Published in final edited form as:

J Phys Act Health. 2012 July ; 9(5): 634–641.

Physical activity and risk of type 2 diabetes among Native Hawaiians, Japanese Americans and Caucasians: The Multiethnic Cohort

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Abstract

Background—Physical inactivity is an established risk factor for diabetes; however, little is known about this association across ethnic groups with different diabetes risk. Therefore, we evaluated the association between physical activity and diabetes and potential effect modification by ethnicity in the Hawaii component of the Multiethnic Cohort.

Methods—Participants, aged 45–75 years, were enrolled by completing a questionnaire on demographics, diet, and self-reported weekly hours of strenuous sports, vigorous work, and moderate activity. Among the 74,913 participants (39% Caucasian, 14% Native Hawaiian, 47% Japanese American), 8561 incident diabetes cases were identified by self-report, a medication questionnaire, and through health plan linkages. Cox regression was applied to estimate hazard ratios (HR) and 95% confidence intervals (95%CI) while adjusting for known confounders.

Results—Engaging in strenuous sports was inversely related to diabetes risk with HRs (4+ h/week vs. never) of 0.67 (95%CI: 0.57–0.79) in women and 0.80 (95%CI: 0.72–0.88) in men. In stratified analyses, the inverse association was consistent across ethnic groups. The inverse association of vigorous work with diabetes was limited to men, while beneficial effects of moderate activity were observed only in Caucasians.

Conclusions—These findings support a role of high-intensity physical activity and ethnic-specific guidelines in diabetes prevention.

Keywords

ethnicity; prospective study; effect modification

Introduction

Prevalence rates of type 2 diabetes mellitus vary widely by ethnicity, with considerably higher rates in Asian Americans and Pacific Islanders than in Caucasians residing in the United States.^{1–3} Diabetes is a chronic disease with no cure to date; thus, identification of modifiable risk factors as a tool for primary prevention is important. Besides obesity and weight gain, evidence from prospective studies points to physical inactivity as an independent risk factor for type 2 diabetes.⁴ Intervention studies in individuals with

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Conflict of interest statement: None of the authors has a commercial association or any other conflict of interest.

impaired glucose tolerance have shown that increasing physical activity reduces the risk of developing diabetes.^{5–7} Additionally, not only vigorous sports, but engaging in moderate intensity physical activity might reduce the risk of diabetes.⁸ Current recommendations suggest 2.5 h/week of moderate exercise⁹ or at least 30 minutes of moderate-intensity physical activity on most days.¹⁰ So far, most studies on physical activity and diabetes focus on Caucasians and little is known about the consistency of this association across ethnic groups. Results from the Women's Health Initiative Observational Study show an inverse association in Caucasian women, but not in African American, Hispanic, or Asian/Pacific Islanders.¹¹ Therefore, we sought to evaluate the association between different types of physical activity and diabetes risk in the Hawaii component of the Multiethnic Cohort (MEC) with special focus on effect modification by ethnicity.

Methods

Study population

The MEC was established from 1993 to 1996 to examine the association between diet and cancer among five different ethnic groups in Hawaii and California.¹² For enrollment, participants returned a mailed self-administered survey consisting of a food frequency questionnaire and additional questions on demographics, medical conditions, anthropometric measures, and lifestyle factors. More than 215,000 men and women, aged 45–75 years at baseline, were recruited with response rates ranging from 28% to 51% in the different ethnic-sex groups. Comparisons with US census data indicated that the MEC participants represent all levels of education, although cohort members were somewhat better educated than the general population. For the present analysis, we focused on the Hawaii component of the MEC, consisting of 103,898 participants of primarily Caucasian, Japanese American, and Native Hawaiian ancestry, since a linkage with health plans to identify incident diabetes cases was only possible in Hawaii.¹³ We further excluded subjects with prevalent diabetes at study entry ($n = 10,028$), missing follow-up information ($n = 10$), questionable incident diabetes status ($n = 1036$), other ethnicity ($n = 8692$), missing dietary data needed as covariate ($n = 4415$), or missing data on physical activity variables ($n = 4804$), leaving 74,913 participants (35,976 men and 38,937 women). In comparison to the entire Hawaii component of the MEC,¹³ cohort members 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. 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 asking about medical conditions between 1999 and 2003 (response rate 84%), a medication questionnaire including diabetes drugs administered between 2003 and 2006 (response rate 38%) and linkage with health insurance plans in 2007.¹³ All participants of the cohort, known to be alive and not refusing to participate, were linked with the diabetes care registries of the two major health insurers, which capture 90% of the population of Hawaii: Kaiser Permanente Hawaii and Blue Cross/Blue Shield. If diabetes was self-reported in the follow-up questionnaire but not confirmed by the health plans, diabetes status was deemed questionable and not included in analysis to avoid misclassification. Annual linkage with state and national death certificate files was performed for information on vital status.

