

## Physical Activity in Elderly Subjects with Impaired Glucose Tolerance and Newly Diagnosed Diabetes Mellitus

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The authors carried out a study to investigate the association between different indicators of physical activity and the prevalence of impaired glucose tolerance (IGT) and newly diagnosed diabetes (nDM) in a population-based cohort of elderly men and women in the Netherlands. A sample of participants of the Rotterdam Study ( $n = 1,016$ ) aged 55–75 years who were not known to have diabetes mellitus underwent an oral glucose tolerance test. Physical activity was assessed by means of a self-administered questionnaire and expressed as time spent on activities per week. Associations with the prevalence of IGT and nDM were assessed by logistic regression analysis after adjustment for age, body mass index, waist-hip ratio, family history of diabetes, and smoking. A total of 745 subjects had normal glucose tolerance, 153 IGT, and 118 nDM. The total amount of time spent on physical activity decreased with increasing glucose intolerance. Adjusted for main confounders, vigorous activities such as bicycling (men: odds ratio (OR) = 0.26, 95% confidence interval (CI) 0.14–0.49; women: OR = 0.37, 95% CI 0.18–0.78) and sports (men: OR = 0.28, 95% CI 0.11–0.74) showed an inverse association with the presence of nDM. For IGT, the associations pointed in the same direction but did not reach statistical significance. These results indicate that physical inactivity and glucose intolerance are associated among older adults similar to the way they are associated among middle-aged adults. *Am J Epidemiol* 1999;149:219–27.

activities of daily living; aged; diabetes mellitus; glucose intolerance; glucose tolerance test; physical fitness

Cross-sectional studies have shown an inverse association of physical activity with the prevalence of clinically diagnosed diabetes mellitus and diabetes newly diagnosed by an oral glucose tolerance test (OGTT) (1, 2). In addition, the prevalence of impaired glucose tolerance is higher in inactive subjects than in active subjects (1). In prospective studies, physical inactivity was found to be a risk factor for the incidence of diabetes mellitus, independent of body weight (3–7).

These findings indicate that promotion of physical activity may be important in the prevention of diabetes mellitus. From a public health perspective, the health benefits that accrue from increased physical activity may be greater in older populations than among middle-aged subjects, given the higher prevalence of diabetes

mellitus and lower levels of physical activity observed among older persons (8). Yet, most studies to date have focused on the association between physical activity and diabetes in middle-aged populations. To our knowledge, thus far, only two studies have been conducted in elderly subjects (9, 10). However, in both studies, physical activity was presented as a single index and no information was reported about specific types of physical activity or the intensity of the activity.

The present study was conducted in men and women aged 55 years and older, diagnosed with impaired glucose tolerance, newly diagnosed diabetes, or normal glucose tolerance. The aim of the study was to evaluate the association between different indicators of physical activity and the prevalence of newly diagnosed diabetes and impaired glucose tolerance.

### MATERIALS AND METHODS

#### Selection of the study population

The selection of the study sample is shown in figure 1. The present study was conducted among participants of the Rotterdam Study. The Rotterdam Study is a population-based cohort study that has been carried out in the Netherlands to assess the determinants of chronic disabling diseases in the elderly (11). The baseline examination was conducted from 1990 to

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Abbreviations: IGT, impaired glucose tolerance; nDM, newly diagnosed diabetes; NGT, normal glucose tolerance; NIDDM, non-insulin-dependent diabetes mellitus; OGTT, oral glucose tolerance test.

