Walking Compared With Vigorous Physical Activity and Risk of Type 2 Diabetes in Women

A Prospective Study

Frank B. Hu, MD, PhD
Ronald J. Sigal, MD
Janet W. Rich-Edwards, ScD
Graham A. Colditz, MD, DrPH
Caren G. Solomon, MD, MPH
Walter C. Willett, MD, DrPH
Frank E. Speizer, MD
JoAnn E. Manson, MD, DrPH

Context Although many studies suggest that physical activity may reduce risk of type 2 diabetes, the role of moderate-intensity activity such as walking is not well understood.

Objectives To examine the relationship of total physical activity and incidence of type 2 diabetes in women and to compare the benefits of walking vs vigorous activity as predictors of subsequent risk of type 2 diabetes.

Design and Setting The Nurses' Health Study, a prospective cohort study that included detailed data for physical activity from women surveyed in 11 US states in 1986, with updates in 1988 and 1992.

Participants A total of 70 102 female nurses aged 40 to 65 years who did not have diabetes, cardiovascular disease, or cancer at baseline (1986).

Main Outcome Measure Risk of type 2 diabetes by quintile of metabolic equivalent task (MET) score, based on time spent per week on each of 8 common physical activities, including walking.

Results During 8 years of follow-up (534 928 person-years), we documented 1419 incident cases of type 2 diabetes. After adjusting for age, smoking, alcohol use, history of hypertension, history of high cholesterol level, and other covariates, the relative risks (RRs) of developing type 2 diabetes across quintiles of physical activity (least to most) were 1.0, 0.77, 0.75, 0.62, and 0.54 (P for trend $<.001$); after adjusting for body mass index (BMI), RRs were 1.0, 0.84, 0.87, 0.77, and 0.74 (P for trend = .002). Among women who did not perform vigorous activity, multivariate RRs of type 2 diabetes across quintiles of MET score for walking were 1.0, 0.91, 0.73, 0.69, and 0.58 (P for trend $<.001$). After adjusting for BMI, the trend remained statistically significant (RRs were 1.0, 0.95, 0.80, 0.81, 0.74; P for trend = .01). Faster usual walking pace was independently associated with decreased risk. Equivalent energy expenditures from walking and vigorous activity resulted in comparable magnitudes of risk reduction.

Conclusions Our data suggest that greater physical activity level is associated with substantial reduction in risk of type 2 diabetes, including physical activity of moderate intensity and duration.

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Strong epidemiologic evidence suggests that physical activity is associated with reduced risk of type 2 diabetes. In cross-sectional and ecological studies, higher levels of physical activity are associated with lower prevalence of type 2 diabetes.[1,2] Populations who migrate to westernized countries with more sedentary lifestyles have greater risks of type 2 diabetes than their counterparts who remain in their native countries.[2] Populations undergoing westernization in the absence of migration, such as North American Indians[3] and Western Samoans,[4,5] also have experienced increases in obesity and type 2 diabetes. Such studies must be interpreted with caution, however. In cross-sectional studies, it is difficult to establish cause and effect, and in the studies of migrant or westernizing populations, many other factors in addition to physical activity undergo change, including modifications in diet and other lifestyle factors.

More powerful support for the role of physical activity in the prevention of type 2 diabetes has emerged in the past several years from prospective cohort studies.[6-13] Most of these studies, however, did not examine separately the role of moderate-intensity physical activity such as walking vs vigorous activ-

Author Affiliations: Departments of Nutrition (Drs Hu and Willett) and Epidemiology (Drs Colditz, Willett, and Manson), Harvard School of Public Health, the Channing Laboratory (Drs Sigal, Colditz, Solomon, Willett, Speizer, and Manson), and the Division of Preventive Medicine (Dr Manson), Department of Medicine, Harvard Medical School, and Brigham and Women's Hospital, the Department of Ambulatory Care and Prevention (Dr Rich-Edwards), Harvard Medical School, Boston, Mass; and Clinical Epidemiology Unit, Loeb Health Research Institute, University of Ottawa, Ottawa, Ontario (Dr Sigal).
Corresponding Author and Reprints: Frank B. Hu, MD, PhD, Department of Nutrition, Harvard School of Public Health, 665 Huntington Ave, Boston, MA 02115 (e-mail: Frank.hu@channing.harvard.edu).