Exposure assessment

Physical activity was assessed through the baseline questionnaire.¹² Participants indicated the average hours per week spend on strenuous sport (such as jogging, tennis, aerobics),

vigorous work (such as moving heavy furniture, loading or unloading trucks, shoveling, etc.), or moderate activity (such as housework, brisk walking, gardening) during the previous year by selecting one of 8 categories ranging from never to 31+ h/week. For the statistical analysis, the 8 categories were re-categorized as follows: sports (never, 1/2–1, 2–3, or 4+ h/week), vigorous work (never, 1/2–1, 2–3, or 4+ h/week), and moderate activity (1, 2–3, 4–6, 7–10, or 11+ h/week). Besides physical activity, data on the diet and beverages consumed during the previous year was assessed by a validated food frequency questionnaire specifically designed for use in this multiethnic cohort.¹⁴ Smoking behavior, educational attainment, weight, and height were self-reported by participants at baseline. Body mass index (BMI) was calculated as weight divided by height squared.

Statistical analysis

All analyses were performed separately for men and women. Hazard ratios (HR) and 95% confidence intervals (CI) associated with physical activity were estimated using Cox proportional hazards regression using follow-up time as 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 models were stratified by age at cohort entry as a way of adjustment for age; BMI (continuous), ethnicity (Native Hawaiian, Japanese American vs. Caucasian), and education (13–15, >15 vs. <13 years) were included in the models as covariates. Additional adjustments for alcohol consumption, smoking status, fiber and meat intake, which were shown to be associated with diabetes in this population,^{15;16} did not change the estimates substantially and are not presented. Tests for linear trend were performed by entering the categorical variables as continuous parameters in the adjusted models. Furthermore, we assessed effect modification by ethnicity, education, smoking status, and BMI by fitting interaction terms of physical activity variables and potential effect modifiers to the adjusted models and by evaluating the significance of these cross-product terms with Wald tests. To assess effect modification by ethnicity, we performed stratified analysis by ethnicity. No major violations of the proportional hazard assumption were observed using time-dependant variables. All statistical tests used 2-sided p-values and statistical significance was set at $p < 0.05$. Analyses were performed with SAS statistical software, version 9.2 (SAS Institute, Inc., Cary, NC, USA).

Results

The proportion of incident diabetes cases was highest among Native Hawaiian men and women, followed by Japanese American and lowest in Caucasians (Table 1). Physical activity patterns varied by ethnicity. Caucasian men and women were more likely to engage in strenuous sports for 4+ h/week than Native Hawaiians or Japanese Americans; however, Native Hawaiians were more likely to report vigorous work for 4+ h/week than the other ethnic groups. Engaging in moderate physical activity did not vary much across ethnic groups in men, while among women, Caucasians were more likely to exercise 11+ h/week than Native Hawaiians and Japanese Americans.

We found a significant inverse trend in diabetes risk for engaging in strenuous sports for all men (Table 2); engaging in strenuous sports for 4+ h/week was associated with a HR of 0.80 (95% CI: 0.72–0.88) relative to never with a significant trend ($p < 0.01$). When repeating this analysis without adjustment for BMI, the respective HR was 0.66 (95% CI: 0.60–0.74). The inverse association was consistent across men of all three ethnic groups. A similar association was seen for engaging in vigorous work for 4+ h/week (HR of 0.84; 95% CI: 0.77–0.92) for all men and for Caucasian and Native Hawaiian men separately but not

Japanese American men. Moderate activity showed no association with diabetes risk overall, but there was a statistically significant inverse trend in Caucasian men only ($p_{\text{trend}} = 0.01$). The respective tests for interaction between the physical activity variables and ethnicity were borderline significant with $p_{\text{interaction}}$ of 0.07 for strenuous sports, 0.08 for vigorous work, and significant with 0.02 for moderate activity.