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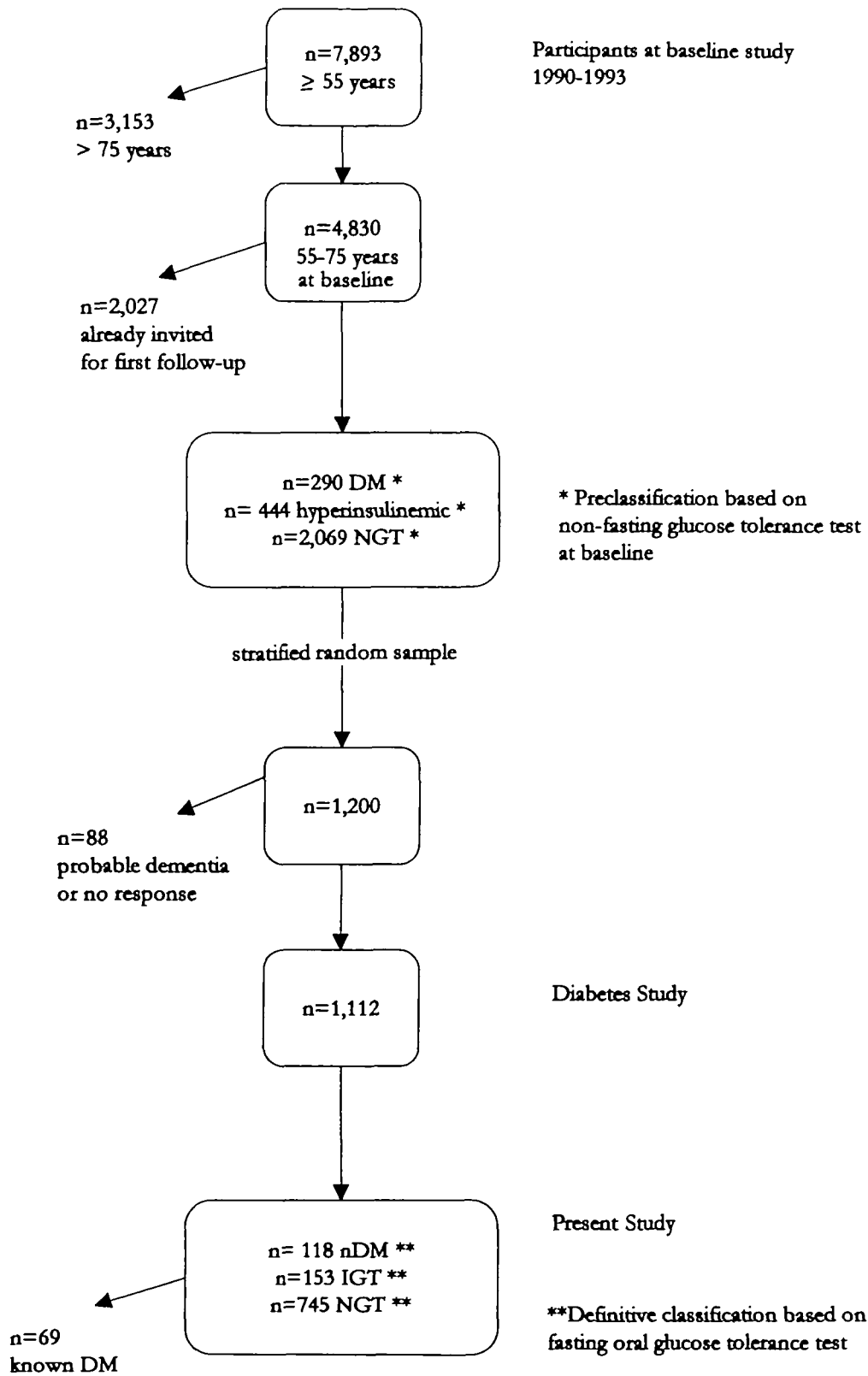


FIGURE 1. Selection of the study sample: the Rotterdam Study, 1990-1994.

1993 and included 7,983 subjects aged 55 years and older (response rate = 78 percent). Informed consent was obtained from all subjects and the study was approved by the medical ethics committee of Erasmus University Medical School.

During the first follow-up examination in 1993–1994 of the 4,830 participants aged 55–75 years at the baseline examination, a sample was invited to participate in the diabetes study. Because the follow-up examination had already started and the invitations to participate in the present study were sent together with the invitation for the examination, only 2,803 subjects were available for sampling in the diabetes study. These subjects did not differ in the main characteristics from the subjects who had already been invited. The subjects were temporarily divided into diabetic (using medication or random or postload level  $\geq 11.1$  mmol/liter), hyperinsulinemic (upper quintile of the sex-specific post-load insulin distribution in subjects without impaired glucose tolerance or diabetes mellitus), or normal glucose tolerant, based on a non-fasting glucose tolerance test at baseline. A random sample was taken from each glucose tolerance group, which resulted in 200 subjects with diabetes, 400 with hyperinsulinemia, and 600 with normal glucose tolerance being invited for the diabetes study. Subjects with probable dementia were not invited. The overall response rate for the follow-up examination was 90 percent, and 1,112 subjects took part in the Rotterdam Diabetes Study. In this study, a definitive classification of the glucose tolerance status was made, based on an OGTT, which is described below.

