Reprinted from the Archives of Internal Medicine June 24, 1996 Volume 156

ORIGINAL INVESTIGATION

Moderately Intense Physical Activities and High Levels of Cardiorespiratory Fitness Reduce the Risk of Non–Insulin-Dependent Diabetes Mellitus in Middle-aged Men

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Background: Physical activity has been advocated as an important factor in the primary prevention of non–insulin-dependent diabetes mellitus (NIDDM), but information concerning the specific intensities and durations that are protective has been unavailable.

Objective: To examine prospectively the association between self-reported levels of the intensity and duration of physical activities, and cardiorespiratory fitness (assessed by respiratory gas exchange) and incident cases of NIDDM (assessed by the oral glucose tolerance test) in a population-based sample of 897 middle-aged Finnish men.

Results: After adjustment for age, baseline glucose values, body mass index, serum triglyceride levels, parental history of diabetes, and alcohol consumption, moderately intense physical activities (≥5.5 metabolic units) that were undertaken for at least a 40-minute duration per week were associated with a reduced risk of NIDDM (odds ratio [OR], 0.44; 95% confidence interval [CI], 0.22-0.88). Activities with less than an intensity of 5.5 metabolic units, regardless of their duration, were not protective. Cardiorespiratory fitness levels greater than 31.0 mL of oxygen per kilogram per minute were protective against NIDDM (OR, 0.26; 95% CI, 0.08-0.82). A subgroup of men at high risk of NIDDM, because they were overweight and were hypertensive and had a positive parental history of NIDDM, who engaged in moderately intense physical activities above the 40-min/wk duration reduced their risk of NIDDM by 64% compared with men who did not participate in such activities.

Conclusions: After adjustment for age, baseline glucose levels, and known risk factors, physical activities with an intensity of 5.5 metabolic units or greater and a duration of 40 minutes or greater per week protected against the development of NIDDM. These protective effects were even more pronounced in a subgroup of men who were at high risk for the development of the disease.

(Arch Intern Med. 1996;156:1307-1314)

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PHYSICAL ACTIVITY has been advocated as an important factor in the primary prevention of non–insulin-dependent diabetes mellitus (NIDDM).[1] This recommendation derives from the convergence of several lines of research evidence. Ecologic studies have shown that societies that are more physically active have a lower prevalence of NIDDM,[2] and laboratory and intervention studies have shown that physical activity increases insulin sensitivity, induces weight loss, and improves glucose tolerance,[3,4] while higher levels of physical activity have been cross-sectionally associated with a decreased prevalence of NIDDM and a reduced insulin resistance.[5-8] Recently, a number of prospective epidemiologic studies have shown that higher levels of physical activity were associated with a decreased risk of NIDDM.[9-11] Even though these prospective studies were only able to examine the total-energy expenditure from leisure-time physical activity or the frequency of "vigorous" physical activity with a self-reported outcome of NIDDM, they have provided the most direct evidence of a protective effect of physical activity on the risk of NIDDM.

We investigated the association between the intensity and duration of leisure-time physical activities, and directly assessed cardiorespiratory fitness and incident cases of NIDDM that were determined from an oral glucose tolerance test in a population-based sample of middle-aged, eastern Finnish men. Considerable information on known risk factors for

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SUBJECTS AND METHODS

Subjects were participants in the Kuopio (Finland) Ischemic Heart Disease Risk Factor Study, which was designed to investigate previously unestablished risk factors for ischemic heart disease, carotid atherosclerosis, and other related outcomes in a population-based sample of eastern Finnish men.[12] Of the 3433 eligible men aged 42, 48, 54, or 60 years who resided in Kuopio or its surrounding rural communities, 198 were not included because of death, serious disease, or migration away from the area; 2682 men (82.9%) agreed to participate in the study. Baseline examinations were conducted between March 1984 and December 1989. No marked sociodemographic differences were found between participants and nonparticipants.[13]

A 4-year follow-up examination was conducted between March 1991 and December 1993 on those men who had undergone ultrasonographic examination of the carotid arteries at baseline. Follow-up examinations were conducted during the same month as the baseline and at the same time of day. The median follow-up was 4.2 years (range, 3.8-5.2 years). Of the 1229 participants who were eligible for the follow-up examinations, 52 had died, were suffering severe illness, or had migrated away from the area. Of the remainder, 139 could not be contacted or refused to participate. Of the 1038 men who participated in the follow-up examinations, complete information on physical activity, blood glucose levels, and all other risk factors was available for 897 participants. Participants who reported a history of NIDDM that was controlled by oral medication (n=4) or whose baseline fasting blood glucose level was 6.7 mmol/L or greater (120 mg/dL) (n=13) were excluded from the analysis. Additional missing data on cardiorespiratory fitness levels limited those analyses to 751 men.

