in the Hawaii component of the Multiethnic Cohort (MEC), a previous analysis found risk estimates of 2.1, 4.1, and 9.5 for a body mass index (BMI) of 22.0–24.9, 25.0–29.9, and ≥ 30.0 kg/m² as compared to <22 kg/m² [5]. However, the risk was highest for Japanese Americans and intermediate for

Address for correspondence: Gertraud Maskarinec, MD, PhD Cancer Research Center of Hawaii 1236 Lauhala Street Honolulu, HI 96813, U.S.A. Phone: 1-808-586-3078 FAX: 1-808-586-2982 gertraud@crch.hawaii.edu.

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Native Hawaiians in each BMI category with relative risks of 1.9 for Native Hawaiians and 2.7 for Japanese Americans as compared to Caucasians [5]. The observation that BMI alone does not explain ethnic differences in diabetes risk has also been reported by others [6;7]. Beyond overweight and obesity, the effect of weight gain is of interest because it indicates a surplus in energy intake over long time periods that promotes insulin resistance and eventually leads to the development of diabetes [8]. Several reports have shown the importance of weight gain in addition to baseline weight [7;9-13]. Furthermore, results of the Nurses Health Study (NHS) indicate that the effects of weight gain on diabetes risk might be modified by ethnicity, because for each 5-kg increment in weight since age 18 the risk for diabetes was 1.8 for Asians, which was significantly higher than the risk estimates of 1.4 for Hispanics, 1.4 for African Americans, and 1.4 for Caucasians [7]. We examined the effect of weight change on diabetes risk among Hawaii MEC participants for two time periods: from age 21 to cohort entry in 1993-1996 (T1) and from cohort entry to 1999-2003 (T2) when a follow-up questionnaire was sent to cohort members. Our hypothesis was that weight gain would confer an additional risk beyond BMI at cohort entry and that the adverse effect would be more pronounced for participants of Japanese descent.

METHODS

Study population

The MEC Study was established from 1993 through 1996 to examine diet and cancer among different ethnic groups in Hawaii and California [14]. The current analysis is limited to the Hawaii component due to the availability of diabetes incidence data from the major local health plans [15]. The Hawaii component of the MEC consists of 103,898 members of three main ethnic groups (Native Hawaiians, Caucasians, and Japanese Americans). Subjects aged 45-75 years entered the cohort by completing a 26-page, self-administered mailed survey (Qx1) that asked about demographic background, medical conditions, current height and weight as well as weight at age 21, lifestyle factors, and regular diet during the recent year [16]. Response rates were highest for Japanese Americans (46% for men and 51% for women) and lowest for Native Hawaiians (28% for men and 35% for women), but the MEC yielded a representative group of the population as evidenced by a comparison of educational levels and marital status with corresponding census data [14]. After exclusion of ineligible subjects (10,028 prevalent diabetes cases, 8,797 other ethnic groups, 6,202 with missing covariates, 855 unconfirmed diabetes cases, and 10 with lack of follow-up information or missing diabetes information at baseline), 78,006 (37,482 men and 40,524 women) were part of the present analysis. The study was approved by the Committee on Human Studies at the University of Hawaii and by the Institutional Review Board at Kaiser Permanente Hawaii.

Case ascertainment

The detailed follow-up and categorization of diabetes cases, as reported previously, was only available for the Hawaii component of the MEC [5]. Incident cases were identified through three sources: 1) a short follow-up questionnaire (Qx2) was sent to all MEC members in 1999-2003 to update information on medical conditions and achieved a response rate of 84%, 2) a medication questionnaire including diabetes drugs administered in 2001-2007 was available for 38% of the 103,898 subjects, and 3) in July 2007, the MEC database was linked with the two major health plans in Hawaii, Blue Cross/Blue Shield and Kaiser Permanente, to identify diabetes cases. After excluding 855 cases that were self-reported in a questionnaire but not confirmed by a health insurance plan, 2,337 of the 8,892 incident cases were first identified in Qx2, 1,029 through the medication questionnaire, and 5,526 by one of the health plans. Since the MEC was established, annual linkages with state and national death certificate files have been performed to obtain information on vital status.

