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The preventable proportion of type 2 diabetes by ethnicity: The Multiethnic Cohort

Astrid Steinbrecher, PhD¹, Yukiko Morimoto, MS, RD¹, Sreang Heak, MPA¹, Nicholas Ollberding, PhD¹, Karly S. Geller, PhD¹, Andrew Grandinetti, PhD², Laurence N. Kolonel, MD, PhD¹, and Gertraud Maskarinec, MD, PhD¹

¹ University of Hawaii Cancer Center, Honolulu, HI, USA

² John A. Burns School of Medicine, University of Hawaii, Honolulu, HI, USA

Abstract

Purpose—To estimate the population attributable risk (PAR) associated with modifiable risk factors for diabetes among Caucasians, Native Hawaiians, and Japanese Americans in the Hawaii component of the Multiethnic Cohort.

Methods—This analysis is based on 74,970 cohort participants aged 45–75 years who completed a questionnaire on demographics, diet, and lifestyle factors in 1993–1996. After a mean follow-up time of 12.1 (0.01–14.4) years, 8559 diabetes cases were identified by self-report, a medication questionnaire, and through health plan linkages. Hazard ratios for diabetes and partial PARs for single and different combinations of modifiable risk factors were estimated.

Results—Overweight, physical inactivity, high meat intake, no alcohol consumption, and smoking were positively associated with diabetes risk in all ethnic groups. The estimated PARs suggested that among men, 78%, and among women, 83%, of new diabetes cases could have been avoided if all individuals had been in the low risk category for all of the modifiable risk factors. The slightly lower PARs in Japanese Americans were not significantly different from those in Caucasians and Native Hawaiians.

Conclusions—Although PARs varied slightly over ethnicity, our findings do not support ethnic-specific prevention strategies; interventions targeted at multiple behaviors are needed in all ethnic groups.

Keywords

ethnicity; prevention; prospective study; risk factors; type 2 diabetes mellitus

Introduction

Given the large burden of morbidity and mortality caused by type 2 diabetes mellitus, the identification of modifiable risk factors as a tool for primary prevention is essential. While obesity and physical inactivity are established risk factors, alcohol consumption, processed

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

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red meat and fiber intake, and smoking also influence risk (1–5). Since some behaviors cluster or co-occur (6;7) and lead to a multiplication of negative health outcomes (8), it is important to investigate these factors in combination (9). The population attributable risk (PAR) describes the proportion of cases in a population that could be prevented if all the individuals were in a lower risk category for risk factors of interest (10–12). The great advantage of this method is that it provides an estimate of the public health importance of the risk factors (12) because it considers the strength of the exposure-disease association and the prevalence of the exposure in the population (10). The full PAR quantifies the proportional reduction expected if all known risk factors were to be eliminated (10). However, type 2 diabetes is a multi-factorial disease, and some factors, e.g., age and race/ethnicity, cannot be eliminated. Partial PAR calculations make it possible to estimate the proportion of disease that can be prevented if single risk factors or specific combinations are eliminated while others remain unchanged but are still included in the model (10).

Diabetes incidence is considerably higher among Japanese Americans than Caucasians (13) and the prevalence of risk factors also varies by ethnicity (14). For example in the Multiethnic Cohort (MEC) (15), Native Hawaiians have higher and Japanese Americans lower rates of obesity and smoking than Caucasians, while Caucasians consume more alcohol. To assess the relative importance of modifiable risk factors across ethnic groups, we evaluated risk factors for which associations with diabetes had been described, and estimated the proportion of preventable cases if the exposures could be eliminated. While controlling for non-modifiable risk factors, we calculated the partial PAR for single or combinations of modifiable risk factors for the Hawaii component of the MEC (13;15) and separately for Caucasians, Native Hawaiians, and Japanese Americans.

Methods

Study population

The MEC was designed to evaluate associations between diet and cancer among five different ethnic groups living in Hawaii and California, USA (15). In 1993–1996, >215,000 men and women, aged 45–75 years, were enrolled by returning a mailed self-administered survey consisting of a food frequency questionnaire (FFQ) and questions on demographics, medical conditions, anthropometric measures, and lifestyle factors. Response rates ranged from 28–51% in the different ethnic-sex groups, and comparisons with US census data indicated that the MEC participants represent all levels of education. Since a linkage with health plans was only possible in Hawaii, we restricted the present study to the Hawaii component of the MEC, consisting of 103,898 participants of primarily Caucasian, Japanese American, and Native Hawaiian ancestry (13). We further excluded subjects with prevalent diabetes at study entry (n=10,028), questionable incident diabetes status (n=1036), other ethnicity (n=8692), and invalid or missing data on covariates (n=9172), resulting in a study population of 74,970 participants (36,075 men and 38,895 women). In comparison to the entire Hawaii component of the MEC (13), individuals included in the present study were very similar. The slightly younger age, better education, and lower obesity rate are primarily due to the exclusion of persons with diabetes at baseline and of those who died before the health plan linkage. Study protocols were approved by the Committee on Human Studies at the University of Hawaii and by the Institutional Review Board of Kaiser Permanente.