ASSESSMENT OF NIDDM STATUS

At the 4-year follow-up examination, an oral glucose tolerance test was performed with a 75-g oral load after at least 12 hours of overnight fasting. Samples were drawn from whole blood, preceding and at 2 hours after the glucose load. Blood glucose samples were determined daily after precipitation with trichloroacetic acid (Granutest 100, Merck, Darmstadt, Germany). Subjects were considered to have NIDDM if they had either a fasting blood glucose level of 6.7 mmol/L or greater (120 mg/dL) or a 2-hour oral glucose tolerance test score of 10.0 mmol/L or greater (180 mg/dL), or a history of taking medication for treatment of diabetes.[14]

ASSESSMENT OF PHYSICAL ACTIVITY

Physical activity was assessed at baseline from a 12-month leisure-time history. The measure was modified from the Minnesota Leisure Time Physical Activity Questionnaire to represent the 15 most common leisure-time physical activities of middle-aged Finnish men (eg, walking, jogging, skiing, bicycling, swimming, gardening, fishing, hobbies) and by inclusion of a self-report of the intensity of physical activity.[15,16] For each of the 15 physical activity types on the questionnaire, subjects could either respond that they did not engage in the activity or that they would enter the frequency per month during the preceding year, the average duration per occasion, and the intensity of the particular activity. Subjects were asked to estimate the intensity with which they engaged in the activities by rating their usual participation on a scale from 0 to 3. These classes on the scale corresponded to the following effects that were related to the intensities of a particular activity: 0, "no breathlessness, no sweating"; 1, "breathlessness, no sweating"; 2, "breathlessness, some sweating"; and 3, "breathlessness, a lot of sweating."

Specific metabolic units (METs) were assigned for each type of activity according to the reported intensity level. The MET is the ratio of the metabolic rate during exercise to the metabolic rate at rest, and it is an indication of the relative intensity of an activity; 1 MET is approximately equal to an energy expenditure of 4.2 kJ/kg of body weight per hour. For example, a subject who reported walking that involved "breathlessness, some sweating" was assigned an intensity score of 6.0 METs, while a subject who reported walking with "no breathlessness, no sweating" was assigned an intensity score of 3.0 METs. These MET values

NIDDM enabled an examination of the independent association among physical activity, cardiorespiratory fitness, and NIDDM. In addition, this extensive risk factor information allowed stratified analyses to be conducted in groups that were considered to be at high and low risks of NIDDM to examine the potential of physical activity for reducing the risk of NIDDM in these groups.

RESULTS

At the 4-year follow-up, there were 46 incident cases of NIDDM, and 851 men remained nondiabetic. **Figure 1** shows the overall pattern of NIDDM risk for various combinations of the intensities and durations of leisure-time physical activity. The risk estimates were derived from logistic regression models that contained age, baseline glucose levels, all the risk factors, and 2 measures of physical activity that were dichotomized for a range of intensities and durations. The specific estimated risks for each combination of intensity and duration depended on the values that were assigned for each variable in the model. These estimates were based on a subject with the following profile: age, 50 years; baseline fasting blood glucose level, highest tertile of normal values (4.7-6.6 mmol/L [85-119 mg/dL]); median serum triglyceride level, 1.2 mmol/L (106 mg/dL); median BMI, 26.8; median systolic blood pressure, 126 mm Hg; parental history of diabetes, positive for both parents; and

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alcohol consumption, second quartile. While the absolute values estimated for the risks will change with the covariate levels, the relative differences in risk according to variations in the intensity and duration of physical activity will remain approximately the same.

Thresholds were observed for both intensity and duwere calculated on the basis of a synthesis of available empiric data.[16,17] Details of the methods of calculation, reliability, and validity of these measures have been described elsewhere.[11] The present analyses used intensity-dependent measures of the total duration of physical activity. Intensity was measured in METs, and total duration was assessed as the frequency multiplied by the average duration per sessions of leisure-time physical activity.

Two measures of physical activity were created by examining the total durations of physical activity above and below various intensity thresholds. For instance, the duration of moderate to higher-intensity physical activities was created by summing only those durations that were associated with any of the 15 physical activities that were conducted at or above 5.5 METs. Similarly, a measure of the duration of physical activities that was conducted at intensity levels lower than this was created by summing the total durations of any of the 15 activities that were conducted at less than 5.5 METs. The creation of a series of measures in this way at various intensity thresholds enabled the relative effects of exposure to different durations of higher- and lower-intensity activities to be examined together.