Statistical Methods

All statistical analyses were performed using the SAS statistical software, version 9.2 (SAS Institute, Inc., Cary, NC). We computed self-reported weight change between age 21 and Qx1 (T1) as well as change from Qx1 to Qx2 (T2). For weight change since age 21, we created seven categories (>5 kg weight loss; ± 5 kg as stable weight; and 5-10, 10-15, 15-20, 20-25, and ≥ 25 kg weight gain). Categories were limited to four during T2 (>5 kg weight loss, ± 5 kg, 5-10, and ≥ 10 kg weight gain). The follow-up time for non-cases was calculated as the time between the date of Qx1 and the date of death or the last date when data on diabetes status was available, 2007 for cohort members who had not died. For incident cases, the follow-up time was calculated from Qx1 to an estimated diagnosis date as described elsewhere [5].

We used Cox proportional hazards regression models to estimate diabetes risk related to categories of weight change using ± 5 kg as the reference category. We calculated hazard ratios (HR) and 95% confidence intervals (CI) using follow-up time as the underlying time metric [17] while controlling for age at Qx1 by stratification. Because of previously established associations, all models were adjusted for sex, ethnicity (Japanese Americans and Native Hawaiians vs. Caucasians), physical activity level (quintiles), and education (13-15 and >15 vs. ≤ 12 years). The models for weight change during T1 also included BMI category at age 21 (23.0-24.9, 25.0-29.9, and ≥ 30.0 vs. <23.0 kg/m²). The T2 models included BMI category at Qx1 (25.0-29.9, and ≥ 30.0 vs. <25.0 kg/m²) and excluded diabetes cases diagnosed at Qx2. Due to missing values, the respective sample sizes for T1 and T2 were 75,590 and 61,982 persons. Linear trend tests were performed by fitting a model with weight change categories as a single ordinal variable. We performed stratifications by ethnicity, BMI at age 21 (<23 vs. ≥ 23 kg/m²), and BMI at Qx1 (<25 vs. ≥ 25 kg/m²). Furthermore, we fitted a T1 model for weight change that adjusted simultaneously for BMI at age 21 and at Qx1. No major violations of the proportional hazards assumption were observed when examined with Kaplan-Meier survival curves [18].

RESULTS

Of the 8,892 incident diabetes cases, 1,870 were Caucasian, 5,230 Japanese American, and 1,792 Native Hawaiian (Table 1). Mean age at cohort entry was 58.5 ± 9.2 years. Mean time periods for T1 and T2 were 37.4 ± 9.2 years ($N = 75,590$) and 5.5 ± 0.8 years ($N = 61,982$). The mean weight gain was 10.5 ± 11.0 kg during T1 and 0.8 ± 5.6 kg during T2. Japanese Americans were the leanest group at each time point and reported the least weight gain from age 21 to Qx1, while Native Hawaiians had the highest BMI at each time point and reported the greatest weight gain since age 21.

Cox regression models indicated significant associations of weight change during T1 and T2 with diabetes incidence (Table 2). The relative risk related to a weight loss of >5 kg since age 21 was 25% lower as compared to no weight change (HR = 0.74; 95% CI: 0.61-0.88). The respective HRs for those who gained 5-10 kg and ≥ 25 kg were 1.82 (95% CI: 1.68-1.97) and 7.74 (95% CI: 7.13-8.41) with a clear dose-response relation ($p < 0.0001$). Weight loss during T2 did not lower diabetes risk and a weight gain of >10 kg increased diabetes incidence significantly by 60% with no difference by ethnicity (p for interaction = 0.89).

