Epidemiology/Health Services Research
ORIGINAL ARTICLE

Dietary Patterns and Risk for Diabetes

The Multiethnic Cohort

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OBJECTIVE — The high diabetes incidence among Japanese Americans and Native Hawaiians cannot be explained by BMI. Therefore, we examined the influence of three dietary patterns of "fat and meat," "vegetables," and "fruit and milk" on diabetes risk in the Hawaii component of the Multiethnic Cohort with 29,759 Caucasians, 35,244 Japanese Americans, and 10,509 Native Hawaiians.

RESEARCH DESIGN AND METHODS — Subjects aged 45–75 years completed a baseline food frequency questionnaire. After 14 years of follow-up, 8,587 subjects with incident diabetes were identified through self-reports or health plan linkages. Risk was assessed using Cox regression stratified by age and adjusted for ethnicity, BMI, physical activity, education, total energy, smoking, alcohol intake, marital status, and hypertension.

RESULTS — Fat and meat was significantly associated with diabetes risk in men (hazard ratio 1.40 [95% CI 1.23–1.60], $P_{\text{trend}} < 0.0001$) and women (1.22 [1.06–1.40], $P_{\text{trend}} = 0.004$) when extreme quintiles were compared. Except in Hawaiian women, the magnitude of the risk was similar across ethnic groups although not always significant. After stratification by BMI, fat and meat remained a predictor of disease primarily among overweight men and among overweight Japanese women. Vegetables lowered diabetes risk in men (0.86 [0.77–0.95], $P_{\text{trend}} = 0.004$) but not in women, whereas fruit and milk seemed to be more beneficial in women (0.85 [0.76–0.96], $P_{\text{trend}} = 0.005$) than in men (0.92 [0.83–1.02], $P_{\text{trend}} = 0.04$).

CONCLUSIONS — Foods high in meat and fat appear to confer a higher diabetes risk in all ethnic groups, whereas the effects of other dietary patterns vary by sex and ethnicity.

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Native Hawaiians have extremely high rates of obesity and diabetes, but despite their relatively low body weight, individuals with Japanese ancestry are also disproportionately affected by diabetes (1). Among the >44,000 Japanese Americans, 14,000 Native Hawaiians, and 35,000 Caucasians in the Hawaii component of the Multiethnic Cohort (MEC), a previous analysis had found diabetes incidence rates of 15.5, 12.5, and 5.8 per 1,000 person-years, respectively, that could not be explained by BMI (2). Dietary patterns have been identified as additional predictors of disease but have only rarely been investigated prospectively among non-Caucasian populations (3–5). The most commonly identified patterns are the so-called "western," "unhealthy," or "conservative" pattern (3–11), which is high in meat, high-fat foods, and sweets, and the "prudent" or "healthy" pattern, rich in fruit and vegetables (3–8,10,12,13). With the goal to contribute to the prevention of diabetes, we examined the effect of three dietary patterns, "fat and meat," "vegetables," and "fruit and milk," which had been previously identified in the MEC, on diabetes risk (14).

RESEARCH DESIGN AND METHODS

The MEC study was established from 1993 to 1996 to examine diet and cancer among different ethnic groups in Hawaii and California (15). The Hawaii component of the MEC consists of 103,898 members, primarily Caucasians, Japanese Americans, and Native Hawaiians. Subjects aged 45–75 years entered the cohort by completing a 26-page, self-administered mailed survey that included a food frequency questionnaire and asked about demographics, medical conditions, anthropometric measures, and lifestyle factors (16). Although 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), the MEC yielded a representative population as evidenced by a comparison of educational levels and marital status with census data (15). After exclusion of ineligible subjects (10,028 with prevalent diabetes, 8,797 of other ethnic groups, 6,202 with missing covariates, 2,537 with missing dietary information, 812 subjects with unconfirmed diabetes, and 10 with missing information on follow-up or diabetes at baseline), 36,256 men and 39,256 women were part of this analysis.