Case ascertainment

Incident diabetes cases were identified through a short follow-up questionnaire (1999–2003) asking about medical conditions (response rate 84%), a medication questionnaire (2003–2006) including diabetes drugs (response rate 38%), and linkage with health insurance plans in 2007 (13). All cohort participants known to be alive and not refusing to participate were

linked with the diabetes care registries of the two major health insurers that capture 90% of the population of Hawaii: Kaiser Permanente Hawaii (KP) and Blue Cross/Blue Shield. Entrance into the diabetes care registries is based on multiple pieces of evidence from several databases, such as repeated outpatient visits for diabetes, clinical information, pharmacy records, or hospital discharge diagnoses. Linkage with the health plan was performed through probability matching of last and first name, middle initial, birth month and year, and sex; questionable matches were reviewed manually using current address information. The success rate was high; of the 20,539 KP members who reported diabetes in a questionnaire (n=2524), 83% were identified as cases by KP (13). Self-reported diabetes cases not confirmed by a health plan were excluded from the current analysis. Annual linkages with state and national death certificate files were performed for information on vital status.

Exposure assessment

We categorized relevant risk factors from the baseline questionnaire as follows: age (5-year groupings), educational attainment (<13, 13–15, ≥16 years), physical activity (mean hours per week of strenuous sports, e.g., jogging, tennis, aerobics, as never, 1/2–1, 2–3, ≥4 h/week) and smoking status (never, former, current smoker) (15). Weight and height were self-reported and body mass index (BMI) was calculated and classified into normal weight (<25.0 kg/m²), overweight (25.0–29.9 kg/m²), and obese (≥30.0 kg/m²). Furthermore, we repeated the analysis with lower BMI cut points set at <23.0 kg/m², 23.0–27.5 kg/m², and ≥27.5 kg/m² for Japanese Americans as recommended for Asians (16), which better reflect their higher health risks at lower BMI as compared to Caucasians. Data on the diet consumed during the previous year was assessed by a FFQ specifically designed for use in the MEC (17). In a calibration study using three 24-hour dietary recalls, average correlation coefficients indicated good validity; they ranged from 0.57 to 0.75 for nutrient densities in the different sex-ethnic groups and there was only a weak trend for higher correlations in Caucasian than Japanese American women but not in men (17). Red meat, dietary fiber, and alcohol intake were included as dietary modifiable risk factors, since these foods had shown significant associations with diabetes risk in previous analyses (18–20). Food group intake for processed red meat and dietary fiber was calculated as energy densities (g/4184 kJ*d) and grouped into sex-specific quintiles. Persons consuming <0.4 g/d alcohol, i.e., one drink per month, were classified as non-drinkers and those consuming ≥0.4 g/d as drinkers.

Statistical analysis

All analyses were performed stratified by sex to take into account differences in the prevalence of risk factors and the incidence of diabetes (13;15). Hazard ratios (HR) and 95% confidence intervals (CI) for diabetes associated with modifiable and non-modifiable risk factors were estimated using Cox proportional hazards regression with follow-up time as the underlying time metric. Follow-up time was calculated as the time between the date of baseline questionnaire and date of diabetes diagnosis, date of death, or last date when diabetes status was available, i.e., date of the follow-up or medication questionnaire or date of health plan linkage (13). All risk factors, non-modifiable (age, ethnicity, education), considered non-modifiable (hypertension), and modifiable (BMI, physical activity, processed red meat intake, dietary fiber, alcohol, smoking), were fit simultaneously using the lowest risk level as the referent. Analyses were repeated stratified by ethnicity. Partial PARs for single modifiable risk factors or combinations of modifiable risk factors were estimated through the method described by Spiegelman and colleagues (10) using a publicly available SAS Macro (<http://www.hsph.harvard.edu/faculty/spiegelman/par.html>). Ethnic differences were assessed using interaction terms in the regression models and F-tests for the PARs. All analyses were performed with the SAS statistical software, version 9.2 (SAS Institute, Inc., Cary, NC, USA).

Results

During a mean follow-up time of 12.1 (0.01–14.4) years, 8559 incident cases of diabetes were identified. The proportion of incident diabetes cases was highest among Native Hawaiians, followed by Japanese Americans and lowest in Caucasians (Table 1). In all men (Table 2), overweight and obesity, physical inactivity, processed red meat intake, no alcohol, and being a former or current smoker increased the risk of diabetes significantly. Stratified by ethnicity, most of these positive associations remained significant in all groups, with the exception of smoking, which did not confer a higher risk in Caucasians. In men and women, the interaction terms with ethnicity were statistically significant for all risk factors except dietary fiber. For example, the strength of the association with obesity varied considerably by ethnicity ($p < 0.0001$), with HRs of 6.79 (95% CI 5.64–8.18) for Caucasians, 3.69 (95% CI 2.90–4.69) for Native Hawaiians, and 3.91 (95% CI 3.45–4.43) for Japanese Americans. Processed red meat intake increased diabetes risk by 71% in Caucasians and by 46% in the two other groups. Dietary fiber intake showed an association in Caucasian men only. Similarly, a high BMI, physical inactivity, processed red meat intake, no alcohol, and current or former smoking were significantly associated with diabetes in women (Table 3). When stratified by ethnicity, current or former smoking increased risk only in Japanese Americans. The magnitude of the HRs associated with BMI, physical activity, alcohol intake, or processed red meat intake tended to be higher in Caucasians than in Japanese Americans. Dietary fiber intake showed no significant associations.