The interaction term of weight change since age 21 and ethnicity was highly significant ($p < 0.0001$). Therefore, we conducted ethnic specific analyses using Caucasians with stable weight as reference group (Table 2). Each weight gain category conferred a higher risk of diabetes; however, weight gain of ≥ 25 kg was associated with a HR of 11.57 (95% CI: 9.65-13.88) in Caucasians, 18.50 (95% CI: 15.44-22.17) in Hawaiians, and 30.59 (95% CI: 25.31- 36.97) in Japanese Americans. Weight loss of >5 kg was associated with a 44%

reduced diabetes risk in Caucasians. When we examined this association in Japanese Americans (using stable-weight Japanese-Americans as reference), the HR for weight loss was 0.70 (95% CI: 0.56-0.87) and in Native Hawaiians (using stable-weight Hawaiians as reference) the HR was 0.89 (95% CI: 0.58-1.38) (data not shown).

In addition, we found a strong interaction between weight gain and BMI at age 21 ($p = 0.0001$). Thus, we conducted analysis stratified by BMI at age 21 (<23 and ≥ 23 kg/m²), again using Caucasians with stable weight as reference group (Figure 1). Due to the higher absolute diabetes risk in Japanese Americans and Native Hawaiians, the incidence of diabetes exceeded that for Caucasians across weight gain categories. The HRs associated with weight gain categories for participants with a BMI of <23 kg/m² at age 21 were considerably higher than for those with a BMI of ≥ 23 kg/m² at age 21. For the low BMI group, the respective HRs for the highest category were 16.7, 30.1, and 47.0 for Caucasians, Native Hawaiians, and Japanese Americans, whereas for the ≥ 23 kg/m² group, the HRs ranged between 7.0 and 14.7.

The interaction of BMI at Qx1 with weight change during T2 (Figure 2) was not statistically significant ($p = 0.23$). Nevertheless, those with a BMI of ≥ 25 kg/m² experienced little additional risk due to weight gain, whereas the risk estimates among normal weight participants were elevated for weight gains ≥ 10 kg in all ethnic groups (HR = 2.6, 6.8, and 10.8 for Caucasians, Native Hawaiians, and Japanese Americans, respectively).

Simultaneous adjustment for BMI at age 21 and BMI at Qx1 attenuated the diabetes risk estimates for weight change during T1, but the associations remained significant. The HR for a weight gain of ≥ 25 kg was 4.3 (95%CI: 3.8-4.8) for all participants as compared to those with stable weight and 6.1 (95%CI: 5.0-7.5), 15.8 (95%CI: 12.8-19.4), and 10.1 (95%CI: 8.3-12.3) for Caucasians, Japanese Americans and Native Hawaiians as compared to stable weight Caucasians. BMI at age 21 and BMI at Qx1 both increased diabetes risk significantly.

DISCUSSION

This analysis among three ethnic groups in Hawaii detected a strong effect of weight gain over more than 25 years after taking into account BMI at age 21 and at cohort entry when the mean age of participants was 58.5 years. A weight gain of 5-10 kg between age 21 and cohort entry doubled diabetes risk and a gain of ≥ 25 kg was associated with an 8-fold higher risk, while weight loss of >5 kg reduced risk by 25%. As compared to stable weight Caucasians, the adverse effects of weight gain were more pronounced for participants of Japanese and Native Hawaiian descent. Similarly, the association between weight gain and diabetes was stronger for those with a BMI of <23 kg/m² at age 21 as compared with those with BMI ≥ 23 kg/m². Weight gain during 5.5 years of follow-up after cohort entry conferred a 60% increased risk, but weight loss in this interval was not associated with diabetes incidence, probably because older participants might have already experienced weight loss due to aging or chronic conditions.

Although modeling BMI at age 21 and at cohort entry attenuated the risk estimates for weight change slightly, each variable remained a significant predictor for diabetes risk. Also, the association between diabetes risk and weight gain was strongest in initially normal weight participants, i.e., those with a BMI of <23 kg/m² at age 21, thus, underlining the importance of maintaining a low body weight throughout life. As hypothesized, the association between weight gain and diabetes was more pronounced for participants of Japanese descent. The prevailing theory is that excess BMI and weight gain have a stronger effect among persons with Asian descent due to their relatively higher proportion of body fat