ASSESSMENT OF CARDIORESPIRATORY FITNESS

As part of the baseline examinations, cardiorespiratory fitness was measured directly from respiratory gas exchange during a maximal, symptom-limited exercise tolerance test on a bicycle ergometer. Details of the protocol have been described earlier.[18] The distribution of cardiorespiratory fitness scores was divided into quartiles, with the lowest quartile as the reference. The reference category corresponded to a cardiorespiratory fitness level of less than 25.8 mL of oxygen per kilogram per minute, while the boundaries for the other quartiles were 31.0 and greater than 36.0 mL of oxygen per kilogram per minute, respectively.

ASSESSMENT OF RISK FACTORS

The baseline blood glucose level was derived from venous blood samples that were taken after a 12-hour fast. All those subjects with baseline fasting blood glucose levels of 6.7 mmol/L or greater (120 mg/dL) were excluded from the analysis. The remaining distribution was divided into tertiles, with the lowest tertile as the reference. The body mass index (BMI) was calculated by dividing the subject's weight by his height in meters squared in kilograms . The waist-hip ratio was computed as the ratio of the circumference at the waist to the circumference at the hip. Blood pressure was measured with a random-zero sphygmomanometer after a supine rest of 5 minutes. Three systolic and 3 diastolic blood pressure measurements were taken with a subject in the supine position and averaged. Average systolic blood pressure was used in this analysis. The serum triglyceride level was based on photometric measurements of enzymatic calorimetric reactions (Boehringer Mannheim, Mannheim, Germany). High-density lipoprotein was separated from fresh serum samples by using precipitation and ultracentrifugation.[19] The cholesterol contents of lipoprotein fractions were photometrically measured from enzymatic calorimetric reactions (Boehringer Mannheim) on the day after the last ultracentrifugation. A parental history of diabetes was assessed from questionnaires that were administered at baseline. Alcohol consumption was assessed by instructed dietary recording for a 4-day period and by a self-administered questionnaire for the previous 12 months.[20] Four indicator variables were created to represent quartiles of alcohol consumption. The lowest quartile acted as the reference for those subjects who were classified as consumers of alcohol. A separate category that was compared with all others was created for those subjects who reported that they abstained from alcohol consumption.

STATISTICAL ANALYSIS

The association between the total durations of higher- and lower- intensity leisure-time physical activities, cardiorespiratory fitness, potential risk factors, and NIDDM was assessed by multivariate logistic regression. The analyses were conducted by using the LOGISTIC procedure in a statistical software package (SAS version 6.09 on a Sun Sparc Station II).[21]

ration. A significantly reduced risk of NIDDM appeared to accrue at moderate intensitiesof 5.5 METs or greater, and at durations of more than 40 min/wk. A total of 537 of the 897 men reported that they engaged in at least moderately intense physical activity for more than 40 min/wk. There were 17 cases of NIDDM recorded in this group. The reduction in risk may be even more pronounced at higher intensities of physical activity. There was little evidence of a similar protective effect for physical activities that were conducted at an intensity of less than 5.5 METs, regardless of their duration. In addition, there was no evidence of interaction between the durations of moderately intense and nonintense activities. The odds ratio (OR), after adjustment for age, baseline glucose levels, and risk factors that compared men who participated in leisure-time physical activities at the observed thresholds of an intensity of 5.5 METs or greater and durations longer than 40 min/wk with those who did not, was 0.44 (95% CI, 0.22-0.88).

When the age- and baseline glucose level–adjusted association between the duration of physical activities (<5.5 METs) and NIDDM was adjusted for the duration of physical activities of 5.5 METs or greater, the OR increased from 0.52 to 0.57 (95% CI, 0.30-1.09). Additional adjustment for the BMI greatly attenuated the association between the duration of nonintense physical activities and NIDDM (OR, 0.77; 95% CI, 0.38-1.53). However, in this same model, the relationship between the age- and baseline glucose level–adjusted association between the duration of physical activities (≥5.5 METs) and NIDDM was unaffected by further adjustment for nonintense durations and the BMI (OR, 0.46; 95% CI, 0.24-0.90). In a model that contained age, baseline glucose levels, the durations of physical activities (≥5.5 [moderately intense] and <5.5 [nonintense] METs), and all the risk factors, only the baseline glucose level, the duration of moderately intense physical activities, the BMI, and serum triglyceride levels remained statistically significant predictors of NIDDM.