Overall, these findings suggest that 92% (95% CI 83–97%) of diabetes in men could be prevented if all modifiable and non-modifiable diabetes risk factors were eliminated (Table 4). For individual risk factors, 50% of diabetes cases could be prevented by lowering BMI to $< 25 \text{ kg/m}^2$. Limiting meat intake or moderate alcohol consumption would each prevent 30% of cases, while engaging in sports for $\geq 4 \text{ h/week}$ would prevent 13% of cases. Although the ethnic-specific PARs varied slightly, the order of the risk factors stayed the same within each group. BMI remained the factor with the highest partial PAR although the proportion of preventable cases was significantly lower in Japanese Americans (38%) than in Caucasians (65%), or Native Hawaiians (60%). Lowering the cut point for BMI to 23 kg/m^2 increased the proportion of preventable cases to 52% in Japanese Americans. Eliminating all modifiable risk factors would avoid 78% of all cases; however, eliminating all modifiable risk factors except BMI may prevent as many as 57% of cases. Other combinations, e.g., dietary (meat, fiber, alcohol) or behavioral factors (physical activity, alcohol, smoking), might prevent a large proportion of cases (57% and 40%).

In women, 95% of diabetes cases would be preventable if all risk factors, and 83% if all modifiable risk factors, were eliminated (Table 5). BMI had a PAR of 50% for all women, 64% for Caucasians, 67% for Native Hawaiians, and 38% for Japanese Americans. Again, setting the BMI cut point at 23 kg/m^2 in Japanese Americans increased the PAR to 54%. Drinking alcohol, reducing meat intake, and engaging in physical activity would prevent considerable proportions of diabetes, although being active would avoid more cases in Caucasians (41%) than in Japanese Americans (18%). Furthermore, several combinations of modifiable risk factors yielded PARs of over 50%, with lower PARs in Japanese Americans than in Caucasians. However, F-tests in men and women indicated that only the partial PARs for BMI differed significantly by ethnicity, while the full and the other partial PARs did not.

Discussion

In this large multiethnic study, modifiable risk factors, including BMI, physical activity, processed red meat intake, alcohol consumption, and smoking were all independently

associated with the risk of diabetes. Based on our PAR computations, 78% and 83% of incident diabetes cases could have been prevented among men and women, respectively, if all individuals had been in the lowest risk category for all the modifiable risk factors studied. When we examined the risk factors separately, the highest PAR was associated with having a BMI of ≥ 25 kg/m², irrespective of sex or ethnicity. In general, the percentage of avoidable diabetes cases was highest among Caucasians, followed by Native Hawaiians, and lowest among Japanese Americans. Defining normal weight as < 23 kg/m² in Japanese Americans increased the PAR because, at equal BMI, Asians tend to have a higher proportion of body fat and a larger amount of visceral adipose tissue than Caucasians (21;22).

The evidence from previous studies is compelling for most risk factors we used to estimate the PARs, but BMI emerges as the strongest risk factor. Intervention studies with weight reduction as the primary target indicate that the development of diabetes can be prevented or delayed (23;24). Regular physical activity reduces the risk of diabetes by 20–30% (1) and even moderate physical activity, such as 30 min/d of brisk walking, seems to be beneficial (25). Besides its influence on body weight and body fat accumulation, physical activity might directly impact diabetes risk by increasing insulin-independent muscle glucose uptake and improving insulin sensitivity (26;27). As seen in a recent meta-analysis of 20 cohort studies, moderate alcohol use may reduce the risk of developing diabetes (4), probably due to increased insulin sensitivity (28) or the anti-inflammatory effects of alcohol (29). In addition, specific food groups like meat have been linked to increased diabetes risk (2), presumably through heme iron, which promotes oxidative damage, or nitrites, which can be converted to nitrosamines, both causing damage to pancreatic beta cells (30;31). Dietary fiber and magnesium have been associated with reduced diabetes risk (5), possibly because they are found in foods with a low glycemic index, which produce a lower demand for insulin and decrease insulin resistance (32). However, we found no association of dietary fiber with diabetes risk in this study, except for a weak association in Caucasian men. Active smoking was significantly associated with diabetes, but the HRs in our study were lower than the relative risk of 1.44 reported by a meta-analysis of 25 prospective cohort studies (3). Due to the small proportion of smokers, and in particular heavy smokers (5.3% reported > 20 cigarettes per day), separate risk estimates for light and heavy smokers were not feasible. This approach may have slightly underestimated the role of smoking.