and, in particular, their tendency to accumulate visceral fat [19]. Visceral fat, but not abdominal subcutaneous fat was shown to be a risk factor for insulin resistance in Japanese-Americans [20]. Furthermore mechanistic studies indicate decreased insulin secretion during early stages of diabetes development among Japanese but not among Caucasian subjects [8], thus Japanese subjects might not be able to compensate for insulin resistance through increased insulin production as seen in Caucasians. In our analyses, the diabetes risk estimates for Native Hawaiians were intermediate of those for Caucasians and Japanese-Americans. This may be explained by the ethnic admixture of this group. In the baseline questionnaire that allowed more than one ethnicity, more than 95% of Caucasians or Japanese-Americans indicated only one ethnicity, while among Native Hawaiians 53% reported some Caucasian ancestry and 54% some Asian ancestry [21].

Our findings agree with previous reports from Caucasian populations that found elevated diabetes risks associated with weight gain [9;10;12;22-24]. In the NHS, the relative risks for diabetes among women with weight gains of 5.0-7.9 kg and 8.0-10.9 kg were 1.9 and 2.7, respectively, as compared to women with stable weight since age 18 [22]. Similar risk estimates were reported in a community-based study in California [23], British men [10], the Johns Hopkins Precursors Study [12], and NHANES I [9]. In 10 years of follow-up within NHANES I, a 5-8 kg weight gain doubled risk and a gain of more than 20 kg quadrupled risk [9]. Also comparable to our findings, weight gain or fluctuation between the ages of 40 and 60 of at least 10 lbs significantly increased the diabetes rate by 40% [23]. In agreement with our stratified results, weight gain in Pima women was related to diabetes incidence only in those who were not initially overweight [24]. Similarly, another report observed that among middle-aged men with a BMI ≥ 28 further weight gain made little difference in their risk for diabetes [10]. However, in the NHANES I report, stratification by weight status at baseline showed little difference [9].

Few previous investigations included persons from ethnic backgrounds other than Caucasian. Three reports included participants with Asian descent, one from Japan [11], one from China [13], the NHS with only 801 Asians [7], and one study focused on Pima Indians [24]. A report from male Japanese employees showed a high diabetes incidence of 14.7 cases per 1,000 person years and a 14% higher diabetes risk with a >2 kg weight gain [11]. The 801 women of Asian descent in the NHS had a 2-fold higher incidence rate than Caucasians. For each 5-kg increase in weight gain, the risk estimates differed significantly by ethnicity with 1.84 for Asians and 1.37 for Caucasians ($p < 0.05$) [7]. Among middle aged Chinese women in Shanghai, a weight gain of >0.75 kg/year since age 20, which corresponded to approximately 20 kg total, was associated with a risk of 12.7 as compared to those with no weight gain [13]. Among Pima Indian men, the age-adjusted diabetes incidence was 56.7 per 1,000 person-years in those with ≥ 3 kg annual weight gain and 16.9 for those losing weight [24].

Several limitations of this investigation need to be kept in mind. Body weight at all points in time relied on self-reports. In particular, weight at age 21 may have been recalled incorrectly after more than 25 years. There is evidence, however, that remote weight earlier in life can be recalled with some accuracy as shown in elderly subjects [25], the NHS [26], a follow-up of U.S. adults [27], and the Newton Girls' Study [28]. Unfortunately, no information on body weight between the three time points was available. Therefore, we could not investigate the possible effect of weight fluctuation. Also, no information on reasons for weight loss was collected, i.e., voluntary or involuntary. Weight loss, in particular during T2, may have been involuntary as a result of disease or aging. Because BMI is not an accurate estimate of body fat and because the proportion of body fat differs by ethnicity [29;30], it is possible that the true ethnic differences are of a different magnitude. It would have been preferable to examine other anthropometric measures, such as waist

circumference. The risk estimates for T1 were based exclusively on new cases diagnosed after cohort entry and excluded the 10,028 self-reported prevalent cases.