Because this paper proposes to examine the etiology of the development of diabetes mellitus, the known clinically diagnosed diabetic patients (those using medication,  $n = 69$ ) were excluded from analysis. The analyses are thus based on the data of 1,016 participants.

### Examinations

Information on medication use, medical history, smoking habits, and family history (in first-degree relatives) of diabetes was obtained by means of a self-administered questionnaire.

The participants came to the research center after an overnight fast (no food intake after 11:00 p.m.). Blood was drawn between 8:00 a.m. and 9:00 a.m. by venipuncture and subjects not using antidiabetes medication underwent an oral glucose tolerance test (75 g glucose in 200 ml water). Fasting and 2-hour plasma levels were determined using the glucose hexokinase method. Diabetes mellitus was defined as the use of antidiabetes medication (insulin or oral hypoglycemic medication), or a 2-hour plasma glucose concentration

of  $\geq 11.1$  mmol/liter according to the World Health Organization (WHO) criteria (12). Subjects with a glucose level in the diabetic range and who did not use antidiabetes medication were classified as newly diagnosed cases of diabetes mellitus (nDM). Impaired glucose tolerance (IGT) was defined as a 2-hour plasma glucose concentration of  $\geq 7.8$  mmol/liter, but  $< 11.1$  mmol/liter, combined with a fasting plasma glucose concentration of  $< 7.8$  mmol/liter.

Sitting blood pressure was measured with a random-zero sphygmomanometer, and the mean of two measurements, obtained at one occasion, was used in the analyses. Hypertension was defined as the use of anti-hypertensive medication or blood pressure of  $\geq 160/95$  mmHg. Weight and height were measured with the participants wearing indoor clothes and no shoes. Waist circumference was measured midway between the lower rib margin and iliac crest, and hip circumference was measured at the trochanter major. Body mass index was determined by dividing the weight by the height squared ( $\text{kg}/\text{m}^2$ ), and body fat distribution was assessed by means of the waist-to-hip circumference ratio (waist-hip ratio).

### Physical activity

Physical activity was estimated using a self-administered questionnaire derived from a validated questionnaire designed to measure physical activity in elderly men (13), modified for use in the current study. Modification comprised primarily of adding activities considered to be relevant for elderly women, which means including questions about housekeeping activities. The questionnaire consisted of questions about the average frequency (times/week) and duration (hours/day) of walking and bicycling in summer, winter, and for transportation purposes; the average frequency (times/week) and length of time (hours/day) spent on work (paid or volunteer), hobbies, sports, gardening in both summer and winter, housekeeping, and odd jobs. There was no defined time period queried.

Estimated times were converted to minutes per week for each type of activity and summed to obtain the total weekly duration of physical activity. If someone reported to perform an activity only during summer or winter, the amount of minutes/week were divided by two. Leisure-time activity was calculated by summing the minutes per week for walking, bicycling, hobbies, odd jobs, gardening, and sport.

If a subject did not report engaging in a particular activity, it was coded as zero. Activities were only included when they demanded a certain amount of physical effort expressed as an intensity code (13). The classification of household chores was based on the intensity codes proposed by Ainsworth et al. (14).

Mopping and window cleaning were classified as vigorous activities; all remaining household chores were classified as moderate activities. All activities with an intensity code  $\leq 1.5$  (e.g., doing puzzles, reading, and playing chess) were excluded from the calculations (15). Billiards, fishing, bowling, and dancing were classified as hobbies. Activities were also grouped by level of intensity using the intensity codes and categories proposed by Caspersen et al. (13): light (intensity code  $\geq 1.5$  but  $< 2$ , e.g., tending animals), moderate (intensity code  $\geq 2$  but  $< 4$ , e.g., walking, odd jobs, billiards, fishing), and vigorous (intensity code  $> 4$ , e.g., sport, gardening, bicycling, dancing).