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ity, although increasing evidence supports the beneficial effects of moderate-intensity activity.[14-16] Except for subjects in our own previous report,[7] subjects in these studies have been predominantly male. All have suggested an inverse association between physical activity and diabetes, but there have been discrepancies among studies in terms of the relationship between risk of type 2 diabetes and the frequency and intensity of physical activity. Whether the effects of physical activity on diabetes risk differ between individuals at high vs low risk of type 2 diabetes (ie, the presence or absence of diabetes risk factors) has also been controversial.

In this study, we used detailed and repeated assessments of physical activity to quantify the dose-response relationship between total physical activity and incidence of type 2 diabetes in women. We also examined in detail the potential benefits of walking (the most common form of physical activity in middle-aged and older populations) compared with more vigorous activity.

METHODS

Subjects

The Nurses' Health Study cohort was established in 1976 when 121 700 female registered nurses aged 30 to 55 years residing in 1 of 11 US states responded to mailed questionnaires regarding their medical history and health practices; details have been published elsewhere.[17] The subjects for the present analysis were 70 102 women from this cohort who in 1986 were free from diagnosed diabetes, cardiovascular disease, and cancer (except nonmelanoma skin cancer) and who completed the questions on physical activity in 1986.

Assessment of Physical Activity

A detailed assessment of physical activity was first obtained by questionnaire in 1986 and updated in 1988 and 1992. Subjects were asked the amount of time they spent on average per week on each of the following physical activities: walking; jogging; running; bicycling; calisthenics, aerobics, aerobic dance, or rowing machine use; lap swimming; playing squash or racquetball; and playing tennis. They were also asked about their usual walking pace, specified as easy or casual (less than 3.2 km/h), normal, average (3.2-4.8 km/h), brisk (4.8-6.2 km/h), and very brisk or striding (6.4 km/h or faster). From this information, weekly energy expenditure in metabolic equivalent task–hours (MET-hours) was calculated.[18] Because only 2% of women reported a very brisk or striding pace, we combined brisk and very brisk categories in the analyses of walking pace and diabetes risk. We defined any physical activity requiring 6 METs or greater (a 6-fold or greater increase above resting metabolic rate) as vigorous. These activities included jogging, running, bicycling, performing calisthenics, lap swimming, playing squash or racquetball, and playing tennis. In contrast, walking requires an energy expenditure of only 2 to 4.5 METs, depending on pace, and therefore we considered it to be a moderate-intensity activity.

The reproducibility and validity of the physical activity questionnaire has been described elsewhere.[19] In a representative sample (n = 147) of participants in the Nurses' Health Study II cohort, the 2-year test-retest correlation for activity was 0.59. The correlation between physical activity reported on 1-week recalls and that reported on the questionnaire was 0.79. The correlation between activity reported in diaries and that reported on questionnaires was 0.62. In a separate study on a population aged 20 to 59 years recruited from a university community (n = 103), the correlation between physical activity score on a similar questionnaire and maximum oxygen consumption was 0.54.[20]

Earlier analyses from this cohort had used only a single activity question about number of episodes of vigorous (sweat-inducing) activity per week.[7] These earlier analyses demonstrated an inverse association between such vigorous activity and risk of type 2 diabetes but did not assess the potential role of walking and other moderate-intensity activities. Walking is by far the most prevalent physical activity among older adults[21] and is feasible, accessible, and relatively safe. We undertook the present analyses to examine the relationship between walking and risk of type 2 diabetes.

Diagnosis of Diabetes

A supplementary questionnaire regarding symptoms, diagnostic tests, and hypoglycemic therapy was mailed to women who indicated on any biennial questionnaire that they had been diagnosed as having diabetes. Women reporting a diagnosis of diabetes before 1986 were excluded from these analyses.