The strength of the exposure-disease association was strongest for BMI; in combination with the high prevalence of overweight and obesity in this cohort, the estimated PAR for BMI indicated that half of the incident diabetes cases may have been preventable through adequate weight control. In comparing men and women, we saw that the PARs for processed red meat intake were of similar magnitude, while the PARs for regular physical activity and alcohol consumption tended to be higher in women. This was due to the stronger exposure-disease associations and the lower prevalence of engaging in physical activity and drinking alcohol among women. Although current smoking was associated with a higher risk of diabetes in men and women, the respective PARs were small and non-significant. If all modifiable risk factors were optimized, 3 out of 4 cases could be avoided, which underlines the importance of lifestyle changes for diabetes prevention. Even changes in factors other than BMI could lead to a reduction of as many as 50% of all cases. Clustering of risk factors is common (33–35), but promotion of several lifestyle changes at one time seems warranted as individuals who adopt one healthy behavior are more likely to adopt an additional healthy behavior (36). Thus, interventions targeting multiple risk factors may be more effective in preventing diabetes (33–36).

Our results agree with other studies estimating PARs for diabetes, although, due to variations in the prevalence of risk factors, PARs always depend on the underlying study population. In the Nurses Health Study (37), 87% (95% CI 83–91%) of the diabetes cases

could be attributed to BMI, diet, and physical activity; adding smoking and alcohol intake increased the proportion to 91% (95% CI 83–95%). In a pooled dataset from Finland (11), five risk factors, including BMI, physical activity, alcohol intake, smoking, and serum vitamin D levels, were responsible for 82% (95% CI 70–90%) of the incident cases. BMI alone accounted for 77% (95% CI 53–88%) of diabetes cases. A prospective study in older adults found that even later in life, the combination of physical activity, diet, smoking, alcohol use, waist circumference, and BMI was associated with a markedly lower incidence of new-onset diabetes mellitus and 9 out of 10 diabetes cases appeared to be attributable to these factors (38). In all reports, BMI was by far the most important risk factor, underlining the importance of inadequate weight control in diabetes etiology.

Ethnic-specific PARs for all six modifiable risk factors were higher among Caucasians than Japanese Americans, but, with the exception of the partial PAR for BMI, not statistically significant. When we examined single modifiable risk factors, the relative contribution of each factor to diabetes incidence followed the same ordering irrespective of ethnicity. Even after reducing the BMI cut point to 23 kg/m², the gap between Japanese Americans and Caucasians persisted. Weaker differences were observed for physical activity and alcohol intake and none for processed red meat intake. Thus, the lower PARs in Japanese Americans might in part be explained by the different cut points for obesity. However, the degree to which non-modifiable factors like age or genetic background might contribute to diabetes risk in different ethnic groups may also differ as shown for several genetic variants (39). For BMI and weight gain, not only the prevalence of the risk factor differs by ethnicity but also the strength of the association; the HRs were significantly higher for Asians than Caucasians (13;40). It is important to consider the absolute diabetes risk by ethnic group; with 58 cases per 10,000 persons-years, the age-adjusted incidence rate in Caucasians was considerably lower than for Japanese Americans (125 cases) and Native Hawaiians (155 cases) (13). Thus, if all participants were in the low risk category of the modifiable risk factors, the number of preventable cases per 10,000 person-years would be 50 and 52 for Caucasian men and women, 88 and 91 for Japanese American men and women, and 129 and 138 for Native Hawaiian men and women.

Limitations of the present study include the data collection method, which relied primarily on self-reports. However, the FFQ was validated (17), the comprehensibility of all questionnaires was pre-tested, and 812 self-reported diabetes cases not confirmed by a health plan were excluded from the analysis. Thus, the self-reported cases of the estimated 10% of MEC participants who were not insured by one of the two health plans were not part of the analysis. Lifestyle changes during follow-up were not assessed and, thus, not considered in the analysis. A longer observation period and the incorporation of modified behavior may have modified the PAR estimates (12). As shown recently, the Spiegelman method of estimating PAR has some limitations (12). A shorter observation time and the lack of censoring for death appears to overestimate PARs. The latter bias should be minimal given that the current analysis had excluded all MEC participants who were not alive in 2007.

Unfortunately, waist circumference data, an important risk factor in Asians and a good marker for the metabolically more active abdominal visceral fat that contributes to diabetes risk, were not available (41). Hypertension can be considered a modifiable or non-modifiable risk factor because high blood pressure can be modified with drugs or lifestyle changes (42). Since information on treatment was not available, realistic RR or PAR estimates for blood pressure modification could not be estimated; the reference category may include those with low blood pressure due to drug treatment. Therefore, we considered hypertension a non-modifiable factor. Although alcohol intake probably has a U-shaped relation to diabetes (4), subjects were dichotomized as non-drinkers and drinkers due to the

high proportion of alcohol abstainers and the low proportion of heavy drinkers in the MEC; only 5.6% of men and 1.7% of women consumed more than 60 and 50 g/d, respectively (4), the levels at which an elevated diabetes risk was observed in a large meta-analysis (4). It cannot be ruled out that some non-cases suffered from undiagnosed diabetes because the population has not been screened for diabetes and 10% of the population of Hawaii is not part of the two insurance plans used for linkage, hence they are not part of the diabetes registries. Furthermore, our participants tended to have a higher education and a healthier lifestyle in comparison to the general population (15).