### Data analysis

The SPSS computer package version 7.0 (SPSS Inc., Chicago, Illinois) was used for all statistical analyses. For each physical activity variable, the mean time spent on it and standard deviation were calculated, as well as the frequency of subjects who reported no activity. The difference in mean time spent on a physical activity was estimated according to category of glucose tolerance for physical activity variables in which 60 percent or more of the participants reported that they engaged. In this calculation, we used linear regression with physical activity as a dependent variable and presence or absence of nDM/IGT as an independent variable, adjusting for age. Because the distributions of these physical activity variables were skewed, the data were transformed by taking the square root. For the other variables, the difference in frequency of subjects who reported no activity was estimated with logistic regression, with physical activity (active/inactive) as a dependent variable and the

presence or absence of nDM/IGT as an independent variable, adjusting for age.

Next, the variables for which more than 60 percent of the respondents reported some activity were divided into tertiles, with the lowest tertile as a reference category. All the other variables were divided into active ( $> 0$  minutes/week) or inactive (0 minutes/week). Odds ratios were calculated using logistic regression with the presence or absence of nDM/IGT as a dependent variable and physical activity as an independent variable, adjusting for age, body mass index, waist-hip ratio, family history of diabetes mellitus, and smoking.

The relation between continuous glucose levels (fasting and post-load) and physical activity was estimated using linear regression, adjusted for the main confounders, age, body mass index, waist-hip ratio, family history of diabetes mellitus, and smoking.

### RESULTS

Table 1 gives the main characteristics of the study population. Both male and female subjects with normal glucose tolerance (NGT) were younger, had a lower body mass index and waist-hip ratio, and a lower percentage of positive family history of diabetes compared with the subjects with impaired glucose tolerance (IGT) or newly diagnosed diabetes mellitus (nDM). The percent of smokers was similar in all three groups for both men and women. The differences between the subjects with IGT or nDM were small for most studied variables.

The physical activity patterns differed between men and women. Men reported spending 1,557 minutes/week on physical activity. Of these, 701 minutes/week were spent on leisure activities. On average,

**TABLE 1. Selected characteristics of subjects with normal glucose tolerance (NGT), impaired glucose tolerance (IGT), or newly diagnosed diabetes mellitus (nDM): the Rotterdam Study, 1990–1994**

Variable	NGT	IGT	nDM
<b>Men</b>	( <i>n</i> = 357)	( <i>n</i> = 77)	( <i>n</i> = 69)
Age (years), mean (SD)†	66.2 (5.2)	67.1 (5.4)	67.9 (5.5)
BMI† (kg/m <sup>2</sup> ), mean (SD)	25.9 (2.8)	27.1 (2.9)**	26.9 (3.2)*
Waist-hip ratio, mean (SD)	0.95 (0.07)	0.97 (0.06)	0.97 (0.07)*
Smoking (% current)	29	25	25
Family history (% first-degree relatives with diabetes)	22	20	33**
<b>Women</b>	( <i>n</i> = 388)	( <i>n</i> = 76)	( <i>n</i> = 49)
Age (years), mean (SD)	66.3 (5.7)	68.5 (5.6)	67.7 (5.9)
BMI (kg/m <sup>2</sup> ), mean (SD)	26.2 (3.6)	28.7 (4.9)**	28.3 (4.6)**
Waist-hip ratio, mean (SD)	0.86 (0.08)	0.91 (0.09)**	0.89 (0.08)*
Smoking (% current)	19	22	14
Family history (% first-degree relatives with diabetes)	23	35*	36*

\*  $p < 0.10$ ; \*\*  $p < 0.05$ ; different from NGT, adjusted for age.