Although all cases of diabetes were confirmed by a health plan [15], detection bias is possible given obese subjects or those with high-risk ethnic backgrounds may be more likely to undergo testing for diabetes. This type of bias would overestimate the association between BMI and diabetes. Also, we did not have information on the type of diabetes. However, given the median age of 59 years at Qx1, more than 90% of diabetes cases are likely type 2. On the other hand, this study had several important strengths, foremost its prospective nature with 14 years of follow-up and the inclusion of three ethnic groups with great variations in BMI and diabetes risk. Other strengths include the large sample size and the ascertainment of diabetes status through linkages with health plans [5]. Although diabetes at Qx2 was self-reported, only cases that were confirmed by the health plan linkages in 2007 were included in the analysis.

In conclusion, we observed a strong dose-response relation between weight gain and diabetes risk in all ethnic groups. Data from this analysis indicate that weight gain over time leads to an increasing diabetes risk, particularly among lean individuals and Native Hawaiians and Japanese Americans. The implications of the findings are that even low levels of weight gain lead to an elevated diabetes risk and that lifestyle modifications leading to weight loss are effective in lowering diabetes risk. Our observations support current public health recommendations to reduce the risk of diabetes risk by preventing weight gain throughout adulthood and encourage weight loss in overweight and obese individuals. This advice is even more important for Japanese Americans and Native Hawaiians who, relative to Caucasians, develop diabetes at a higher rate across all weight and weight gain categories. Future analyses should also explore potentially causal mechanisms that promote greater diabetes risk with equal weight gain in some population subgroups (e.g. dietary intakes, body-fat distribution and frequency of weight fluctuation).

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REFERENCES

- [1]. Wild S, Roglic G, Green A, Sicree R, King H. Global prevalence of diabetes: estimates for the year 2000 and projections for 2030. *Diabetes Care*. 2004; 27:1047–1053. [PubMed: 15111519]
- [2]. Burchfiel CM, Curb JD, Rodriguez BL, Yano K, Hwang LJ, Fong KO, et al. Incidence and predictors of diabetes in Japanese-American men. The Honolulu Heart Program. *Ann Epidemiol*. 1995; 5:33–43. [PubMed: 7728283]
- [3]. Grandinetti A, Kaholokula JK, Theriault AG, Mor JM, Chang HK, Waslien C. Prevalence of diabetes and glucose intolerance in an ethnically diverse rural community of Hawaii. *Ethn Dis*. 2007; 17:250–255. [PubMed: 17682354]
- [4]. McNeely MJ, Boyko EJ. Type 2 diabetes prevalence in Asian Americans: results of a national health survey. *Diabetes Care*. 2004; 27:66–69. [PubMed: 14693968]
- [5]. Maskarinec G, Erber E, Grandinetti A, Verheus M, Oum R, Hopping BN, et al. Diabetes incidence based on linkages with health plans: the multiethnic cohort. *Diabetes*. 2009; 58:1732–1738. [PubMed: 19258435]