As the distribution of the physical activity variables was highly skewed, **Table 1** presents the Spearman rank-order correlations among the total duration of moderately intense (≥5.5 METs) and nonintense (<5.5 METs) physical activities, cardiorespiratory fitness, and the risk factors for NIDDM. There was only a modest correlation of 0.11 between the duration of moderately intense and nonintense physical activities. Durations of physical activity, undertaken at 5.5 METs or greater, were positively correlated with cardiorespiratory fitness levels (r=0.32), while durations less than 5.5 METs were unrelated. **Table 2** shows the mean (SD) or median (inner 95th percentile) and prevalence (percentage) for the duration of moderately intense and nonintense physical activities, cardiorespiratory fitness, and risk factors for subjects with NIDDM and for nondiabetic subjects.

A total of 88 men (9.8%) reported that they engaged in no physical activities of at least moderate intensity (≥5.5 METs). Of the remainder, 61% of the men reported that they participated in 1 to 3 moderately intense physical activities, while more than 90% of the men claimed that they engaged in 10 or more activities of lower intensity than 5.5 METs. The median total duration of the activities at 5.5 METs or greater was 58.3 min/wk (range, 0-1464 min/wk), while the median duration for activities less than 5.5 METs was 222.3 min/wk (range, 0-2346.5 min/wk).

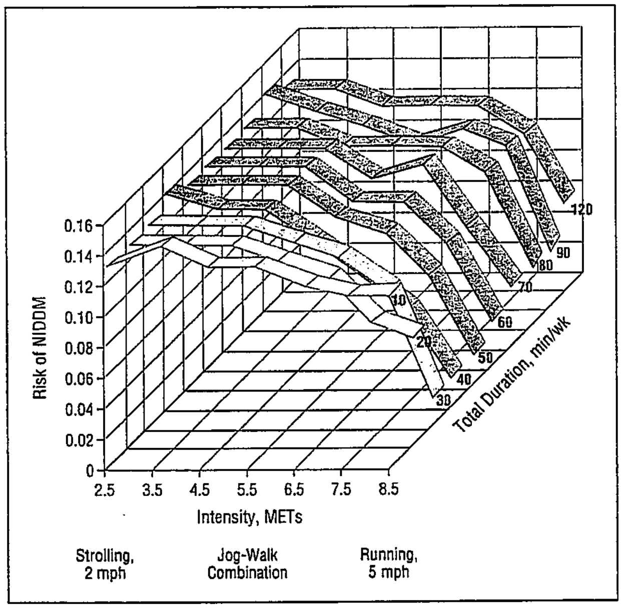

Figure 1. *The relationship between the intensity and duration of leisure-time physical activity and risk of non–insulin-dependent diabetes mellitus (NIDDM) (46 cases) in 897 Finnish men. METs indicates metabolic units.*

Table 3 presents the adjusted associations for age and the baseline fasting blood glucose levels; these associations were derived from separate logistic regression models among physical activity, cardiorespiratory fitness, other risk factors, and NIDDM. The BMI, waist-hip ratio, serum triglyceride and high-density lipoprotein levels, cardiorespiratory fitness, and the total duration of both moderately intense and nonintense physical activities were significantly associated with NIDDM.

CARDIORESPIRATORY FITNESS AND NIDDM

Compared with the lowest quartile of cardiorespiratory fitness, the age-, baseline glucose level–, and risk factor–adjusted ORs of incident NIDDM for the second, third, and highest quartiles were 0.77 (95% CI, 0.32-1.85), 0.26 (95% CI, 0.08-0.82), and 0.15 (95% CI, 0.03-0.79), respectively.

Figure 2 presents the estimated risks of NIDDM for each quartile of cardiorespiratory fitness. Because of missing information on cardiorespiratory fitness, there were only 39 cases of NIDDM that were available for these analyses. There were 17 cases in the lowest fitness quartile, with 14, 6, and 2 cases in the second, third, and high-

Table 1. Spearman Rank-Order Correlations (*P* Values) Among the Total Durations of Moderately Intense (≥5.5 METs) and Nonintense (<5.5 METs) Physical Activities, Cardiorespiratory Fitness, and Risk Factors for NIDDM*