A case of diabetes was considered confirmed if at least 1 of the following was reported on the supplementary questionnaire: (1) 1 or more classic symptoms (excessive thirst, polyuria, weight loss, hunger) plus fasting plasma glucose levels of at least 140 mg/dL (7.8 mmol/L) or random plasma glucose levels of at least 200 mg/dL (11.1 mmol/L); (2) at least 2 elevated plasma glucose concentrations on different occasions (fasting levels of at least 140 mg/dL [7.8 mmol/L], random plasma glucose levels of at least 200 mg/dL [11.1 mmol/L], and/or concentrations of at least 200 mg/dL after 2 hours or more shown by oral glucose tolerance testing) in the absence of symptoms; or (3) treatment with hypoglycemic medication (insulin or oral hypoglycemic agent).

All women with diabetes in these analyses were at least 40 years old at the time of diagnosis. We excluded 27 cases of type 1 diabetes, 40 women classified as having gestational diabetes only, and an additional 183 cases of self-reported diabetes that did not satisfy all of our criteria for type 2 diabetes. The remaining women who reported new-onset diabetes were classified as having type 2 diabetes and were included in the present analyses.

Because of potential associations between weight and physical activity, no body weight criteria were used in the classification of type of diabetes for these analyses. Our criteria for diabetes classification are consistent with those proposed by the National Diabetes Data Group.[22] The validity of this

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questionnaire has been verified in a subsample of this study population.[7] Among a random sample of 84 women classified by the questionnaire as having type 2 diabetes, 71 gave permission for their medical records to be reviewed, and records were available for 62. An endocrinologist (J.E.M.) blinded to the information reported on the supplementary questionnaire reviewed the records according to National Diabetes Data Group criteria.[22] The diagnosis of type 2 diabetes was confirmed in 61 (98%) of 62 of the women.[7]

Statistical Analysis

Person-years for each participant were calculated from the date of return of the 1986 questionnaire to the date of confirmed type 2 diabetes, death from any cause, or June 1, 1994, whichever came first. Incidence rates of type 2 diabetes were obtained by dividing number of cases by person-years in each category of physical activity. Relative risks (RRs) were computed as the incidence rate in a specific category of MET score divided by that in the lowest quintile, with adjustment for 5-year age categories. Tests of linear trend across increasing categories of MET were conducted by treating the categories as a continuous variable and assigning the median score for the category as its value. To best represent long-term physical activity levels of individual women and reduce measurement error, we created measures of the cumulative average of MET scores from all available questionnaires up to the start of each 2-year follow-up interval.[23] For example, the 1986 MET score was related to the incidence of type 2 diabetes between 1986 and 1988, and the average of the 1986 and 1988 scores was related to the incidence between 1988 and 1990.

We used pooled logistic regression with 2-year intervals[24] to adjust simultaneously for potential confounding variables including age (5-year interval), smoking status (never; past; current smoking of 1-14, 15-24, and 25 or more cigarettes per day), alcohol consumption (0, 1-4, 5-14, or 15 or more g/d), menopausal status and postmenopausal hormone use, parental history of diabetes, and history of hypercholesterolemia or hypertension at baseline. In additional analyses, we included body mass index (BMI) in quintiles in the model to examine the degree to which the relation with physical activity was mediated through BMI.

RESULTS

A total of 1419 cases of type 2 diabetes were confirmed during 8 years (534 928 person-years) of follow-up, corresponding to an incidence rate of 265 per 100 000 person-years. **Table 1** shows the distributions of selected characteristics according to quintile of total energy expenditure on physical activity, standardized to the age distribution of the study population. Compared with their sedentary colleagues, physically active women tended to be leaner and were less likely to be current smokers or hypertensive. Dietary intakes of fats and cholesterol did not differ appreciably across quintiles.