- [6]. Kim HS, Park SY, Grandinetti A, Holck PS, Waslien C. Major dietary patterns, ethnicity, and prevalence of type 2 diabetes in rural Hawaii. *Nutrition*. 2008; 24:1065–1072. [PubMed: 18586461]
- [7]. Shai I, Jiang R, Manson JE, Stampfer MJ, Willett WC, Colditz GA, et al. Ethnicity, obesity, and risk of type 2 diabetes in women: a 20-year follow-up study. *Diabetes Care*. 2006; 29:1585–1590. [PubMed: 16801583]
- [8]. Kosaka K, Kuzuya T, Yoshinaga H, Hagura R. A prospective study of health check examinees for the development of non-insulin-dependent diabetes mellitus: relationship of the incidence of diabetes with the initial insulinogenic index and degree of obesity. *Diabet Med*. 1996; 13:S120–S126. [PubMed: 8894495]
- [9]. Ford ES, Williamson DF, Liu S. Weight change and diabetes incidence: findings from a national cohort of US adults. *Am J Epidemiol*. 1997; 146:214–222. [PubMed: 9247005]
- [10]. Wannamethee SG, Shaper AG. Weight change and duration of overweight and obesity in the incidence of type 2 diabetes. *Diabetes Care*. 1999; 22:1266–1272. [PubMed: 10480769]
- [11]. Ishikawa-Takata K, Ohta T, Moritaki K, Gotou T, Inoue S. Obesity, weight change and risks for hypertension, diabetes and hypercholesterolemia in Japanese men. *Eur J Clin Nutr*. 2002; 56:601–607. [PubMed: 12080398]
- [12]. Brancati FL, Wang NY, Mead LA, Liang KY, Klag MJ. Body weight patterns from 20 to 49 years of age and subsequent risk for diabetes mellitus: the Johns Hopkins Precursors Study. *Arch Intern Med*. 1999; 159:957–963. [PubMed: 10326937]
- [13]. Villegas R, Shu XO, Yang G, Matthews CE, Li H, Cai H, et al. Energy balance and type 2 diabetes: a report from the Shanghai Women's Health Study. *Nutr Metab Cardiovasc Dis*. 2009; 19:190–197. [PubMed: 18774701]
- [14]. Kolonel LN, Henderson BE, Hankin JH, Nomura AMY, Wilkens LR, Pike MC, et al. A multiethnic cohort in Hawaii and Los Angeles: baseline characteristics. *Am J Epidemiol*. 2000; 151:346–357. [PubMed: 10695593]
- [15]. Maskarinec G, Erber E, Grandinetti A, Verheus M, Oum R, Hopping BN, et al. Diabetes incidence based on linkages with health plans: the multiethnic cohort. *Diabetes*. 2009; 58:1732–1738. [PubMed: 19258435]
- [16]. Stram DO, Hankin JH, Wilkens LR, Henderson B, Kolonel LN. Calibration of the dietary questionnaire for a multiethnic cohort in Hawaii and Los Angeles. *Am J Epidemiol*. 2000; 151:358–370. [PubMed: 10695594]
- [17]. Thiebaut AC, Benichou J. Choice of time-scale in Cox's model analysis of epidemiologic cohort data: a simulation study. *Stat Med*. 2004; 23:3803–3820. [PubMed: 15580597]
- [18]. Kleinbaum, DG. *Survival Analysis*. Springer; New York: 1995.
- [19]. Tanaka S, Horimai C, Katsukawa F. Ethnic differences in abdominal visceral fat accumulation between Japanese, African-Americans, and Caucasians: a meta-analysis. *Acta Diabetol*. 2003; 40(Suppl 1):S302–S304. [PubMed: 14618500]
- [20]. Hayashi T, Boyko EJ, McNeely MJ, Leonetti DL, Kahn SE, Fujimoto WY. Visceral adiposity, not abdominal subcutaneous fat area, is associated with an increase in future insulin resistance in Japanese Americans. *Diabetes*. 2008; 57:1269–1275. [PubMed: 18299316]
- [21]. Albright CL, Steffen AD, Wilkens LR, Henderson BE, Kolonel LN. The prevalence of obesity in ethnic admixture adults. *Obesity (Silver Spring)*. 2008; 16:1138–1143. [PubMed: 18356848]
- [22]. Colditz GA, Willett WC, Rotnitzky A, Manson JE. Weight gain as a risk factor for clinical diabetes mellitus in women. *Ann Intern Med*. 1995; 122:481–486. [PubMed: 7872581]
- [23]. Holbrook TL, Barrett-Connor E, Wingard DL. The association of lifetime weight and weight control patterns with diabetes among men and women in an adult community. *Int J Obes*. 1989; 13:723–729. [PubMed: 2583926]
- [24]. Hanson RL, Narayan KM, McCance DR, Pettitt DJ, Jacobsson LT, Bennett PH, et al. Rate of weight gain, weight fluctuation, and incidence of NIDDM. *Diabetes*. 1995; 44:261–266. [PubMed: 7883111]
- [25]. Must A, Willett WC, Dietz WH. Remote recall of childhood height, weight, and body build by elderly subjects. *Am J Epidemiol*. 1993; 138:56–64. [PubMed: 8333427]