Similar to men, engaging in strenuous sports was associated with a reduced risk of diabetes for women overall (Table 3) (HR = 0.67; 95% CI: 0.57–0.79) for 4+ h/week compared to never. Without adjustment for BMI, the risk was even lower (HR = 0.51; 95% CI: 0.43–0.60). As seen in men, the inverse association was consistent across ethnic strata ($p_{\text{interaction}} = 0.34$) with a reduced diabetes risk of 46%, 34% and 24% in Caucasian, Native Hawaiian, and Japanese American women, respectively. Fewer women than men engaged in vigorous work, which did not show any significant associations with diabetes risk overall or in ethnic strata ($p_{\text{interaction}} = 0.87$). As seen for men, engaging in moderate activity was not associated with diabetes risk in women overall, but showed a statistically significant inverse trend in Caucasian women only ($p_{\text{trend}} = 0.03$) with a significant ethnic interaction effect ($p_{\text{interaction}} = 0.03$).

We found no indication of any effect modification of the association between physical activity and diabetes risk by BMI category, smoking status, or education; all p -values for tests of interaction were >0.05 in men and women and for the different physical activity variables.

Discussion

This study found a significant inverse association of strenuous sports with diabetes risk across all three ethnic groups and in both sexes. The magnitude of risk reduction for strenuous sports appeared to be greater in women than in men, and for Caucasians compared to Native Hawaiians and Japanese Americans. Engaging in moderate activity was associated with lower diabetes risk in both men and women but only in Caucasians. Vigorous work was inversely associated with diabetes in men only, probably because few women are active in jobs with high activity, and the protective effect was not seen in Japanese Americans. BMI is a strong risk factor for diabetes and is related to physical activity because activity increases energy expenditure and might, thus, lower body weight or prevent weight gain. Our findings support a role of high-intensity physical activity in addition to weight control in diabetes prevention.

As we showed for this population in a previous analysis, BMI has a stronger association with diabetes risk among Japanese Americans than Caucasians, with HR of 15.51 (95% CI: 12.78–18.82) for obese Caucasians and 30.76 (95% CI: 25.30–37.40) for obese Japanese Americans as compared to Caucasians with BMI $< 22 \text{ kg/m}^2$.¹³ Physical activity might influence body weight and BMI and thus impact on diabetes risk. However, we adjusted all models for BMI (and other known confounders) but still found significant risk estimates suggesting that physical activity might influence diabetes risk through other mechanisms than reducing BMI. Although some studies found beneficial effects of physical activity to be more pronounced in overweight subjects,^{17,18} we found no indication for effect modification by BMI status at baseline, concurring with the results of several other reports.^{19–22} In previous analyses, we also found a lower diabetes incidence rate among subject with higher than lower education,¹³ but no indication for effect modification by educational status.

The findings of this study agree with previous prospective cohort studies reporting that regular physical activity reduces the risk of diabetes by 20–30% after adjustment for BMI and other confounding factors as reviewed recently.⁴ As in our analysis of strenuous sports,

most studies reported a dose-response relationship. When focusing on the type of physical activity, the majority of studies established an inverse association between diabetes and activities of moderate or vigorous intensity, while lighter activities showed less of a protective effect. However, most of these studies were performed in Caucasian subjects⁴ and only a few reported results from other ethnic groups^{23–26} or were able to stratify their study population into ethnic subgroups.¹¹ Among Japanese men vigorous physical activity tended to be more beneficial in diabetes prevention than moderate or light activity^{24;25} Among Chinese women leisure time physical activity was associated with lower risk of diabetes, as was stair climbing and cycling, but household activities and walking were not.²⁶ Finally, ethnic-specific analyses in the Women's Health Initiative study indicated inverse associations between walking or total physical activity and diabetes risk only in Caucasian women, but not in African American, Hispanic or Asian/Pacific Islander women.¹¹ It is possible that non-Caucasian groups need greater intensity of physical activity to obtain a beneficial effect against diabetes because they are more susceptible to the disease at lower BMIs. Alternate explanations are that the effects of physical activity may be attenuated by genetic factors or that the lower total amount of physical activity in Japanese Americans and Native Hawaiians than Caucasians (Table 1) was insufficient to reach a hypothetical threshold for a benefit.¹¹ Taken together, results of these studies are supported by our findings, which for the first time are based on a sufficient large number of participants of different ethnic groups to enable ethnic-specific analyses and tests for interaction.