There was a progressive reduction in the age-adjusted RR of diabetes with increasing physical activity (**Table 2**). After adjustment for smoking, alcohol use, history of hypertension, and elevated cholesterol level, the RRs across quintiles of total MET-hours per week were 1.0, 0.77, 0.75, 0.62, and 0.54 (*P* for

Table 1. Distribution of Potential Type 2 Diabetes Risk Indicators According to Quintile of Total Physical Activity Score at Baseline (1986)*

	Quintile, MET-Hours per Week (Median)†				
	1 0-2.0 (0.8)	2 2.1-4.6 (3.3)	3 4.7-10.4 (7.7)	4 10.5-21.7 (15.7)	5 ≥21.8 (35.4)
No. of women	13 283	14 564	14 064	13 928	14 263
% of group					
Current smokers	28.3	23.9	19.7	17.4	17.5
History of hypertension	24.8	24.0	22.8	21.5	20.2
History of hypercholesterolemia	11.3	10.9	11.1	11.5	10.1
Family history of diabetes	16.3	17.1	16.1	16.3	15.3
Current postmenopausal hormone use	19.7	21.7	23.4	23.9	24.3
Mean (SD)					
Age, y	52.0 (7.1)	52.2 (7.1)	52.1 (7.2)	52.2 (7.2)	52.2 (7.2)
Alcohol, g/d	6.1 (11.6)	5.8 (10.6)	6.1 (10.2)	6.5 (10.5)	7.1 (10.8)
BMI, kg/m^2	24.9 (4.9)	24.5 (4.4)	24.1 (4.0)	23.7 (3.9)	23.4 (3.7)
Waist circumference, cm	80.5 (11.9)	79.2 (10.9)	78.2 (10.4)	77.0 (9.9)	75.4 (9.7)
Saturated fat, % of energy‡	12.2 (2.7)	11.9 (2.5)	11.7 (2.5)	11.5 (2.5)	11.2 (2.6)
Polyunsaturated fat, % of energy‡	6.2 (1.7)	6.1 (1.6)	6.2 (1.6)	6.1 (1.6)	6.1 (1.6)
Trans fat, % of energy‡	1.8 (0.6)	1.7 (0.5)	1.7 (0.5)	1.6 (0.5)	1.5 (0.5)
Dietary cholesterol, mg/4184 kJ‡	154 (50.7)	152 (45.1)	150 (45.0)	149 (43.5)	148 (45.2)

*Percentages and means for variables other than age are standardized according to the age distribution of the overall study group. BMI indicates body mass index; MET, metabolic equivalent task.
†Average time per week spent in each of 8 activities multiplied by the MET value of each activity. The MET value is the energy need per kilogram of body weight per hour of activity divided by the energy need per kilogram of body weight per hour at rest.
‡Per energy intake per day.