Case ascertainment

The detailed identification of case subjects was only available for the Hawaii component of the MEC (2). Subjects with incident diabetes were identified through three sources. A follow-up questionnaire sent to all MEC members in 1999–2003 asked about medical conditions including diabetes and achieved a response rate of 84%. A medication questionnaire administered in 2001–2007 was available for 38% of subjects who had agreed to a blood draw. In 2007, diabetic subjects were identified through a linkage with the two major health plans in Hawaii, Kaiser Permanente and Blue Cross/Blue Shield. After excluding 812 subjects with self-reported diabetes not confirmed by a health plan, 2,251 of the 8,587 subjects with incident diabetes were identified in the follow-up questionnaire, 996 in the medication questionnaire, and 5,340 through the health plans. Annual linkages with state and national death certificate files provided information on vital status.

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Table 1—*Food groups with high factor loadings for the three dietary patterns*

	Food groups	Factor loadings
Fat and meat	Discretionary fat	88
	Meat and organ meat	83
	Frankfurters, sausage, and luncheon meat	72
	White potatoes	68
	Non–whole grains	68
	Eggs	67
	Cheese	63
Vegetables	Dark-green vegetables	87
	Other vegetables	86
	Deep-yellow vegetables	79
	Other fruits	44
	Citrus fruits, melons, and berries	36
Fruit and milk	Milk and yogurt	71
	Cheese	35
	Other fruits	71
	Citrus fruits, melons, and berries	71

Dietary patterns from ref. 14.

Dietary patterns

Based on the food frequency questionnaire calibrated within the different ethnic groups (16), nutrients were determined and Food Guide Pyramid servings were computed using an ethnicity-specific food composition database with information from the U.S. Department of Agriculture and additional laboratory analyses performed in Hawaii (15). Subjects who reported energy, fat, protein, or carbohydrate intakes outside the mean ± 3 relative SDs were excluded.

In a previous analysis, exploratory factor analysis with an acceptable goodness of fit was applied to the MEC (14). Three distinct dietary patterns were identified, and factor scores were obtained for each participant (Table 1). The pattern fat and meat was characterized by discretionary fat, meat, eggs, and cheese and explained 30% of variation. The vegetables pattern (20% variation explained) included high amounts of vegetables and also fruits with a relatively low loading, whereas fruit and milk had high loadings on milk, yogurt, cheese, and fruits and explained 14% of variation. The factor analysis was repeated in each ethnic group and produced similar results (14). Therefore, the patterns are expected to be unchanged after the exclusion of the California component with primarily African Americans and Latinos.

Statistical methods

All statistical analyses were performed using SAS statistical software (version 9.2, SAS Institute, Cary, NC). We used Cox proportional hazards regression models with follow-up time as the underlying time metric to estimate hazard ratios (HRs) and 95% CI for sex-specific quintiles of factor scores in relation to diabetes. Ordinal variables representing the median values for each quintile were used to test for linear trends. The final models were stratified by age at cohort entry and adjusted for ethnicity (Japanese Americans and Native Hawaiians versus Caucasians), BMI (continuous), physical activity (quintiles), education (13–15 and

Table 2—*Baseline characteristics of the Hawaii component of the MEC, 1993–2007*

	Caucasian		Japanese American		Native Hawaiian		
	Men	Women	Men	Women	Men	Women	All
n	15,116	14,643	16,572	18,672	4,568	5,941	75,512
Cases (%)	7	5	16	13	18	16	11
Noncases (%)	93	91	84	87	83	84	89
Age (%)							
45–54 years	45	47	33	32	51	53	41
55–64 years	28	27	28	31	29	28	28
≥65 years	28	26	39	37	20	19	31
Education (%)							
≤12 years	19	23	39	41	48	52	34
13–15 years	29	34	29	28	32	30	30
>15 years	52	43	32	31	21	18	36
BMI (%)							
<25.0 kg/m^2	47	63	58	74	27	39	57
25.0–29.9 kg/m^2	41	25	37	21	44	33	32
≥30 kg/m^2	12	13	6	5	29	28	11
Cigarette smoking (%)							
Never	33	44	30	69	33	45	44
Past	51	40	54	22	45	31	40
Current	16	17	16	9	23	24	15
Fat and meat	0.33	−0.28	0.12	−0.48	0.57	0.07	−0.06
Vegetables	−0.22	−0.01	0.32	0.47	0.18	0.29	0.18
Fruit and milk	0.10	0.22	−0.68	−0.30	−0.44	−0.14	−0.19
Total energy (kcal)	2,316 ± 891	1,824 ± 689	2,293 ± 833	1,823 ± 674	2,800 ± 1,322	2,341 ± 1,219	2,125 ± 907
Red meat (g/day)	43 ± 35	28 ± 24	44 ± 32	30 ± 23	60 ± 45	46 ± 37	38 ± 32
Dairy foods (g/day)	262 ± 211	254 ± 207	137 ± 137	157 ± 154	211 ± 211	230 ± 231	201 ± 192
Vegetables (g/day)	339 ± 202	332 ± 205	318 ± 189	322 ± 194	385 ± 267	407 ± 300	337 ± 213
Fruits (g/day)	326 ± 273	340 ± 268	306 ± 265	371 ± 296	337 ± 335	405 ± 412	342 ± 295
Rice (g/day)	110 ± 134	73 ± 92	408 ± 245	270 ± 180	353 ± 261	221 ± 193	231 ± 223
Physical activity (METs)	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