Variable	Duration, <5.5 METs	Cardiorespiratory Fitness	Baseline Fasting Blood Glucose Level	BMI	Waist-Hip Ratio	Serum Triglyceride Level	Alcohol Consumption	HDL Level	Systolic Blood Pressure
Duration									
≥5.5 METs	0.11 (<.001)	0.32 (<.001)	−0.10 (.002)	−0.03 (.40)	−0.08 (<.02)	−0.07 (.04)	0.001 (.97)	0.10 (<.003)	0.06 (.11)
<5.5 METs		−0.06 (.07)	−0.05 (.14)	−0.05 (.12)	−0.05 (.17)	0.002 (.95)	−0.02 (.50)	0.05 (.13)	−0.02 (.64)
Cardiorespiratory fitness			−0.17 (<.001)	−0.32 (<.001)	−0.40 (<.001)	−0.30 (<.001)	0.07 (.06)	0.21 (<.001)	−0.09 (.01)
Baseline fasting blood glucose level				0.28 (<.001)	0.25 (<.001)	0.14 (<.001)	0.05 (.14)	−0.07 (.03)	0.10 (.003)
BMI					0.67 (<.001)	0.35 (<.001)	0.07 (<.04)	−0.26 (<.001)	0.24 (<.001)
Waist-hip ratio						0.33 (<.001)	0.14 (<.001)	−0.26 (<.001)	0.20 (<.001)
Serum triglyceride level							0.03 (.35)	−0.42 (<.001)	0.14 (<.001)
Alcohol consumption								0.15 (<.001)	0.07 (.03)
HDL level									−0.004 (.88)

**METs indicates metabolic units; NIDDM, non–insulin-dependent diabetes mellitus; BMI, body mass index; and HDL, high-density lipoprotein.*

Table 2. Mean (SD) or Median (Inner 95th Percentile) and Prevalence of Baseline Risk Factors for Subjects With NIDDM and for Normal Individuals in 897 Finnish Men*

Variable	Subjects With NIDDM (n=46)	Normal Individuals (n=851)
Mean (SD)		
Fasting blood glucose level at baseline, mmol/L†	5.37 (0.61)	4.52 (0.46)
Age, y	52.2 (6.2)	51.2 (6.66)
BMI, kg/m²	30.15 (4.19)	26.50 (3.25)
Waist-hip ratio	0.98 (0.05)	0.94 (0.06)
Serum triglyceride level, mmol/L†	2.23 (1.44)	1.37 (0.81)
HDL level, mmol/L†	1.19 (0.24)	1.31 (0.30)
Systolic blood pressure, mm Hg	131.93 (15.28)	127.83 (16.19)
Cardiorespiratory fitness, mL of O_2/kg per minute	25.3 (7.4)	31.7 (8.0)
Parental history of NIDDM, %		
Mother	26.1	18.7
Father	13.0	8.6
Median (inner 95th percentile)‡		
Alcohol consumption, g/wk	33.9 (0-570)	33.2 (0-288)
Duration of moderately intense (≥5.5 METs) physical activities, min/wk	31.2 (0-301.2)	60.0 (0-384.3)
Duration of nonintense (<5.5 METs) physical activities, min/wk	183.1 (20.2-853.5)	260.0 (36.3-994.3)

*NIDDM indicates non–insulin-dependent diabetes mellitus; BMI, body mass index; HDL, high-density lipoprotein; METs, metabolic units; and O_2, oxygen.

†Conventional units were as follows: glucose level, 98 (11) and 81 (8) mg/dL for subjects with NIDDM and normal individuals, respectively; triglyceride level, 198 (128) and 121 (72) mg/dL for subjects with NIDDM and normal individuals, respectively; and HDL level, 46 (9) and 51 (12) mg/dL for subjects with NIDDM and normal individuals, respectively.

‡Median (inner 95th percentile) was used when distribution was highly skewed.

est quartiles, respectively. The risks were estimated from a multivariate logistic regression model by using the same profile of risk factors as described above. Men who had higher than median cardiorespiratory fitness experienced a significantly lower risk of NIDDM than those below the median, with men in the highest quartile of fitness having a risk of NIDDM approximately 80% lower than those in the least-fit quartile. Men with cardiorespiratory fitness levels greater than 36.0 mL of oxygen per kilogram per minute had an NIDDM risk of 0.06 (95% CI, 0.009-0.42), while those in the third, second, and lowest quartiles of cardiorespiratory fitness had risks of 0.10 (95% CI, 0.02-0.49), 0.25 (95% CI, 0.07-0.85), and 0.30 (95% CI, 0.09-1.0), respectively.

PHYSICAL ACTIVITY IN A GROUP AT HIGH RISK OF NIDDM

To examine whether moderately intense physical activity modified the relationship between levels of baseline risk factors and NIDDM, we conducted a separate analysis that stratified the sample into high- and low-risk groups. Men were classified as being at high risk (n=71, 10 cases of NIDDM) if they were above the median BMI (≥26.8) and had either parent with a history of diabetes and were hypertensive (blood pressure, ≥140 [systolic] or ≥90 [diastolic] mm Hg, or used medication to treat hypertension). In each group, the effect of moderately intense physical activities on the risk of NIDDM was estimated from logistic regression models that were adjusted for age and the level of baseline fasting blood glucose. **Figure 3** shows the risk of NIDDM in high- and low-risk groups for moderately intense physical activities (≥5.5 METs) at a 40-min/wk duration or greater. In the high-risk group, men who participated in physical activities with an intensity of 5.5 METs or greater and a 40-min/wk duration or greater had an NIDDM risk of 0.16 (95% CI, 0.05-0.47), while men who did not engage in