From a biological perspective, physical activity may influence glucose homeostasis and confer protection against the development of diabetes through several proposed mechanisms.²⁷ Physical activity leads to an increased muscle glucose uptake during activity and improves insulin sensitivity, which can persist for some hours or even days after activity cessation.^{28;29} More and more evidence has accumulated that the extent of improvement with exercise training differs substantially across individuals and that these differences might be associated with genetic polymorphisms.³⁰ Frequencies of these polymorphisms are likely to vary by ethnicity and might be one reason for different effects of physical activity on risk in diverse populations. In the future, more gene-physical activity interaction studies may elucidate this issue.

Methodological issues related to physical activity assessment via questionnaire may explain the slight ethnic differences observed in our and other studies because questions might be answered differently depending on the ethnic background of participants. A limitation of this study is that no information on validity and reproducibility of the physical activity questions was available. However, the questions followed those of other studies using validated questionnaires and were pre-tested extensively to assure that participants from all educational and ethnic backgrounds were able to understand them. Most epidemiological studies on physical activity and diabetes risk rely on questionnaires to assess exercise⁴ although self-reported physical activity is an incomplete proxy for exercise or fitness. Moreover, questionnaires tend to assess vigorous activities with greater sensitivity than light activities³¹ and physical activity patterns may have changed over time. A further limit of this study is that we did not have information on the type of diabetes, but given the age of our participants, it is likely that >90% of cases are type 2. On the other hand, we cannot rule out that some of our non-cases might have suffered from undiagnosed diabetes because the population has not been screened for diabetes and information on individual fasting blood glucose level was not available. Another limitation is that body weight, a major risk factor for diabetes, was self-reported. Although we adjusted for BMI, information on waist-to-hip ratio as measure of abdominal fatness might improve the analysis, since Japanese Americans in particular are prone to abdominal fat accumulation.³² Unfortunately, this information was not available. As a common in epidemiologic studies, our participants tended to have a higher education and a healthier lifestyle in comparison to the general population.¹² Finally,

we included only subjects between 45–75 years, thus, inferences to younger persons are not possible.

Strengths of our study are the prospective design (avoiding any potential for the physical activity reports to have been biased by a diabetes diagnosis), case ascertainment through health insurance plans, and information on various known confounding factors. In addition, the large sample size and, in particular, the large number of subjects with ethnic background other than Caucasian enabled us to examine interactions across ethnic groups.

In conclusion, the findings of this study, combined with those of other reports, suggest that although vigorous work or strenuous physical activity protects against diabetes, moderate physical activity might not be sufficient to prevent diabetes among individuals with Asian and Pacific Islander ancestry than Caucasians. Our study results underscore the importance of vigorous physical activity in diabetes prevention; it is clear from the non-significant HRs (Table 2 and 3) that men and women in all ethnic groups experienced very little protection against diabetes from 2–3 h/week of moderate activity as recommended by current guidelines.^{9;10} Increasing physical activity in sedentary populations like that of the United States is a challenge, and guidelines to promote healthy lifestyles often focus on increasing moderate physical activity instead of vigorous physical activity.^{9;10} However, it has to be kept in mind that strenuous physical activity recommendations might not be achievable, especially among older populations. Our findings suggest that low- or moderate-intensity physical activity may have little or no benefit for certain non-Caucasian groups, at least with regard to diabetes risk, thus raising the issue of whether ethnic-specific guidelines to promote optimal health may be needed.