Data are %, medians (pattern scores only), or means ± SD. The following subjects were excluded from the 103,898 members of the Hawaii component of the MEC: 10,028 with prevalent diabetes, 8,797 of other ethnicity, 812 with unconfirmed diabetes, 6,202 with missing covariates, 2,537 with missing dietary information, and 10 with lack of follow-up information or missing diabetes information at baseline.

Table 3—*Dietary patterns and diabetes risk in men, Hawaii component of the MEC, 1993–2007*

	All men		Caucasian		Japanese American		Native Hawaiian	
	n*	HR (95% CI)†	n*	HR (95% CI)†	n*	HR (95% CI)†	n*	HR (95% CI)†
n		4,555		1,080		2,677		798
Fat and meat								
Quintile 1	773	1.00	142	1.00	539	1.00	92	1.00
Quintile 2	812	1.03 (0.93–1.14)	166	0.99 (0.78–1.24)	523	1.01 (0.89–1.14)	123	1.13 (0.86–1.49)
Quintile 3	912	1.17 (1.06–1.30)	216	1.24 (0.99–1.56)	572	1.14 (1.00–1.30)	124	0.99 (0.74–1.32)
Quintile 4	958	1.23 (1.10–1.37)	238	1.25 (0.98–1.59)	543	1.18 (1.02–1.36)	177	1.12 (0.84–1.50)
Quintile 5	1,100	1.40 (1.23–1.60)	318	1.38 (1.05–1.81)	500	1.38 (1.16–1.64)	282	1.22 (0.88–1.29)
P_{trend}		<0.0001		0.007		<0.0002		0.27
Vegetables								
Quintile 1	783	1.00	362	1.00	303	1.00	118	1.00
Quintile 2	907	0.98 (0.89–1.08)	232	0.92 (0.78–1.09)	527	1.02 (0.88–1.18)	148	1.03 (0.81–1.32)
Quintile 3	982	1.03 (0.94–1.14)	203	0.97 (0.81–1.16)	605	1.03 (0.90–1.19)	174	1.21 (0.95–1.54)
Quintile 4	976	0.98 (0.88–1.08)	183	0.99 (0.82–1.19)	612	0.97 (0.83–1.12)	181	1.16 (0.91–1.49)
Quintile 5	907	0.86 (0.77–0.95)	100	0.67 (0.53–0.84)	630	0.86 (0.74–0.99)	177	1.17 (0.90–1.51)
P_{trend}		0.004		0.01		0.007		0.17
Fruits and milk								
Quintile 1	1,144	1.00	124	1.00	819	1.00	201	1.00
Quintile 2	1,011	0.98 (0.90–1.07)	168	0.72 (0.57–0.91)	675	1.05 (0.95–1.17)	168	0.96 (0.78–1.18)
Quintile 3	925	0.97 (0.89–1.06)	232	0.79 (0.63–0.99)	520	1.02 (0.91–1.14)	173	1.02 (0.83–1.27)
Quintile 4	770	0.89 (0.81–0.98)	253	0.72 (0.57–0.89)	390	0.96 (0.85–1.10)	127	0.84 (0.67–1.07)
Quintile 5	705	0.92 (0.83–1.02)	303	0.71 (0.56–0.89)	273	1.08 (0.93–1.26)	129	0.85 (0.66–1.09)
P_{trend}		0.04		0.02		0.76		0.14