Table 3. Age and Baseline Fasting Blood Glucose Level–Adjusted β, SE, OR, 95% CI, and *P* Value for the Bivariate Associations Between Physical Activity, Cardiorespiratory Fitness, Baseline Risk Factors, and Incident NIDDM*

Variable	β	SE	OR	95% CI	*P*
BMI, kg/m²					
Lowest 25% (reference)	...	...	...	...	...
2nd quartile	1.50	1.11	4.50	0.51-39.35	.17
3rd quartile	2.42	1.05	11.20	1.44-86.88	.02
Highest 25% (≥28.7)	2.87	1.03	17.63	2.33-133.20	.005
Waist-hip ratio					
Lowest 25% (reference)	...	...	...	...	...
2nd quartile	.92	0.68	2.52	0.66-9.65	.18
3rd quartile	.72	0.70	2.06	0.53-8.04	.30
Highest 25%	1.73	0.63	5.64	1.63-19.49	.006
Serum triglyceride level	.64	0.13	1.91	1.48-2.46	<.001
HDL level	−1.42	0.62	0.24	0.07-0.81	.02
Systolic blood pressure	.01	0.01	1.01	1.00-1.03	.28
Alcohol consumption					
Abstainers	−1.05	0.67	0.35	0.09-1.29	.11
1st quartile (reference)	...	...	1.0	...	...
2nd quartile	−.35	0.47	0.70	0.28-1.76	.45
3rd quartile	−.26	0.47	0.77	0.30-1.93	.58
4th quartile	−.27	0.44	0.77	0.33-1.80	.54
Parental history of NIDDM					
Mother	.40	0.36	1.49	0.73-3.03	.27
Father	.74	0.49	2.10	0.80-5.51	.13
Physical activity					
≥5.5 METs and ≥40-min/wk duration	−.86	0.32	0.42	0.22-0.79	.008
<5.5 METs and ≥2-h/wk duration	−.65	0.32	0.52	0.28-0.99	.05
Cardiorespiratory fitness					
Lowest 25% (reference)	...	...	1.0	...	...
2nd quartile	−.36	0.41	0.70	0.31-1.457	.38
3rd quartile	−1.34	0.53	0.26	0.09-0.74	.01
Highest 25% (≥36.0 mL of O_2/kg per minute)	−2.41	0.81	0.09	0.02-0.44	.003

*OR indicates odds ratio; CI, confidence interval; NIDDM, non–insulin-dependent diabetes mellitus; METs, metabolic units; and O_2, oxygen. Estimates were derived from separate logistic regression models.

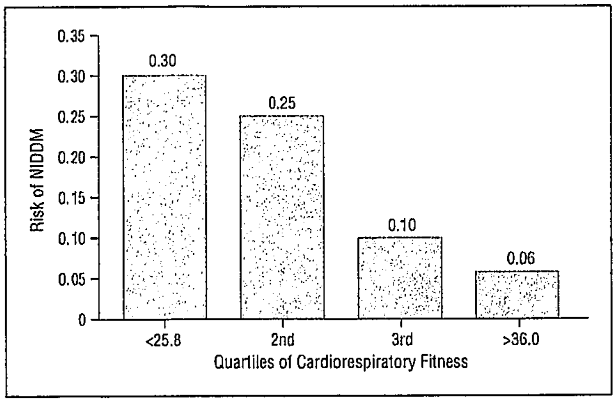

Figure 2. *Risk of non–insulin-dependent diabetes mellitus (NIDDM) (39 cases) by quartiles of cardiorespiratory fitness (given in milliliters of oxygen per kilogram per minute) for 751 Finnish men.*