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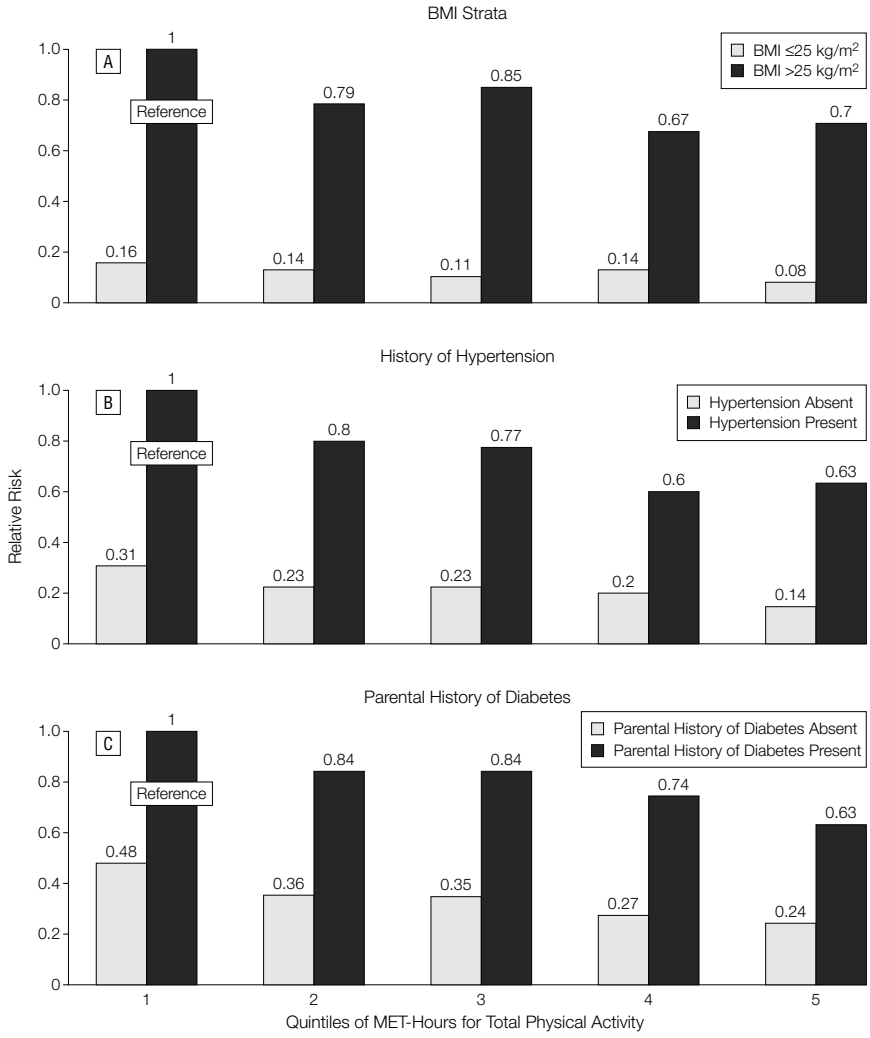
Table 2. Relative Risks (95% Confidence Intervals) of Type 2 Diabetes According to Quintile of Total Physical Activity Score From the Nurses' Health Study, 1986-1994*

	Quintile, MET-Hours per Week (Median)					
	1 0-2.0 (0.8)	2 2.1-4.6 (3.3)	3 4.7-10.4 (7.7)	4 10.5-21.7 (15.7)	5 ≥21.8 (35.4)	*P* Value
No. of cases	422	296	287	226	188	
Person-years	108 829	104 467	107 254	107 247	107 131	
Age-adjusted	1.0	0.71 (0.61-0.83)	0.67 (0.57-0.78)	0.52 (0.44-0.61)	0.43 (0.36-0.52)	<.001
Multivariate†	1.0	0.77 (0.66-0.90)	0.75 (0.65-0.88)	0.62 (0.52-0.73)	0.54 (0.45-0.64)	<.001
Additional adjustment for BMI‡	1.0	0.84 (0.72-0.97)	0.87 (0.75-1.02)	0.77 (0.65-0.91)	0.74 (0.62-0.89)	.002

*Computed as cumulative updated average across 1986, 1988, and 1992 (see the "Methods" section). See footnotes to Table 1 for definition of metabolic equivalent task (MET).
†Models included age (5-year category); time period (4 periods); cigarette smoking (never, past, and current smoking of 1-14 or ≥15 cigarettes per day); menopausal status (premenopausal, postmenopausal without hormone replacement, postmenopausal with past hormone replacement, or postmenopausal with current hormone replacement); parental history of diabetes; alcohol consumption (4 categories); history of hypertension; and history of high cholesterol level.
‡BMI indicates body mass index; in quintiles.

Figure. Multivariate Relative Risks of Type 2 Diabetes



Multivariate relative risks of type 2 diabetes according to MET-hours for Total Physical Activity quintile, within strata of body mass index (BMI), history of hypertension, and parental history of diabetes. Adjusted for the same covariates as in Table 2 (BMI not included in the model). See footnotes to Table 1 for definition of metabolic equivalent task (MET).

trend <.001). This inverse gradient remained statistically significant after adjusting for BMI (RRs across quintiles were 1.0, 0.84, 0.87, 0.77, and 0.74; *P* for trend = .002). Adjustment for glycemic load, dietary fiber, and whole grain consumption did not appreciably change the results. The physical activity score was inversely associated with risk of type 2 diabetes in both lean and overweight women, in women with and without a history of hypertension, and in women with and without parental history of diabetes (FIGURE).