Strengths of the study are its prospective design, case ascertainment through health insurance plans, and availability of information on various factors known to be associated with diabetes risk. Timeliness of diabetes registry information should not be an issue because the last self-reports occurred in 2003–2006 and the linkage was done in mid-2007. Although no data documenting the quality of the diabetes care registries for Hawaii are available, validation studies of similar registries in other locations have shown that care registries are highly specific and adequately sensitive (43;44). In addition, the large sample size and, in particular, the large number of subjects with ethnic backgrounds other than Caucasian enabled us to perform stratified analyses. The method used to estimate PARs was designed for cohort studies and allowed calculation of partial PARs. However, it assumes no interaction between the modifiable and non-modifiable risk factors of interest, which may not necessarily hold true. Finally, the PAR may give a good estimate for potential risk factor reduction and may be helpful for setting priorities, but other factors, such as the achievability and efficacy of changing risky behaviors, as well as cost, determine the final success of health interventions.

Our findings indicate that the majority of diabetes cases are preventable if overweight and obesity, physical inactivity, smoking, and high processed meat intake could be eliminated. This is the first study that compared PARs across ethnic groups, and our results indicate that most interventions aiming at the discussed modifiable risk factors would not avoid a significantly larger proportion of cases in Caucasians than in the other ethnic groups, though on an absolute basis, more cases would be avoided in the other ethnic groups, due to their higher diabetes incidence (13). However, our results do not support ethnic-specific prevention strategies. Intervention research has revealed the clustering of risk factors, and suggests that multiple-behavior interventions produce a greater impact on public health; thus, intervention strategies that target multiple health behaviors have the greatest potential to prevent a substantial proportion of all diabetes cases (8).

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Abbreviations

BMI	Body mass index
CI	Confidence interval
FFQ	Food frequency questionnaire
HR	Hazard ratio

MEC	Multiethnic Cohort
PAR	Population attributable risk

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Table 1
Baseline characteristics of participants in the Hawaii component of the Multiethnic Cohort Study, 1993–2007^a

	Men			Women		
	Caucasian	Native Hawaiian	Japanese American	Caucasian	Native Hawaiian	Japanese American
Number of Subjects	14,952	4574	16,549	14,356	5941	18,598
Diabetes Cases	7.2	17.3	16.1	4.9	15.9	12.7
Age						
<55 years	45.0	50.3	32.7	47.2	53.1	32.4
55–64 years	27.8	29.2	28.0	26.6	28.1	30.4