† SD, standard deviation; BMI, body mass index.

the most time was spent on housekeeping (25 percent), walking (18 percent), work (19 percent), and bicycling (13 percent), whereas much less time was spent on sports (3 percent), hobbies (7 percent), odd jobs (9 percent), and gardening (5 percent). The percent of men with nDM or IGT who reported no activity was higher for all parameters of physical activity compared with men with NGT (table 2), and it was statistically significant for bicycling and sports in men with nDM (differences, 34 percent and 19 percent, respectively). Men with nDM or IGT reported spending less time on physical activity compared with men with NGT, a difference which was statistically significant for vigorously intense activities (differences, 83 minutes/week for nDM and 143 minutes/week for IGT).

Women spent an average of 1,721 minutes/week on physical activity. These included 416 minutes/week spent on leisure activities. The most time was spent on housekeeping (61 percent), walking (15 percent), and bicycling (7 percent) while much less time was spent on work, sports (2 percent), hobbies (3 percent), odd jobs (3 percent), and gardening (3 percent). As was also the case in men, a decrease in the mean time spent on physical activity was observed with increasing glucose intolerance, accompanied by an increase in the percent of women who reported no activity (table 3). After adjusting for age differences, the mean time spent on leisure activity and vigorous activity was significantly lower in women with nDM compared with women with NGT (differences, 207 and 94 minutes/week, respectively). Again, a significantly higher percent of women with IGT or nDM reported that they did not cycle compared with women with NGT (difference, 23 percent).

In table 4, odds ratios are given for the summary variables of physical activity, adjusted for age, body mass index, waist-hip ratio, family history of diabetes, and smoking. Men with physical activity in the middle or highest tertile had a lower risk of having undiagnosed diabetes compared with the men in the lowest tertile. The inverse association between physical activity and risk of nDM was significant for vigorous activity ( $p$  trend = 0.005). The association between IGT and physical activity was less clear compared with nDM, yet for IGT, vigorous intense activity also seems to be associated with lower prevalence of IGT ( $p$  trend = 0.12).

In women, vigorous activity was also inversely associated with nDM ( $p$  trend = 0.01). In addition, increasing leisure activity was inversely associated with a reduced prevalence of nDM ( $p$  trend = 0.04). For IGT, no clear associations with activity were observed.

When we considered the relation between specific types of activity and glucose intolerance, significant inverse associations with nDM were found in men after adjustment for the main confounders for sports (OR = 0.28, 95 percent CI 0.11–0.74), bicycling (OR = 0.26, 95 percent CI 0.14–0.49), and housekeeping (OR = 0.42, 95 percent CI 0.19–0.96) (table 5). Among women, bicycling was the activity which was most strongly associated with absence of nDM (OR = 0.37, 95 percent CI 0.18–0.78). No such associations were found with IGT for either men or women.

In order to be able to compare the magnitude of the effect of physical activity on diabetes mellitus with other risk factors for diabetes, we estimated the associations of the main confounders (age, body mass

**TABLE 2. Time spent on physical activity (minutes/week) and frequency of subjects reporting no activity in men with normal glucose tolerance (NGT), impaired glucose tolerance (IGT), or newly diagnosed diabetes mellitus (nDM): the Rotterdam Study, 1990–1994**

Type of physical activity	Total (n = 503)		NGT (n = 357)		IGT (n = 77)			nDM (n = 69)		
	Time per PA,* mean (SD)*	Freq* (%)	Time per PA, mean (SD)	Freq (%)	Time per PA, mean (SD)	Freq (%)	<i>p</i> value†	Time per PA, mean (SD)	Freq (%)	<i>p</i> value†
Total activity	1,557 (1,280)	6	1,593 (1,212)	4	1,366 (1,217)	12	0.08	1,582 (1,640)	12	0.48
Leisure activity	701 (770)	11	708 (733)	8	682 (761)	16	0.50	684 (659)	19	0.21
Vigorous intensity	358 (454)	18	391 (454)	15	248 (298)	18	0.01	308 (561)	38	0.004
Moderate intensity	955 (925)	8	955 (874)	6	930 (1,046)	12	0.52	976 (1,046)	15	0.52
Light intensity	243 (691)	79	245 (704)	80	186 (577)	77	0.32	296 (739)	77	0.24
Housekeeping	396 (454)	16	398 (444)	14	377 (405)	16	0.82	405 (550)	22	0.23
Walking	282 (389)	22	284 (402)	20	238 (267)	25	0.55	319 (435)	28	0.81
Bicycling	197 (337)	37	218 (348)	31	131 (207)	39	0.21	172 (386)	65	<0.001
Work	292 (787)	84	313 (812)	82	208 (698)	88	0.34	280 (750)	84	0.72
Hobbies	114 (323)	73	105 (298)	73	138 (352)	69	0.41	129 (403)	75	0.73
Odd jobs	138 (365)	50	125 (322)	48	170 (492)	51	0.83	157 (406)	57	0.32
Gardening	85 (200)	54	86 (189)	52	62 (137)	57	0.58	104 (293)	65	0.10
Sport	54 (160)	76	65 (181)	72	38 (102)	81	0.18	14 (54)	91	0.003