To minimize potential bias from subclinical disease, we conducted additional analyses by excluding cases of type 2 diabetes that occurred during the first 2 years of follow-up (1097 cases were included in this analysis). The multivariate RRs across quintiles of physical activity score were 1.0, 0.90, 0.83, 0.72, and 0.61 (*P* for trend <.001). To address the possibility that surveillance may have varied according to physical activity, we performed an analysis restricted to cases reporting at least 1 symptom of diabetes at diagnosis (n = 859 cases, 61% of all cases). Results from this subgroup were not appreciably different from those for the entire cohort (multivariate RRs were 1.0, 0.78, 0.79, 0.59, and 0.55; *P* for trend <.001).

We examined changes in physical activity between 1986 and 1988 in relation to the incidence of diabetes between 1988 and 1994. Compared with women who were consistently sedentary (MET-hours per week ≤2 in both 1986 and 1988), women who were con-

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Table 3. Relative Risks (95% Confidence Intervals) of Type 2 Diabetes According to Quintile of MET Score for Walking Among Women Who Did Not Perform Vigorous Activities

	Quintile, MET Score for Walking (Median)†					
	1 ≤0.5 (0)	2 0.6-2.0 (1.7)	3 2.1-3.8 (3.0)	4 3.9-9.9 (7.5)	5 ≥10 (20.0)	*P*
No. of cases	250	205	145	133	111	
Person-years	62 977	57 069	52 872	51 277	51 406	
Age-adjusted	1.0	0.88 (0.73-1.07)	0.67 (0.55-0.83)	0.62 (0.50-0.77)	0.51 (0.41-0.64)	<.001
Multivariate*	1.0	0.91 (0.75-1.09)	0.73 (0.59-0.90)	0.69 (0.56-0.86)	0.58 (0.46-0.73)	<.001
Additional adjustment for BMI	1.0	0.95 (0.79-1.15)	0.80 (0.65-0.99)	0.81 (0.66-1.01)	0.74 (0.59-0.93)	.01

*Adjusted for the same covariates as in Table 2. See footnotes to Table 1 for definition of metabolic equivalent task (MET). BMI indicates body mass index.

sistently active (MET-hours per week >10.4 in both 1986 and 1988) had the lowest risk of diabetes (RR = 0.59; 95% confidence interval [CI], 0.46-0.75). Women who increased their activity level from 2.1-10.4 MET-hours in 1986 to >10.4 MET-hours in 1988 had a lower risk (RR = 0.71; 95% CI, 0.55-0.93) compared with those who were consistently sedentary.

We examined the association between walking and incidence of type 2 diabetes among participants who reported no physical activity other than walking to determine whether moderate-intensity physical activity (such as walking) has a similar inverse association with risk of type 2 diabetes and to minimize confounding of results by examining vigorous forms of activity. Approximately 47% of women in 1986 reported no vigorous activity, and 60% of all women reported that they walked at least 1 hour per week. There was a strong inverse association between walking score and risk of type 2 diabetes (TABLE 3). The multivariate RRs across quintiles of walking score were 1.0, 0.91, 0.73, 0.69, and 0.58 (*P* for trend <.001). Additional adjustment for BMI attenuated these RRs, but the trend remained statistically significant (*P* = .01). In addition, exclusion of women who reported they were "unable to walk" on the 1990 or 1992 questionnaire (34 cases excluded) did not alter the results. Independent of the number of hours spent on walking, walking pace was also significantly associated with risk of diabetes. Compared with women whose usual walking pace was "easy, casual," multivariate RRs were 0.72 (95% CI, 0.62-0.85) for "normal, average" pace and 0.41 (95% CI, 0.33-0.52) for "brisk" or "striding" pace (TABLE 4).