≥65 years	27.3	20.5	39.3	26.2	18.8	37.2
Education						
<13 years	19.4	48.1	39.4	23.6	52.9	41.4
13–15 years	28.9	31.7	28.7	34.1	29.9	28.1
≥16 years	51.7	20.3	31.9	42.3	17.2	30.5
Hypertension history	29.3	45.1	43.3	22.7	38.4	34.4

^aIn percent

Table 2

Prevalences and relative risks of diabetes for modifiable risk factors in men, Hawaii component of Multiethnic Cohort

	All men (N=36,075)				Caucasians (N=14,952)				Native Hawaiians (N=4574)				Japanese Americans (N=16,549)			
	n	Prev	HR	(95% CI)	n	Prev	HR	(95% CI)	n	Prev	HR	(95% CI)	n	Prev	HR	(95% CI)
BMI																
< 25.0 kg/m ²	1302	49.3	1.00		180	47.1	1.00		89	26.5	1.00		1033	57.6	1.00	
25.0–29.9 kg/m ²	2078	39.3	2.04	(1.90, 2.19)	500	40.6	2.85	(2.40, 3.39)	315	44.2	1.95	(1.54, 2.47)	1263	36.7	1.87	(1.72, 2.04)
≥ 30.0 kg/m ²	1156	11.4	4.40	(4.03, 4.81)	394	12.3	6.79	(5.64, 8.18)	386	29.3	3.69	(2.90, 4.69)	376	5.7	3.91	(3.45, 4.43)
Physical activity																
≥ 4 h/week	414	13.3	1.00		109	17.5	1.00		95	14.2	1.00		210	9.2	1.00	
2–3 h/week	479	12.9	1.05	(0.92, 1.20)	126	15.0	1.16	(0.90, 1.50)	93	14.3	0.92	(0.69, 1.22)	260	10.7	1.04	(0.87, 1.25)
1/2–1 h/week	875	18.6	1.15	(1.02, 1.29)	201	18.2	1.21	(0.95, 1.53)	199	23.1	1.13	(0.88, 1.45)	475	17.7	1.11	(0.94, 1.31)
Never	2768	55.2	1.21	(1.09, 1.35)	638	49.2	1.28	(1.04, 1.58)	403	48.4	1.19	(0.95, 1.51)	1727	62.4	1.15	(1.00, 1.34)
Processed red meat intake																
Quintile 1	547	20.0	1.00		165	26.0	1.00		69	12.6	1.00		313	16.6	1.00	
Quintile 2	775	20.0	1.23	(1.10, 1.37)	200	22.5	1.14	(0.92, 1.40)	108	16.1	1.17	(0.86, 1.59)	467	18.8	1.26	(1.09, 1.46)
Quintile 3	911	20.0	1.31	(1.17, 1.46)	223	18.9	1.33	(1.08, 1.64)	162	20.5	1.33	(0.99, 1.78)	526	20.9	1.25	(1.08, 1.44)
Quintile 4	1091	20.0	1.45	(1.30, 1.62)	204	16.1	1.30	(1.04, 1.61)	199	22.9	1.46	(1.09, 1.95)	688	22.7	1.46	(1.27, 1.68)
Quintile 5	1212	20.0	1.53	(1.37, 1.71)	282	16.4	1.71	(1.39, 2.11)	252	28.0	1.46	(1.10, 1.95)	678	21.0	1.46	(1.26, 1.69)
Dietary fiber intake																
Quintile 5	656	20.0	1.00		197	26.0	1.00		82	12.5	1.00		377	16.7	1.00	
Quintile 4	810	20.0	1.06	(0.95, 1.18)	234	24.0	1.06	(0.87, 1.29)	119	15.1	1.04	(0.78, 1.39)	457	17.7	1.06	(0.92, 1.22)
Quintile 3	952	20.0	1.08	(0.97, 1.20)	262	20.3	1.26	(1.04, 1.54)	157	19.7	0.98	(0.74, 1.30)	533	19.9	1.01	(0.88, 1.17)
Quintile 2	989	20.0	1.02	(0.92, 1.14)	193	17.2	1.01	(0.81, 1.25)	179	23.0	0.90	(0.68, 1.19)	617	21.7	1.03	(0.90, 1.19)
Quintile 1	1129	20.0	1.07	(0.96, 1.20)	188	12.5	1.30	(1.04, 1.62)	253	29.8	0.95	(0.72, 1.26)	688	24.1	1.02	(0.88, 1.18)
Alcohol intake																
Drinker	2560	63.6	1.00		697	72.9	1.00		450	61.3	1.00		1413	55.9	1.00	
Non-drinker	1976	36.4	1.26	(1.19, 1.34)	377	27.1	1.37	(1.21, 1.56)	340	38.7	1.30	(1.13, 1.50)	1259	44.1	1.21	(1.12, 1.31)
Smoking status																
Non-smoker	1303	31.7	1.00		316	32.7	1.00		246	32.7	1.00		741	30.4	1.00	
Former smoker	2466	51.6	1.11	(1.03, 1.18)	588	50.8	1.03	(0.90, 1.19)	373	44.8	1.16	(0.98, 1.37)	1505	54.1	1.12	(1.02, 1.23)