\* PA, physical activity; Freq, frequency of subjects reporting no activity; SD, standard deviation.

† For the activities in which >60% of the subjects reported engaging, the difference in mean time spent between NGT and IGT/nDM was tested. For the other variables, the difference between NGT and IGT/nDM in frequency was tested. All adjusted for age.

**TABLE 3. Time spent on physical activity (minutes/week) and the frequency of subjects reporting no activity in women with normal glucose tolerance (NGT), impaired glucose tolerance (IGT), or newly diagnosed diabetes mellitus (nDM): the Rotterdam Study, 1990–1994**

Type of physical activity	Total (n = 513)		NGT (n = 388)		IGT (n = 76)		p value†	nDM (n = 49)		p value†
	Time per PA,* mean (SD*)	Freq* (%)	Time per PA, mean (SD)	Freq (%)	Time per PA, mean (SD)	Freq (%)		Time per PA, mean (SD)	Freq (%)	
Total activity	1,721 (1,024)	5	1,768 (1,039)	5	1,578 (1,104)	5	0.34	1,566 (958)	6	0.28
Leisure activity	416 (460)	16	449 (479)	14	356 (474)	20	0.15	242 (267)	20	0.005
Vigorous intensity	272 (313)	15	293 (318)	13	210 (299)	20	0.06	199 (267)	22	0.03
Moderate intensity	1,370 (853)	6	1,387 (840)	6	1,350 (987)	7	0.77	1,287 (1,048)	6	0.40
Light intensity	77 (296)	86	86 (310)	85	18 (66)	91	0.29	99 (388)	88	0.74
Housekeeping	1,058 (655)	9	1,064 (648)	9	1,029 (654)	11	0.71	1,055 (719)	12	0.71
Walking	256 (372)	24	257 (369)	24	266 (427)	26	0.93	230 (306)	27	0.59
Bicycling	122 (215)	50	134 (222)	44	89 (201)	67	0.003	77 (169)	67	0.007
Work	96 (350)	89	104 (353)	87	55 (311)	96	0.07	96 (388)	88	0.93
Hobbies	49 (150)	82	53 (150)	94	25 (85)	96	0.17	53 (155)	96	0.67
Odd jobs	47 (206)	84	53 (198)	82	45 (290)	88	0.42	5 (21)	92	0.14
Gardening	53 (134)	64	56 (138)	62	44 (110)	71	0.42	36 (131)	71	0.36
Sport	38 (98)	73	44 (108)	71	23 (57)	80	0.19	12 (29)	84	0.08

\* PA, physical activity; Freq, frequency of subjects reporting no activity; SD, standard deviation.

† For the activities in which >60% of the subjects reported engaging, the difference in mean time spent between NGT and IGT/nDM was tested. For the other variables, the difference between NGT and IGT/nDM in frequency was tested. All adjusted for age.