Table 4. Relative Risk of Type 2 Diabetes According to Usual Walking Pace Among Women Who Did Not Perform Vigorous Activities*

	Usual Walking Pace		
	Easy <3.2 km/h	Normal 3.2-4.8 km/h	Brisk or Very Brisk >4.8 km/h
No. of cases	244	448	133
Person-years	46 321	141 708	84 177
Age-adjusted RR (95% CI)	1.0	0.61 (0.52-0.72)	0.31 (0.25-0.38)
Multivariate RR† (95% CI)	1.0	0.72 (0.62-0.85)	0.41 (0.33-0.52)
Additional adjustment for BMI	1.0	0.86 (0.73-1.01)	0.59 (0.47-0.73)

*The number of cases was less than 844 (Table 3) due to missing values on walking pace. RR indicates relative risk; CI, confidence interval; and BMI, body mass index.
†Adjusted for the same covariates as in Table 2 as well as time spent walking per week.

Approximately 6% of women reported any jogging; 3%, any running; 30%, any biking; 12%, any swimming; 5%, playing any tennis; 27%, performing any calisthenics, aerobics, or aerobic dance; and 0.6%, playing any squash sports. After controlling for nonvigorous and other vigorous activities, the RRs of type 2 diabetes across categories of time spent on calisthenics or aerobics—classified as 0, less than 1 h/wk, and at least 1 h—were 1.0, 0.67 (95% CI, 0.55-0.81), and 0.56 (95% CI, 0.46-0.69), respectively (*P* for trend <.001). In the same model, the multivariate RRs were 0.58 (95% CI, 0.40-0.83) for jogging (any vs none), 0.74 (95% CI, 0.46-1.19) for running (any vs none), 0.79 (95% CI, 0.57-1.10) for tennis (any vs none), 1.14 (95% CI, 0.97-1.34) for swimming (any vs none), and 0.96 (95% CI, 0.85-1.09) for biking (any vs none).

When included simultaneously in the same model as continuous variables, walking and vigorous activity were associated with comparable risk reductions for equivalent energy expenditures. The multivariate RRs associated with a 5 MET-hours per week increase in energy expenditures were 0.95 (0.92-0.98) for vigorous activity and 0.92 (0.88-0.95) for walking.

COMMENT

In this large prospective cohort study, greater leisure-time physical activity level, in terms of both duration and intensity, was associated with reduced risk of type 2 diabetes. The dose-response relationship was consistent in those at low or high risk for diabetes, and remained significant after adjustment for BMI. The inverse association between energy expenditure from walking and risk of type 2 diabetes was similar to that for total physical activity and likewise persisted after controlling for BMI. This finding is reassuring, since walking is a physical activity that is

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highly accessible, readily adopted, and rarely associated with physical activity–related injury. In addition, we found a strong association between walking pace and risk of type 2 diabetes, even after adjustment for BMI and other known confounders.

Few women engaged in regular vigorous activities. Among the individual vigorous activities, calisthenics or aerobics was associated with the greatest reduction in type 2 diabetes risk. Other vigorous activities, including jogging, running, and playing tennis, were also inversely associated with the risk. Swimming and bicycling were not significantly associated with risk of diabetes. This finding may be due to the highly variable intensity with which these activities may be performed.

Overweight and obese people are less likely to engage in physical activity, because excess body weight may increase the difficulty of physical activity. This self-selection of heavy subjects for lower physical activity levels could account in part for the attenuation of the physical activity–diabetes relationship in regression models that included adjustment for BMI. However, other factors may also be involved in the relationship. Physical activity facilitates weight loss and weight maintenance.[25] Therefore, individuals expending a great deal of energy on physical activity tend to have lower adiposity. Furthermore, the adipose tissue loss resulting from physical activity is often of visceral rather than subcutaneous fat,[26-29] and visceral fat is strongly associated with insulin resistance and the related metabolic syndrome. Leaner individuals have a reduced risk of diabetes.[30-32] To the extent that physical activity causes individuals to have lower BMI, adjustment for BMI in regression models may constitute statistical overcorrection and result in underestimation of the true beneficial effect of physical activity.