*Number of case subjects with diabetes. †HRs (95% CI) were stratified by age at cohort entry and adjusted for ethnicity (Japanese American and Native Hawaiian vs. Caucasian), physical activity (quintiles), education (12–15 and >15 vs. ≤ 12 years), energy intake (log-transformed), BMI (continuous), alcohol intake (quintiles), smoking status (past and current vs. never), marital status, and self-reported high blood pressure at baseline.

>15 vs. ≤ 12 years), energy intake (log-transformed), alcohol intake (quintiles), marital status, smoking status (past and current versus never), and self-reported hypertension at baseline. The effect of the fat and meat pattern independent of BMI was determined after stratification by BMI. No major violations of the proportional hazards assumption were observed when examined with Kaplan-Meier survival curves and Schoenfeld residuals.

RESULTS

RESULTS— BMI, median factor scores, and intake from major food groups differed significantly by ethnicity and sex ($P < 0.001$) (Table 2). Caucasians had higher median scores for the fruit and milk pattern and consumed more dairy foods than the other groups. Japanese Americans had a higher proportion of normal-weight subjects, scored higher on the vegetables pattern, and consumed the most rice. Native Hawaiians were more likely to be obese, to have high median scores on the fat and meat pattern, and to report high energy intakes. Women consumed more dairy foods and fruits than men, who had a higher meat intake. All dietary patterns were significantly correlated with BMI ($r_s = 0.3$ for fat and meat and <0.1 for the other patterns).

Fat and meat was significantly associated with diabetes risk in men with HR 1.40 ([95% CI 1.23–1.60], $P_{\text{trend}} < 0.0001$) when the highest quintile of the factor score was compared with the lowest (Table 3). This trend was consistent across ethnic groups although not statistically significant for Native Hawaiians. High scores on the fat and meat pattern also showed a significant trend with diabetes risk in women overall (HR 1.22, [1.06–1.40], $P_{\text{trend}} = 0.004$). The association was significant in Japanese American women ($P_{\text{trend}} = 0.045$), the group with a largest sample size, whereas it was similar in magnitude, although not significant, in Caucasian women, and showed no association in Native Hawaiian women (Table 4).

The pattern vegetables was inversely associated with diabetes risk in men overall (HR 0.86 [95% CI 0.77–0.95], $P_{\text{trend}} = 0.004$) as well as in Caucasian and Japanese American men but not in Native Hawaiian men and not in women. Whereas the fruit and milk pattern was weakly related to diabetes in all men ($P_{\text{trend}} = 0.04$), the association was stronger among Caucasians ($P_{\text{trend}} = 0.02$) and in all women (0.85 [0.76–0.96], $P_{\text{trend}} = 0.005$). Although the risk reduction was similar in all ethnic groups for women, the trend tests failed to reach statistical significance.

Because of the fairly consistent fat and meat results, we stratified the analysis by BMI (Fig. 1). In all men, the risk for diabetes increased with higher factor scores for fat and meat among overweight (HR 1.49 [95% CI 1.23–1.81], $P_{\text{trend}} < 0.0001$) and obese (1.57 [1.16–2.12], $P_{\text{trend}} = 0.004$) individuals. By ethnicity, the effect was observed in overweight Caucasian ($P_{\text{trend}} = 0.006$) and Japanese American ($P_{\text{trend}} = 0.002$) men with borderline associations among obese Japanese American ($P_{\text{trend}} = 0.08$) and Native Hawaiian ($P_{\text{trend}} = 0.13$) men. In women, no significant trends were observed for the entire population; only the trend for overweight Japanese American women was significant ($P_{\text{trend}} = 0.04$).