- [26]. Troy LM, Hunter DJ, Manson JE, Colditz GA, Stampfer MJ, Willett WC. The validity of recalled weight among younger women. *Int J Obes Relat Metab Disord*. 1995; 19:570–572. [PubMed: 7489028]
- [27]. Perry GS, Byers TE, Mokdad AH, Serdula MK, Williamson DF. The validity of self-reports of past body weights by U.S. adults. *Epidemiology*. 1995; 6:61–66. [PubMed: 7888448]
- [28]. Must A, Phillips SM, Naumova EN, Blum M, Harris S, wson-Hughes B, et al. Recall of early menstrual history and menarcheal body size: after 30 years, how well do women remember? *Am J Epidemiol*. 2002; 155:672–679. [PubMed: 11914195]
- [29]. Deurenberg P, Durenberg-Yap M, Guricci S. Asians are different from Caucasians and from each other in their body mass index/body fat per cent relationship. *Obes Rev*. 2002; 3:141–146. [PubMed: 12164465]
- [30]. Lear SA, Humphries KH, Kohli S, Chockalingam A, Frohlich JJ, Birmingham CL. Visceral adipose tissue accumulation differs according to ethnic background: results of the Multicultural Community Health Assessment Trial (M-CHAT). *Am J Clin Nutr*. 2007; 86:353–359. [PubMed: 17684205]

Figure 1. Diabetes risk related to weight change between age 21 and Qx1 By BMI at age 21 and ethnicity, Hawaii component of the Multiethnic Cohort*

*Qx1 was administered at cohort entry in 1993-1996; all models were adjusted for sex, age, education, physical activity, and BMI at age 21; the reference group is Caucasians with ± 5 kg weight change.

Figure 2. Diabetes risk related to weight change between Qx1 and Qx2 By BMI at cohort entry and ethnicity, Hawaii component of the Multiethnic Cohort*

*Qx1 was administered at cohort entry in 1993-1996 and Qx2 in 1999-2003; all models were adjusted for sex, age, education, physical activity, and BMI at cohort entry; the reference group is Caucasians with $\pm 5 \text{ kg}$ weight change.

Table 1

Incident cases of diabetes and baseline characteristics of the Hawaii Component of the Multiethnic Cohort Study *

		Caucasian		Japanese American		Native Hawaiian		All
Characteristic		Men (n = 15,604)	Women (n = 15,111)	Men (n = 17,147)	Women (n = 19,267)	Men (n = 4,731)	Women (n = 6,146)	(n = 78,006)
Cases (%)	Cases	7.2	5.0	16.1	12.8	17.2	15.9	11.4
	Non-cases	92.8	95.0	83.9	87.2	82.8	84.1	88.6
Age (%)	45-54 y	44.7	47.1	32.8	32.5	50.1	53.2	40.5
	55-64 y	27.7	26.7	27.9	30.5	29.3	28.2	28.4
	65+ y	27.6	26.2	39.3	37.0	20.6	18.6	31.1
Education (%)	12 y	19.5	23.6	39.4	41.4	48.1	53.0	34.4
	13-15 y	29.0	34.3	28.8	28.1	31.6	29.8	30.0
	> 15 y	51.5	42.1	31.8	30.5	20.3	17.2	35.6
BMI at Qx1 (%)	< 25 kg/m ²	47.0	62.3	57.5	73.9	26.9	38.3	47.0
	25-30	40.7	25.1	36.7	21.4	44.0	33.5	40.7
	30 kg/m ²	12.3	12.6	5.8	4.7	29.1	28.2	12.3
BMI (kg/m ²)								
At age 21	mean ± SD	22.3±2.8	20.4±2.6	21.6±2.6	20.1±2.4	23.3±3.5	21.4±3.4	21.2±2.9
At Qx1	mean ± SD	25.8±3.9	24.6±4.9	24.7±3.3	23.1±3.8	28.1±5.0	27.5±5.9	24.9±4.5
At Qx2	mean ± SD	26.6±4.1	25.6±5.2	25.3±3.5	23.9±4.0	28.8±5.2	28.5±6.2	25.7±4.7
Weight change (kg) ^								
Age 21 to Qx1 (T1)	mean ± SD	11.1±11.2	11.3±11.8	9.0±8.6	7.5±8.2	15.5±14.7	16.5±13.8	10.5±11.0
Qx1 to Qx2 (T2)	mean ± SD	1.0±6.4	1.4±6.0	0.2±4.6	0.7±3.9	0.5±7.4	1.4±7.3	0.8±5.6
Physical activity (METs)	mean ± SD	1.7 ± 0.3	1.6 ± 0.3	1.7 ± 0.3	1.6 ± 0.2	1.7 ± 0.4	1.6 ± 0.3	1.6 ± 0.3
Total energy (kcal)	mean ± SD	2316 ± 891	1824 ± 689	2293 ± 833	1823 ± 674	2800 ± 1322	2341 ± 1219	2125 ± 907