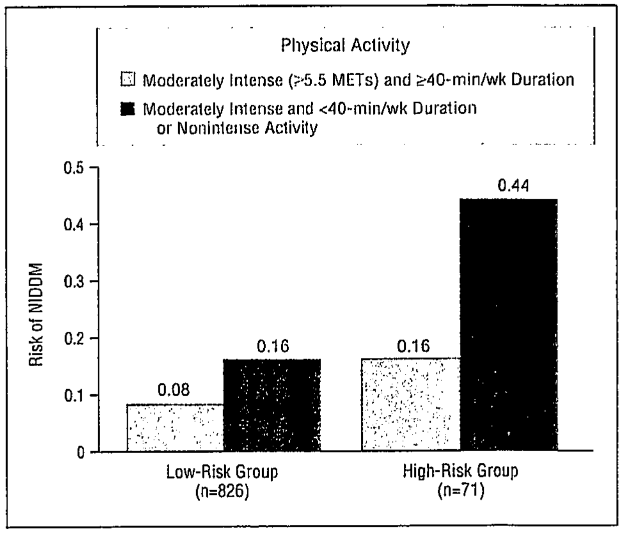

Figure 3. *Risk of non–insulin-dependent diabetes mellitus (NIDDM) in high-risk (10 cases) and low-risk (36 cases) subgroups by the duration (≥40 min/wk) of moderately intense physical activity (≥5.5 metabolic units [METs]) in 897 Finnish men. (The high-risk group included those men who were hypertensive and overweight and had a positive parental history of NIDDM.)*

moderately intense physical activities or whose intense activities were less than a 40-min/wk duration had an NIDDM risk of 0.44 (95% CI, 0.23-0.82). Within the low-risk group, men who participated in moderately intense activities of a 40-min/wk duration or greater had an NIDDM risk of 0.08 (95% CI, 0.05-0.14), while those who did not had an NIDDM risk of 0.16 (95% CI, 0.11-0.24).

Within this high-risk group, there may be a protective effect of physical activity at an even lower intensity threshold than 5.5 METs. For instance, the risk for the development of NIDDM in men who engaged in physical activities of 4.5 METs or greater and a 40-min/wk duration or greater was 0.22 (95% CI, 0.11-0.46), while men who engaged in physical activities at less than these levels had a risk of 0.56 (95% CI, 0.29-1.09). The reduction in the risk associated with physical activities at the lower threshold of 4.5 METs or greater and 40-min/wk duration or greater was similar to that observed at a level of 5.5 METs or greater.

COMMENT

Physical activities of moderate intensity (≥5.5 METs) that were undertaken for more than a 40-minute duration each week and higher levels of cardiorespiratory fitness (≥31.0 mL of oxygen per kilogram per minute) protected against the development of NIDDM in middle-aged Finnish men. This protective effect was evident even after controlling for age, baseline levels of fasting blood glucose, BMI, serum triglyceride levels, systolic blood pressure, parental history of diabetes, and alcohol consumption. In addition, other analyses that are not reported here showed that the inclusion of occupational physical activity did not alter the findings. Within the whole sample, physical activities of a lower intensity than 5.5 METs, regardless of their duration, did not confer a reduction in the risk of NIDDM. Men who engaged in moderately intense physical activities of more than a 40-min/wk duration reduced their risk of NIDDM by 50% compared with men who either did not participate in moderately intense physical activities or participated only at lower durations.

This protective effect of moderately intense physical activities was even more pronounced in a group that was considered to be at a high risk of NIDDM. These men reduced their risk of NIDDM by more than 64% if they participated in moderately intense physical activities for more than 40 min/wk. In this group, we also observed a similar reduction in the risk at intensities (≥4.5 METs) in men who were overweight, hypertensive, and had a positive parental history of the disease. While not statistically significant under traditional criteria (P=.07), this estimate was based on small numbers and suggests that important protective benefits may accrue for high-risk men at lower intensity levels.

The findings of this study are compelling for several reasons. Our results are based on a prospective examination in an unselected population sample in which objective criteria were used to determine incident cases of NIDDM. It is possible that individuals in the early stages of NIDDM might not have been excluded by using a baseline fasting blood glucose screening or medication history, and that these men may have reduced their physical activity because of the subclinical manifestations of the disease. The high correlation between the fasting blood glucose level and the 2-hour oral glucose tolerance test in this population at the follow-up examination (r=0.74) suggests that the impact on the results would be minimal. In addition, other stratified analyses that are not shown here demonstrated the same relationships between the intensity and duration of physical activity in men who had no symptomatic cardiovascular disease at baseline.

Extensive risk factor information enabled the relationship among physical activity, cardiorespiratory fitness, and NIDDM to be examined with adjustment for the extent of any underlying metabolic dysfunction at baseline. In addition to having self-reports of the intensity, duration, and frequency of physical activity for a 12-month period, we were also able to assess the relationship between cardiorespiratory fitness and NIDDM. While levels of cardiorespiratory fitness are not determined only by physical activity, it is reasonable to suggest that cardiorespiratory fitness scores reflect prior patterns of the intensity and duration of physical activity.[22] In this sense, the suggestion of a threshold in the relationship above and below the median levels of cardiorespiratory fitness (≥31.0 mL of oxygen per kilogram per minute), and the risk of NIDDM, provides objective confirmation of the protective effect of a moderately intense physical activity threshold based on self-report.[23]