All men (N=36,075)		Caucasians (N=14,952)				Native Hawaiians (N=4574)				Japanese Americans (N=16,549)			
n	Prev	HR	(95% CI)	n	Prev	HR	(95% CI)	n	Prev	HR	(95% CI)	n	Prev
767	16.8	1.19	(1.09, 1.31)	170	16.5	1.07	(0.88, 1.30)	171	22.5	1.29	(1.05, 1.59)	426	15.5
Current smoker													1.22
													(1.08, 1.38)

CI confidence interval; HR hazard ratio of diabetes adjusted for all risk factors in the table and age (5 year age groups), educational attainment (<13 years, 13–15 years, or ≥16 years), hypertension (considered non-modifiable); model for all men additionally adjusted for ethnicity (Caucasian, Native Hawaiian, Japanese American); N number of participants; n number of diabetes cases; Prev prevalence (in %) of the risk factor

Table 3
Prevalences and relative risks of diabetes for modifiable risk factors in women, Hawaii component of Multiethnic Cohort

	All women (N=38,895)				Caucasian (N=14,356)				Native Hawaiians (N=5941)				Japanese Americans (N=18,598)			
	n	Prev	HR	(95% CI)	n	Prev	HR	(95% CI)	n	Prev	HR	(95% CI)	n	Prev	HR	(95% CI)
BMI																
< 25.0 kg/m ²	1465	64.1	1.00		159	62.2	1.00		133	38.4	1.00		1173	73.8	1.00	
25.0–29.9 kg/m ²	1444	24.7	2.57	(2.39, 2.78)	254	25.2	3.34	(2.73, 4.09)	309	33.6	2.42	(1.97, 2.98)	881	21.5	2.49	(2.28, 2.72)
≥ 30.0 kg/m ²	1114	11.2	5.01	(4.58, 5.47)	297	12.6	7.33	(5.98, 8.99)	505	28.1	4.89	(4.01, 5.96)	312	4.7	4.18	(3.67, 4.77)
Physical activity																
≥ 4 h/week	155	8.1	1.00		33	12.3	1.00		39	7.7	1.00		83	4.9	1.00	
2–3 h/week	288	10.2	1.24	(1.02, 1.50)	66	12.8	1.65	(1.09, 2.51)	80	10.1	1.44	(0.98, 2.11)	142	8.3	0.97	(0.74, 1.27)
1/2–1 h/week	642	15.4	1.48	(1.24, 1.77)	113	16.6	1.75	(1.18, 2.59)	217	21.0	1.58	(1.12, 2.23)	312	12.8	1.27	(0.99, 1.61)
Never	2938	66.3	1.43	(1.21, 1.68)	498	58.4	1.75	(1.23, 2.51)	611	61.2	1.46	(1.05, 2.02)	1829	74.1	1.23	(0.99, 1.54)
Processed red meat intake																
Quintile 1	482	20.0	1.00		126	28.0	1.00		71	11.4	1.00		285	16.6	1.00	
Quintile 2	650	20.0	1.18	(1.05, 1.33)	144	24.8	1.12	(0.88, 1.42)	129	15.4	1.19	(0.89, 1.60)	377	17.8	1.18	(1.01, 1.38)
Quintile 3	806	20.0	1.26	(1.12, 1.42)	147	18.9	1.36	(1.06, 1.74)	168	18.9	1.17	(0.88, 1.56)	491	21.2	1.24	(1.07, 1.45)
Quintile 4	965	20.0	1.36	(1.21, 1.53)	142	15.3	1.37	(1.06, 1.76)	246	22.9	1.34	(1.01, 1.77)	577	22.7	1.33	(1.14, 1.54)
Quintile 5	1120	20.0	1.41	(1.25, 1.58)	151	13.1	1.50	(1.15, 1.95)	333	31.3	1.22	(0.93, 1.62)	636	21.7	1.43	(1.23, 1.67)
Dietary fiber intake																
Quintile 5	653	20.0	1.00		136	24.6	1.00		106	13.5	1.00		411	18.5	1.00	
Quintile 4	686	20.0	0.86	(0.77, 0.96)	130	21.5	0.97	(0.76, 1.23)	143	16.5	0.95	(0.74, 1.23)	413	19.9	0.81	(0.70, 0.93)
Quintile 3	782	20.0	0.92	(0.83, 1.03)	155	20.4	1.04	(0.82, 1.33)	163	17.4	1.00	(0.78, 1.30)	464	20.5	0.86	(0.75, 0.99)
Quintile 2	895	20.0	0.97	(0.87, 1.08)	147	18.5	1.00	(0.78, 1.29)	203	21.6	0.98	(0.76, 1.27)	545	20.6	0.96	(0.83, 1.10)
Quintile 1	1007	20.0	0.97	(0.87, 1.09)	142	15.0	1.12	(0.86, 1.46)	332	30.9	1.08	(0.84, 1.38)	533	20.4	0.90	(0.77, 1.04)
Alcohol intake																
Drinker	920	37.1	1.00		321	61.0	1.00		268	37.6	1.00		331	18.5	1.00	
Non-drinker	3103	62.9	1.35	(1.25, 1.46)	389	39.0	1.44	(1.24, 1.69)	679	62.4	1.35	(1.17, 1.56)	2035	81.5	1.27	(1.12, 1.43)
Smoking status																
Non-smoker	2347	56.0	1.00		330	43.5	1.00		444	44.8	1.00		1573	69.2	1.00	
Former smoker	1123	29.7	1.06	(0.98, 1.14)	277	39.8	1.07	(0.91, 1.26)	292	31.3	0.96	(0.83, 1.11)	554	21.5	1.11	(1.01, 1.23)

	All women (N=38,895)				Caucasian (N=14,356)				Native Hawaiians (N=5941)				Japanese Americans (N=18,598)			
	n	Prev	HR	(95% CI)	n	Prev	HR	(95% CI)	n	Prev	HR	(95% CI)	n	Prev	HR	(95% CI)
Current smoker	553	14.3	1.11	(1.01, 1.23)	103	16.7	1.00	(0.80, 1.26)	211	24.0	1.04	(0.87, 1.23)	239	9.3	1.20	(1.05, 1.39)

CI confidence interval; HR hazard ratio of diabetes adjusted for all risk factors in the table and age (5 year age groups), educational attainment (<13years, 13–15 years, or ≥16 years), hypertension (considered non-modifiable); model for all men additionally adjusted for ethnicity (Caucasian, Native Hawaiian, Japanese American); N number of participants; n number of diabetes cases; Prev prevalence (in %) of the risk factor

Table 4
Population attributable risk for modifiable risk factors of diabetes in men, Hawaii component of the Multiethnic Cohort