CONCLUSIONS

CONCLUSIONS— In this multiethnic population, high scores in the fat and meat pattern were associated with elevated diabetes risk among all ethnic groups in men and to a lesser degree in all and in Japanese American women. After stratification by BMI, the effects were primarily seen in overweight Caucasian and Japanese American men as well as in over-

Table 4—*Dietary patterns and diabetes risk in women, Hawaii component of the MEC, 1993–2007*

	All women		Caucasian		Japanese American		Native Hawaiian	
	*n**	HR (95% CI)†	*n**	HR (95% CI)†	*n**	HR (95% CI)†	*n**	HR (95% CI)†
*n**	4,032		715		2,374		843	
Fat and meat								
Quintile 1	657	1.00	83	1.00	480	1.00	94	1.00
Quintile 2	691	1.01 (0.91–1.13)	114	1.04 (0.78–1.38)	465	1.00 (0.87–1.14)	112	1.02 (0.76–1.35)
Quintile 3	784	1.09 (0.98–1.22)	135	1.07 (0.80–1.44)	498	1.10 (0.96–1.26)	151	1.04 (0.79–1.36)
Quintile 4	823	1.07 (0.95–1.21)	161	1.08 (0.80–1.45)	481	1.08 (0.92–1.25)	181	0.94 (0.71–1.24)
Quintile 5	1,077	1.22 (1.06–1.40)	222	1.21 (0.87–1.68)	450	1.20 (1.00–1.44)	405	1.10 (0.81–1.48)
P_{trend}		0.004		0.24		0.045		0.60
Vegetables								
Quintile 1	665	1.00	207	1.00	277	1.00	181	1.00
Quintile 2	808	1.06 (0.95–1.17)	162	1.12 (0.91–1.38)	473	1.17 (1.01–1.36)	173	0.83 (0.67–1.02)
Quintile 3	816	1.03 (0.93–1.15)	152	1.21 (0.97–1.50)	467	1.06 (0.91–1.23)	197	0.93 (0.76–1.15)
Quintile 4	858	1.05 (0.94–1.17)	113	1.02 (0.80–1.30)	559	1.16 (0.99–1.35)	186	0.88 (0.70–1.09)
Quintile 5	885	1.02 (0.91–1.14)	81	1.03 (0.78–1.35)	598	1.11 (0.95–1.30)	206	0.89 (0.71–1.11)
P_{trend}		0.93		0.78		0.41		0.48
Fruits and milk								
Quintile 1	984	1.00	96	1.00	664	1.00	224	1.00
Quintile 2	862	0.96 (0.88–1.05)	139	1.10 (0.85–1.43)	546	0.95 (0.85–1.07)	177	0.93 (0.76–1.13)
Quintile 3	816	0.95 (0.86–1.04)	143	0.94 (0.72–1.23)	484	0.94 (0.83–1.06)	189	1.06 (0.87–1.30)
Quintile 4	725	0.90 (0.82–1.00)	150	0.81 (0.62–1.06)	400	0.95 (0.83–1.08)	175	0.93 (0.75–1.15)
Quintile 5	645	0.85 (0.76–0.96)	187	0.88 (0.67–1.16)	280	0.86 (0.74–1.01)	178	0.86 (0.68–1.09)
P_{trend}		0.005		0.09		0.09		0.29

*Number of case subjects with diabetes. †HRs (95% CI) were stratified by age at cohort entry and adjusted for ethnicity (Japanese American and Native Hawaiian vs. Caucasian), physical activity (quintiles), education (12–15 and >15 vs. ≤12 years), energy intake (log-transformed), BMI (continuous), alcohol intake (quintiles), smoking status (past and current vs. never), marital status, and self-reported high blood pressure at baseline.

weight Japanese American women. The vegetables pattern lowered diabetes risk in Caucasian and Japanese American men but not in women, whereas fruit and milk lowered diabetes risk more in women than in men. These findings indicate that the type of food consumed might contribute to diabetes risk beyond its effects on body weight.

The positive association with the fat and meat pattern is consistent with similar patterns in several other cohort studies (4–11) and agrees with a recent meta-analysis that associated red and processed meat with diabetes (17). However, in a Japanese study, the animal food pattern was not related to diabetes risk (3). Meat may be harmful because of its content of saturated fat, nitrites (processed meat), and iron and may lead to hyperglycemia and hyperinsulinemia (18). Because women had lower loadings on the fat and meat pattern and lower meat intake than men, the use of sex-specific quintiles might explain the weaker associations among women. The more pronounced risk estimates for the fat and meat pattern in overweight than in normal-weight men are consistent with previous studies (6–8), although another investigation did not detect such an interaction (4).