THIS STUDY has quantified the relationship between the intensity and the amount of physical activity necessary to gain protection against NIDDM. Our finding that significant reductions in the risk of NIDDM were apparent at a moderate intensity and duration is consistent with a "threshold" approach in which the benefits of physical activity are only evident beyond a certain limit of intensity and duration.[24] There was no evidence in these data for the assertion that any combination of intensity and duration is beneficial in reducing risk, as long as the total-energy expenditure in physical activity is high. Overall, lower-intensity activities (<5.5 METs), regardless of their duration, were not associated with protection from NIDDM. However, this general observation should also be weighed against the finding that for men who were at an increased risk for the development of NIDDM, important reductions in disease risk were observed at intensity thresholds of 4.5 METs or greater.

We have reported that in addition to moderately intense physical activities and the level of baseline fasting blood glucose, only BMI and serum triglyceride levels remained statistically significant predictors of NIDDM in multivariate models. Our results do not support the contention that the waist-hip ratio is an independent predictor of NIDDM.[25,26] However, the waist-hip ratio is only an approximate measure of intra-abdominal adiposity. Previous research has also identified a parental history of diabetes as a risk factor for NIDDM. We found elevated but not statistically significant ORs for a positive parental history of diabetes. In addition, in models that contained age, baseline glucose levels, physical activity, and all risk factors, we found a protective but not statistically significant effect of alcohol for men who were in the highest quartile of consumption compared with that for men who abstained from alcohol consumption (OR, 0.50; 95% CI, 0.19-1.33).

Physical activity might reduce the incidence of NIDDM directly through increased insulin sensitivity or indirectly through decreased total-body fat and/or its distribution.[27] In our data, the lack of confounding between moderately intense physical activity, BMI, waist-hip ratio, or any other risk factor and NIDDM provided some evidence for the direct impact of moderately intense physical activity on the development of NIDDM. The initial bivariate analyses presented in Table 2 showed that longer durations (≥2 h/wk) of lower-intensity activities (<5.5 METs) were associated with a reduced risk of NIDDM; however, when this association was adjusted for the duration of higher-intensity physical activities, the relationship was attenuated. Furthermore, additional adjustment for the BMI greatly reduced the association between lower-intensity physical activities and NIDDM risk, but it did not appear to confound the relationship between higher-intensity physical activities and development of NIDDM. It is possible that any relationship between lower-intensity physical activities and the risk of NIDDM is largely mediated by changes in the BMI, but that higher-intensity physical activities have a more direct metabolic impact on the risk for the development of the disease.

The results reported here provide the strongest evidence to date that moderately intense physical activities of more than a 40-min/wk duration provide significant protection against the development of NIDDM. These intensity and duration thresholds correspond to the observed minimum levels of physical activity necessary to confer protection, but these data also show that participation in physical activities with a greater than 5.5-METs intensity may be even more beneficial in reducing the risk of NIDDM. However, it may be difficult to estimate the protective effect of higher-intensity physical activities because relatively few individuals in unselected populations actually engage in physical activities of more than 8 METs. Our data provide direct, quantitative confirmation of previous prospective studies that have suggested that vigorous physical activities, conducted more than once per week, reduced the risk of NIDDM and that these benefits may be even more pronounced in those subjects who are at highest risk for the development of the disease.[9,11]

The following types of activity would conform to the intensity threshold observed in these data: very brisk walking (>5 mph) or brisk walking on soft surfaces (eg, grass or sand); slow swimming; and light effort in bicycling, aerobic dance, or ball games (eg, tennis and basketball) or on commercially available exercise equipment (eg, treadmills, skiing, or rowing machines).[28]

While vigorous physical activity has often been recommended for the population in general, the beneficial effects of moderately intense physical activities appear to be even more important in those subgroups of the population who are at an elevated risk of NIDDM, because of being overweight and having an elevated blood pressure and a positive parental history of NIDDM. Our results suggest that the adoption of moderately intense levels of physical activity represents a major focus in the primary prevention of NIDDM.

Accepted for publication November 28, 1995.

This study was supported in part by grant HL44199 from the National Heart, Lung, and Blood Institute, Washington, DC, and by grants from the Academy of Finland and the Finnish Ministry of Education, Helsinki.

We are indebted to Juha Venäläinen, MD, Esko Taskinen, MD, Hannu Litmanen, MD, and Arno Heikelä, MD, for their participation in the supervision of exercise tests, and to Kari Seppänen, MSc, and Kristiina Nyyssönen, MSc, for supervising laboratory measurements.

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Printed and Published in the United States of America