	All men			Caucasian			Native Hawaiian			Japanese American			Japanese American (BMI cut point at 23.0 kg/m ²)		
	PAR	(95% CI)		PAR	(95% CI)		PAR	(95% CI)		PAR	(95% CI)		PAR	(95% CI)	
Full PAR ^a	0.92	(0.83, 0.97)		0.91	(0.67, 0.98)		0.85	(0.21, 0.98)		0.81	(0.54, 0.93)		0.86	(0.63, 0.95)	
Partial PAR ^b for potential modifiable risk factors															
BMI	0.49	(0.44, 0.52)		0.65	(0.57, 0.72)		0.60	(0.49, 0.69)		0.38	(0.32, 0.44)		0.52	(0.46, 0.57)	
Physical activity	0.13	(0.03, 0.22)		0.17	(-0.01, 0.33)		0.10	(-0.12, 0.31)		0.09	(-0.04, 0.23)		0.12	(-0.02, 0.25)	
Processed red meat intake	0.27	(0.18, 0.35)		0.24	(0.08, 0.39)		0.28	(0.05, 0.48)		0.26	(0.15, 0.36)		0.26	(0.15, 0.36)	
Dietary fiber intake	0.03	(-0.07, 0.13)		0.10	(-0.08, 0.26)		-0.04	(-0.33, 0.25)		0.00	(-0.13, 0.14)		-0.01	(-0.14, 0.13)	
Alcohol intake	0.28	(0.20, 0.35)		0.35	(0.22, 0.46)		0.29	(0.12, 0.45)		0.23	(0.13, 0.33)		0.23	(0.13, 0.33)	
Smoking	0.05	(-0.01, 0.11)		-0.01	(-0.13, 0.12)		0.09	(-0.05, 0.22)		0.06	(-0.02, 0.14)		0.06	(-0.02, 0.14)	
Partial PAR ^a for combinations of modifiable risk factors															
BMI, physical activity, meat, fiber, alcohol, smoking	0.78	(0.63, 0.87)		0.86	(0.64, 0.95)		0.82	(0.38, 0.96)		0.70	(0.44, 0.85)		0.77	(0.55, 0.89)	
Physical activity, meat, fiber, alcohol, smoking	0.57	(0.36, 0.73)		0.62	(0.22, 0.84)		0.56	(-0.08, 0.87)		0.52	(0.19, 0.74)		0.52	(0.20, 0.74)	
Meat, fiber, alcohol	0.49	(0.33, 0.62)		0.55	(0.27, 0.74)		0.47	(0.01, 0.76)		0.43	(0.21, 0.62)		0.43	(0.20, 0.61)	
Physical activity, alcohol, smoking	0.40	(0.24, 0.53)		0.45	(0.16, 0.67)		0.42	(0.05, 0.68)		0.35	(0.12, 0.54)		0.36	(0.14, 0.55)	
PAR population attributable risk															

^a estimates the proportion of preventable diabetes cases if all modifiable, non-modifiable (age, education, and ethnicity (in models not stratified by ethnicity)), and considered non-modifiable (hypertension) risk factors would be eliminated

^b estimates the proportion of preventable diabetes cases, if all persons belong to the lowest risk category of the respective risk factor, while all other modifiable and non-modifiable risk factors remain unchanged

Table 5

Population attributable risk for modifiable risk factors of diabetes in women, Hawaii component of the Multiethnic Cohort

	All women		Caucasian		Native Hawaiian		Japanese American		Japanese American (BMI cut point at 23.0 kg/m ²)	
	PAR	(95% CI)	PAR	(95% CI)	PAR	(95% CI)	PAR	(95% CI)	PAR	(95% CI)
Full PAR ^a	0.95	(0.87, 0.98)	0.93	(0.62, 0.99)	0.93	(0.55, 0.99)	0.85	(0.55, 0.95)	0.87	(0.61, 0.96)
Partial PAR ^b for potential modifiable risk factors										
BMI	0.50	(0.46, 0.54)	0.64	(0.55, 0.72)	0.67	(0.59, 0.73)	0.38	(0.32, 0.44)	0.54	(0.48, 0.59)
Physical activity	0.29	(0.17, 0.41)	0.41	(0.18, 0.60)	0.33	(0.08, 0.54)	0.18	(-0.01, 0.37)	0.19	(0.00, 0.37)
Processed red meat intake	0.23	(0.13, 0.32)	0.21	(0.02, 0.39)	0.20	(-0.03, 0.42)	0.22	(0.10, 0.34)	0.20	(0.07, 0.32)
Dietary fiber intake	-0.06	(-0.17, 0.05)	0.01	(-0.20, 0.23)	0.02	(-0.22, 0.26)	-0.11	(-0.26, 0.04)	-0.12	(-0.26, 0.03)
Alcohol intake	0.42	(0.33, 0.51)	0.43	(0.27, 0.56)	0.42	(0.25, 0.57)	0.36	(0.20, 0.50)	0.33	(0.16, 0.48)
Smoking	0.02	(-0.03, 0.06)	0.00	(-0.11, 0.11)	-0.03	(-0.14, 0.07)	0.04	(-0.01, 0.08)	0.03	(-0.01, 0.08)
Partial PAR ^b for combinations of modifiable risk factors										
BMI, physical activity, meat, fiber, alcohol, smoking	0.83	(0.69, 0.91)	0.90	(0.66, 0.97)	0.89	(0.61, 0.97)	0.73	(0.42, 0.88)	0.78	(0.51, 0.91)
Physical activity, meat, fiber, alcohol, smoking	0.67	(0.46, 0.81)	0.73	(0.34, 0.91)	0.69	(0.19, 0.91)	0.56	(0.18, 0.80)	0.53	(0.13, 0.78)
Meat, fiber, alcohol	0.52	(0.34, 0.67)	0.55	(0.21, 0.78)	0.55	(0.15, 0.80)	0.45	(0.14, 0.68)	0.40	(0.07, 0.65)
Physical activity, alcohol, smoking	0.60	(0.45, 0.71)	0.66	(0.40, 0.82)	0.60	(0.29, 0.79)	0.49	(0.23, 0.69)	0.48	(0.21, 0.68)
PAR population attributable risk										

^a estimates the proportion of preventable diabetes cases if all modifiable, non-modifiable (age, education, and ethnicity (in models not stratified by ethnicity)), and considered non-modifiable (hypertension) risk factors would be eliminated

^b estimates the proportion of preventable diabetes cases, if all persons belong to the lowest risk category of the respective risk factor, while all other modifiable and non-modifiable risk factors remain unchanged