It is biologically plausible that physical activity might reduce the risk of type 2 diabetes, because physical activity increases glucose disposal through a number of pathways. Physical activity has independent effects on glucose disposal by increasing both insulin-mediated and non–insulin-mediated glucose disposal.[33] A single bout of physical activity increases insulin-mediated glucose uptake for more than 24 hours.[34] The increased insulin sensitivity occurs because of increased number and activity of glucose transporters (especially the GLUT4 isoform), both in muscle and in adipose tissue.[35,36] Glycogen synthase activity is also increased, resulting in increased glycogen synthesis and increased nonoxidative disposal of glucose.[35,36] In addition to this direct effect on glucose disposal, physical activity results in decreased adipose tissue mass and preserved or increased lean body mass,[25] which also lead to increased insulin sensitivity. Consistent with these metabolic effects, small clinical trials have demonstrated a benefit of physical activity in the prevention of diabetes among people with impaired glucose tolerance.[37,38]

Equivalent energy expenditures from moderate or vigorous activity may confer comparable benefits. In the Insulin Resistance Atherosclerosis Study, both vigorous and nonvigorous activity were significantly associated with insulin sensitivity among 1467 men and women aged 40 to 69 years.[14] Daily walking combined with dietary therapy not only reduced body weight but also improved insulin sensitivity among diabetic patients.[39] Compared with structured aerobic physical activity, moderate-intensity activity had similar benefits on cardiorespiratory fitness and cardiovascular risk factors including blood pressure and lipid levels.[15,16]

Previous prospective studies have been limited but have generally found an inverse relationship between regular physical activity and risk of type 2 diabetes.[6-11,13,40] Few studies, however, have included women or assessed the role of moderate vs vigorous activity. Also, no previous study has provided updated assessments of physical activity. In 4 studies,[6,8,9,13] the risk of type 2 diabetes was shown to decrease with increasing amounts of physical activity, whereas in 3 other studies,[7,10,11] the degree of protection against diabetes was the same in those who exercised the most compared with those who exercised only moderately. In all studies, individuals whose levels of physical activity were moderate were at lower risk of diabetes than were those who were completely sedentary. The studies showing a dose-response relationship tended to have more detailed quantification of the dose of physical activity, as did the present study.

Some limitations of this study deserve attention. Because our "nondiabetic" cohort was not necessarily screened for glucose intolerance, some cases of diabetes may have been undiagnosed. However, when the analyses were restricted to symptomatic cases of type 2 diabetes, the findings were not appreciably altered, suggesting that surveillance bias according to activity level is unlikely. The diagnostic criteria for type 2 diabetes were changed in 1997,[41] such that lower fasting glucose levels (>126 mg/dL [7.0 mmol/L]) would now be considered diagnostic. We used the criteria proposed by the National Diabetes Data Group,[22] because all our cases were diagnosed prior to June 1994. If the new criteria were used, some women in this study classified as being without diabetes would have been reclassified as having diabetes. However, this would not explain our results, because inclusion of those with diabetes in the groups without diabetes would have caused bias toward the null. In addition, our study focused on leisure-time activity. Nonleisure energy expenditure may be also important in the prevention of chronic diseases.[42]

In conclusion, this large prospective study suggests that both walking and vigorous activity are associated with substantial reductions in risk of type 2 diabetes in women. We observed comparable magnitudes of risk reduction with walking and vigorous activity in this cohort, when total energy expenditures were similar. Our findings lend additional support to current guidelines from the Centers for Disease Control and Prevention[43] and the National Institutes of Health[44] that recommend

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that Americans should accumulate at least 30 minutes of moderate-intensity physical activity on most, but preferably all, days of the week.

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