The inverse associations for vegetables in men and fruit and milk in women are consistent with studies that showed a reduced risk of diabetes for subjects adhering to a prudent or healthy diet high in fruits and vegetables (3,4,6,8,10,12,13). However, contradictory results have been reported for vegetables and fruits. Two reports did not detect a protective effect for a prudent pattern (5,7) and one analysis found a protective effect for the high-vegetable pattern but no effect for the high-fruit pattern (10). Whereas fruit but not vegetables were protective in a U.S. cohort (19), vegetable but not fruit intake was protective among Chinese women (20). The protective effects of fruits and vegetables on diabetes have been attributed to antioxidants, fiber, carotenoids, magnesium, and folic acid (21). Some ingredients in fruits, e.g., dietary fiber, may have beneficial effects on glucose metabolism, whereas others, e.g., sugars, may have adverse effects. Dairy products have been associated with diabetes risk due to their high fat content, but low-fat dairy products may have beneficial effects (4,22). Unfortunately, we were not able to differentiate between high- and low-fat products. The inconsistent results for the vegetables and fruit and milk pattern by sex may be due to diverse dietary habits observed in men and women. Women had higher scores on the vegetables and the fruit and milk pattern (14) and relatively higher intakes of fruits and dairy products (Table 2) (15).

Similar to our nonsignificant associations among Native Hawaiians, a report from diverse ethnic groups in Hawaii indicated that ethnicity was a stronger predictor of diabetes risk than dietary patterns (5). It is possible that the high rate of obesity among Native Hawaiians is a stronger determinant of diabetes than nutritional habits (Fig. 1). The smaller sample size of Native Hawaiians, the high intake of total energy, and the low loadings on fruit and milk (Table 2) may have also contributed to the absence of significant associations. The fact that a diet high in animal fat has been associated with intra-abdominal fat deposition and insulin resistance (23) might explain the significant results for the fat and meat pattern among overweight Japanese Americans. Despite their relatively low BMI, individuals of Japanese ancestry seem to be more susceptible to central obesity with a