Acknowledgments

We thank Mark M. Schmidt and Aileen Uchida at Kaiser Permanente Center for Health Research, Honolulu, HI and Deborah Taira Juarez and Krista Hodges at HMSA (Blue Cross/Blue Shield of Hawaii) for their assistance in linking the cohort with the health plans.

Funding source

The Multiethnic Cohort is supported by NCI grant R37CA54281. The recruitment of Native Hawaiians was funded by grant DAMD 17-94-T-4184. The diabetes project is funded by R21 DK073816.

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Table 1

Baseline characteristics of participants in the Hawaii component of the Multiethnic Cohort Study by ethnicity and sex, 1993–2007^a

	Men			Women		
	Caucasian	Native Hawaiian	Japanese American	Caucasian	Native Hawaiian	Japanese American
Number of subjects	14,904	4,559	16,513	14,346	5,945	18,646
Diabetes cases (%)	7.2	17.4	16.1	5.0	15.9	12.7
Age (y)						
45–54	45.0	50.3	32.7	47.1	53.0	32.3
55–64	27.8	29.3	28.0	26.6	28.1	30.4
65+	27.3	20.4	39.2	26.3	18.9	37.3
BMI (kg/m ²)						
<22.0	13.5	6.9	18.7	33.6	16.2	43.1
22.0–24.9	33.5	19.6	38.9	28.6	22.2	30.8
25.0–29.9	40.7	44.2	36.7	25.2	33.5	21.4
>=30	12.3	29.3	5.7	12.6	28.1	4.7
Education (y)						
<= 12	19.4	48.1	39.4	23.6	52.9	41.5
12–15	28.9	31.7	28.7	34.1	29.9	28.1
>16	51.8	20.2	31.9	42.3	17.2	30.4
Strenuous sport						
Never	49.2	48.4	62.4	58.4	61.2	74.1
1/2–1 h/wk	18.3	23.2	17.7	16.5	21.0	12.8
2–3 h/wk	15.0	14.3	10.7	12.8	10.1	8.2
4+ h/wk	17.5	14.1	9.2	12.3	7.7	4.9
Vigorous work						
Never	36.5	26.1	44.4	66.0	56.0	80.0
1/2–1 h/wk	26.7	24.6	28.8	19.7	22.2	13.9
2–3 h/wk	16.5	19.7	13.0	8.1	11.5	3.8
4+ h/wk	20.2	29.6	13.9	6.2	10.4	2.3
Moderate activity						
1 h/wk	19.0	23.6	22.2	10.8	15.4	17.5

	Men				Women			
	Caucasian	Native Hawaiian	Japanese American	Caucasian	Native Hawaiian	Japanese American	Japanese American	
2–3 h/wk	27.2	30.5	25.2	24.3	31.4		30.1	
4–6 h/wk	21.8	21.3	23.8	24.5	23.2		23.2	
7–10 h/wk	14.9	10.7	13.1	17.5	13.3		13.4	
11+ h/wk	16.9	13.9	15.7	22.9	16.8		15.8	

^aIn percent

Table 2
Diabetes risk associated with physical activity in men, Hawaii component of the Multiethnic Cohort, 1993–2007