* The following subjects were excluded from the 103,898 members of the Hawaii component of the MEC: 10,028 prevalent diabetes cases, 8,797 other ethnicity, 6,202 with missing covariates, 855 unconfirmed diabetes cases, and 10 with lack of follow-up information or missing diabetes information at Qx1.

^ Calculated among those who were included in the first (N = 75,590) and second analysis (N = 61,982).

Table 2

Weight change and diabetes risk in the Hawaii component of the Multiethnic Cohort *

Weight change (kg)		All			Caucasian			Japanese American			Native Hawaiian		
		N	HR*	95% CI	N	HR*	95% CI	N	HR*	95% CI	N	HR*	95% CI
	>-5	134	0.74	0.61-0.88	18	0.56	0.34-0.92	90	2.75	2.11-3.58	26	1.94	1.27-2.96
Between													
age 21	±5	1062	1.00		147	1.00		807	4.06	3.40-4.84	108	3.21	2.50-4.12
and													
Qx1 [#]	5-10	1525	1.82	1.68-1.97	221	2.05	1.67-2.53	1147	7.46	6.28-8.87	157	5.20	4.15-6.52
	10-15	1790	2.67	2.47-2.88	274	3.01	2.46-3.68	1268	11.19	9.43-13.29	248	7.28	5.93-8.94
	15-20	1275	3.74	3.44-4.06	261	4.60	3.76-5.64	775	15.50	12.98-18.51	239	10.05	8.17-12.36
	20-25	1163	4.90	4.50-5.33	313	6.55	5.38-7.97	554	20.03	16.68-24.05	296	12.65	10.36-15.43
	25	1639	7.74	7.13-8.41	579	11.57	9.65-13.88	410	30.59	25.31-36.97	650	18.50	15.44-22.17
	<i>P for trend</i>			<0.0001			<0.0001 [†]			<0.0001 [†]			<0.0001 [†]
Between	-5	532	0.98	0.89-1.07	126	0.88	0.73-1.07	262	3.07	<i>2.66-3.54</i>	144	1.49	1.24-1.80
Qx1 and													
Qx2 [#]	±5	4011	1.00		719	1.00		2717	3.05	2.81-3.32	575	1.97	1.76-2.21
	5-10	699	1.31	1.21-1.42	193	1.30	1.11-1.52	346	4.01	3.53-4.57	160	2.52	2.12-3.00
	10	328	1.59	1.41-1.78	127	1.66	1.37-2.00	84	4.46	3.55-5.59	117	2.44	2.00-2.99
	<i>P for trend</i>			<0.0001			<0.0001 [†]			<0.0001 [†]			<0.0001 [†]

* Adjusted for ethnicity, sex, physical activity (quintiles), education (12-15 and >15 vs. 12 years) and BMI (age 21 or cohort entry).

[#] Qx1 was administered at cohort entry in 1993-1996 and Qx2 in 1999-2003.[†] p for trend derived by fitting a model with weight change categories as single ordinal variable for each ethnic strata separately