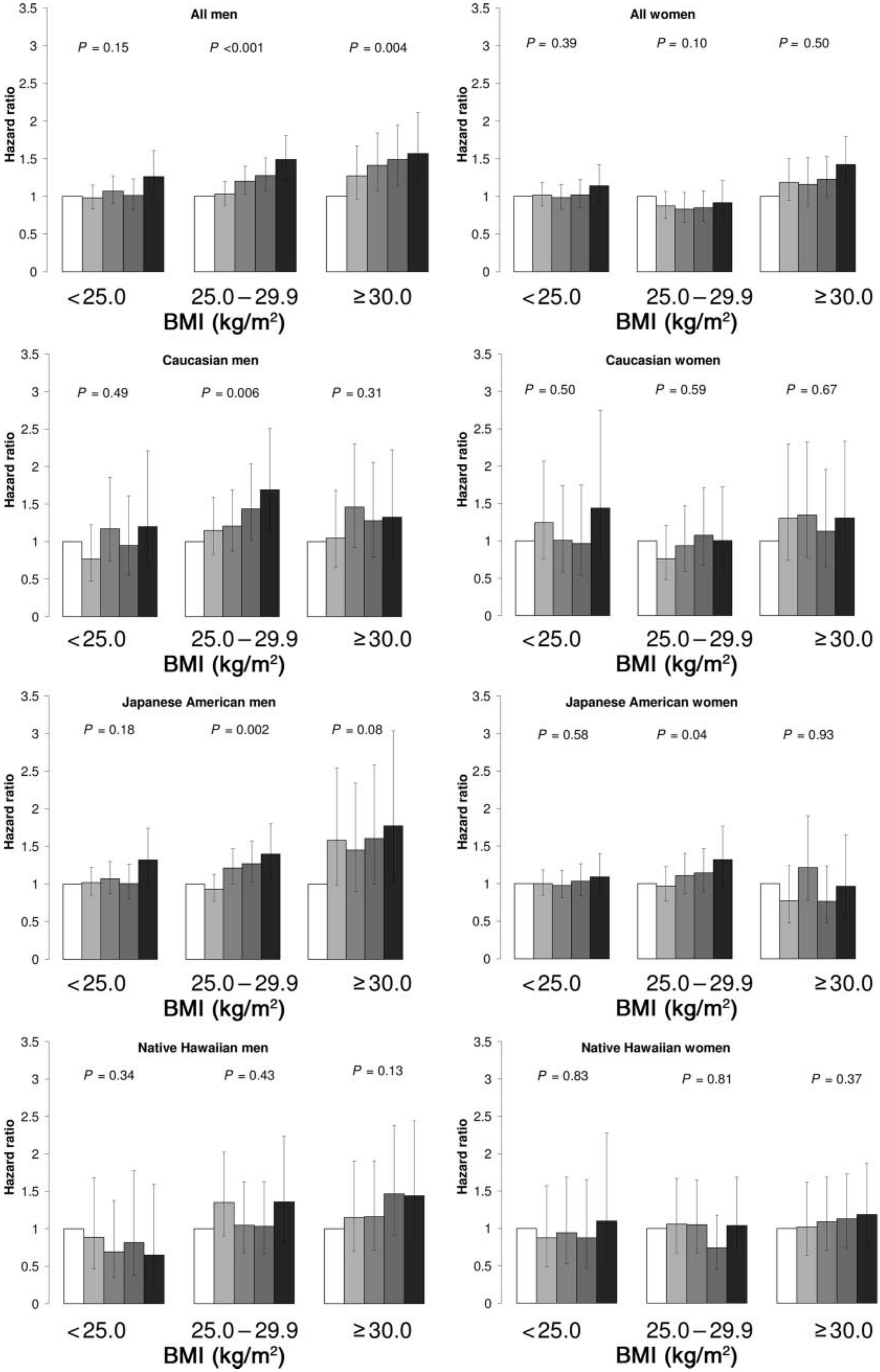

Figure 1—*Diabetes risk and "fat and meat" dietary pattern by weight status, Hawaii component of the MEC, 1993–2007. The models were stratified by age at cohort entry and adjusted for ethnicity (Japanese American and Native Hawaiian vs. Caucasian), physical activity (quintiles), education (12–15 and >15 vs. ≤12 years), BMI (continuous), energy intake (log transformed), alcohol intake (quintiles), smoking status (past and current versus never), marital status, and self-reported high blood pressure at baseline.*

higher proportion of visceral fat than Caucasians (24) that predisposes to insulin resistance (25).

It is necessary to note some weaknesses of this study. Because of the multiple comparisons, some of the findings might be due to chance. We did not have information on the type of diabetes. However, given the median age of 59 years at baseline, >90% of cases of diabetes are probably type 2. The results stratified by BMI should be interpreted with care; residual confounding may be present, and it is unclear whether BMI functions as a confounder or intermediate variable. One limitation of the dietary pattern approach is the difficulty in separating the effects of individual nutrients (8). Because dietary patterns are thought to capture synergistic and antagonistic effects of interrelated nutrients, they may be able to detect the cumulative effect of individual foods whose association with disease risk cannot be detected separately (4). Patterns of diet can also be more easily translated into practical public health advice for diabetes prevention. Other strengths, besides the multiethnic population with a great variation in diabetes risk and BMI, are the large sample size, the long follow-up, and the case ascertainment through health plans (2).

Our findings support previous research that a diet rich in meat and fat predisposes to diabetes independent of its effect on body weight (17), in particular among overweight individuals (6–8). Because our findings were more consistent among Caucasians and Japanese Americans, it seems possible that most of the adverse effect of the fat and meat pattern in Native Hawaiians is mediated through BMI. Our analyses agree with investigations that included individuals with Asian ancestry and reported effects of dietary patterns similar to those in Caucasians (3–5). The results for patterns rich in fruit, vegetables, and dairy products are ambiguous and need to be investigated in other cohorts. A better understanding of dietary factors related to diabetes risk in Japanese Americans and Native Hawaiians will be useful in developing preventive strategies in these high-risk groups. Despite improvements in treatment, ultimately only prevention can reduce the disease burden.

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No potential conflicts of interest relevant to this article were reported.

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