All men			Caucasian			Native Hawaiian			Japanese American			
Cases	HR ^a	95% CI	Cases	HR ^b	95% CI	Cases	HR ^b	95% CI	Cases	HR ^b	95% CI	
Strenuous sport (h/wk)												
Never	2764	1.00	637	1.00		404	1.00		1723	1.00		
1/2-1	874	0.94	0.87, 1.02	201	0.91	0.77, 1.07	200	0.95	0.80, 1.12	473	0.94	0.85, 1.05
2-3	478	0.85	0.77, 0.94	126	0.87	0.72, 1.07	93	0.75	0.59, 0.94	259	0.90	0.79, 1.03
4+	411	0.80	0.72, 0.88	107	0.72	0.58, 0.89	95	0.83	0.66, 1.04	209	0.85	0.74, 0.99
P _{trend}		<0.01			<0.01			0.02				0.01
Vigorous work (h/wk)												
Never	1834	1.00	454	1.00		211	1.00		1169	1.00		
1/2-1	1241	0.91	0.85, 0.98	271	0.83	0.71, 0.97	202	0.89	0.73, 1.08	768	0.95	0.87, 1.05
2-3	675	0.91	0.83, 1.00	145	0.77	0.64, 0.94	167	0.88	0.72, 1.09	363	1.00	0.89, 1.13
4+	777	0.84	0.77, 0.92	201	0.81	0.68, 0.96	212	0.75	0.62, 0.92	364	0.91	0.80, 1.02
P _{trend}		<0.01			<0.01			0.01				0.19
Moderate activity (h/wk)												
1	1063	1.00	255	1.00		182	1.00		626	1.00		
2-3	1164	0.92	0.84, 1.00	306	0.94	0.79, 1.11	234	1.00	0.82, 1.22	624	0.90	0.80, 1.00
4-6	1064	0.97	0.89, 1.06	219	0.84	0.70, 1.01	173	1.08	0.87, 1.33	672	1.00	0.90, 1.12
7-10	543	0.87	0.78, 0.97	122	0.71	0.57, 0.89	92	1.11	0.86, 1.44	329	0.90	0.79, 1.03
11+	693	0.95	0.86, 1.05	169	0.85	0.70, 1.04	111	1.14	0.90, 1.46	413	0.96	0.85, 1.09
P _{trend}		0.20			0.01			0.17				0.69

HR: hazard ratio; CI: confidence interval; wk: week

^a Adjusted for age, ethnicity, education, and BMI

^b Adjusted for age, education, and BMI

Table 3
Diabetes risk associated with physical activity in women, Hawaii component of the Multiethnic Cohort, 1993–2007

	All women				Caucasian				Native Hawaiian				Japanese American			
	Cases	HR ^a	95% CI		Cases	HR ^b	95% CI		Cases	HR ^b	95% CI		Cases	HR ^b	95% CI	
Strenuous sport h/wk																
Never	2950	1.00			499	1.00			611	1.00			1840	1.00		
1/2-1	641	1.00	0.91, 1.09		113	1.01	0.82, 1.24		216	1.08	0.92, 1.27		312	0.97	0.86, 1.09	
2-3	288	0.85	0.75, 0.96		66	0.88	0.68, 1.15		80	0.92	0.73, 1.17		142	0.80	0.68, 0.95	
4+	155	0.67	0.57, 0.79		33	0.54	0.38, 0.77		39	0.66	0.47, 0.91		83	0.76	0.61, 0.95	
P _{trend}			<0.01				<0.01				0.06					<0.01
Vigorous work h/wk																
Never	2895	1.00			476	1.00			542	1.00			1877	1.00		
1/2-1	707	1.03	0.95, 1.12		146	1.16	0.96, 1.40		213	0.95	0.81, 1.11		348	1.05	0.94, 1.18	
2-3	253	0.99	0.87, 1.13		52	1.09	0.82, 1.46		101	0.88	0.71, 1.09		100	1.04	0.85, 1.28	
4+	179	0.91	0.78, 1.06		37	1.01	0.72, 1.42		90	0.87	0.69, 1.09		52	0.93	0.70, 1.23	
P _{trend}			0.47				0.46				0.12					0.79
Moderate activity h/wk																
1	697	1.00			105	1.00			148	1.00			444	1.00		
2-3	1200	0.99	0.90, 1.09		174	0.82	0.64, 1.04		305	1.08	0.89, 1.32		721	0.99	0.88, 1.12	
4-6	944	1.01	0.92, 1.12		185	0.92	0.72, 1.17		201	1.04	0.84, 1.29		558	1.02	0.89, 1.15	
7-10	557	1.01	0.90, 1.12		121	0.85	0.65, 1.11		144	1.26	1.00, 1.60		292	0.94	0.81, 1.09	
11+	636	0.95	0.85, 1.06		126	0.69	0.53, 0.90		148	1.13	0.90, 1.43		362	0.98	0.85, 1.13	
P _{trend}			0.48				0.03				0.15					0.57

HR: hazard ratio; CI: confidence interval; wk: week

^a Adjusted for age, ethnicity, education, and BMI

^b Adjusted for age, education, and BMI