**TABLE 4. Odds ratios (OR) for presence of impaired glucose tolerance (IGT) and newly diagnosed diabetes mellitus (nDM) according to physical activity tertiles, adjusted for age, body mass index, waist-hip ratio, family history of diabetes, and smoking: the Rotterdam Study, 1990–1994**

Type of physical activity	Values (minutes/week)	Men				Women				
		OR	95% CI*	OR	95% CI	OR	95% CI	OR	95% CI	
Total										
Low	<847	†		†		<1,245	†	†		
Medium	847 to <1,860	0.80	0.41–1.59	0.67	0.32–1.43	1,245 to <2,007	0.99	0.45–2.21	0.89	0.40–1.99
High	≥1,860	0.68	0.33–1.40	0.74	0.34–1.59	≥2,007	1.05	0.45–2.43	0.80	0.34–1.88
p trend		0.29		0.41			0.91		0.61	
Leisure activity										
Low	<270	†		†		<135	†	†	†	
Medium	270 to <780	1.26	0.82–2.56	0.86	0.41–1.81	135 to <467	0.70	0.31–1.57	0.69	0.32–1.47
High	>780	1.07	0.52–2.19	0.72	0.34–1.52	≥467	0.83	0.36–1.88	0.39	0.15–0.97
p trend		0.89		0.39			0.66		0.04	
Vigorous intensity										
Low	<90	†		†		<90	†	†	†	
Medium	90 to <390	0.97	0.48–1.94	0.27	0.12–0.59	90 to <298	0.73	0.33–1.63	0.50	0.23–1.09
High	>390	0.56	0.26–1.19	0.35	0.17–0.73	≥298	0.72	0.32–1.62	0.32	0.13–0.79
p trend		0.12		0.005			0.42		0.01	
Moderate intensity										
Low	<510	†		†		<1,007	†	†	†	
Medium	510 to <990	1.01	0.51–2.02	0.86	0.39–1.88	1,007 to <1,520	1.58	0.69–3.55	1.05	0.46–2.40
High	>990	0.77	0.38–1.57	0.95	0.45–1.99	≥1,520	1.18	0.50–2.79	0.95	0.41–2.19
p trend		0.47		0.90			0.72		0.90	
Light intensity	Active vs. inactive	1.23	0.61–2.45	1.34	0.64–2.80	Active vs. inactive	0.77	0.27–2.18	0.77	0.27–2.19

\* CI, confidence interval.

† Reference category.

index, waist-hip ratio, and smoking) with the presence of IGT or nDM. A higher body mass index or waist-hip ratio was associated with a higher prevalence of IGT or nDM in both men and women, independent of the other confounders. The association with IGT was significant for the highest body mass index tertile among

both men and women (men, OR = 2.91, 95 percent CI 1.32–6.35; women, OR = 4.7, 95 percent CI 1.81–11.9) and for the highest waist-hip ratio tertile among women (OR = 3.4, 95 percent CI 1.4–8.1). Smoking showed no association with presence of IGT or nDM.

**TABLE 5. Odds ratios (OR) for presence of impaired glucose tolerance (IGT) and newly diagnosed diabetes mellitus (nDM) according to specific physical activity, adjusted for age, body mass index, waist-hip ratio, family history of diabetes, and smoking: the Rotterdam Study, 1990–1994**

Type of physical activity	Values (minutes/week)	Men				Women				
		IGT		nDM		IGT		nDM		
		OR	95% CI*	OR	95% CI	OR	95% CI	OR	95% CI	
Housekeeping										
Low	<165	‡		‡		‡		‡		
Medium	165 to <457	1.10	0.54–2.23	0.42	0.19–0.96	0.86	0.37–1.95	0.65	0.29–1.50	
High	≥457	0.83	0.40–1.73	0.68	0.32–1.36	1.02	0.46–2.26	0.77	0.34–1.72	
<i>p</i> trend		0.59		0.29		0.95		0.52		
Walking†										
Low	<60	‡		‡		‡		‡		
Medium	60 to <285	1.80	0.87–3.69	1.62	0.73–3.55	1.03	0.45–2.39	0.86	0.38–1.97	
High	≥285	1.24	0.57–2.70	1.45	0.63–3.32	1.40	0.63–3.15	1.05	0.47–2.36	
<i>p</i> trend		0.65		0.42		0.40		0.89		
Bicycling	Inactive vs. active	0.89	0.48–1.65	0.26	0.14–0.49	Inactive vs. active	0.78	0.40–1.55	0.37	0.18–0.78
Work	Inactive vs. active	0.52	0.20–1.33	1.03	0.45–2.36	Inactive vs. active	0.57	0.16–2.03	1.03	0.39–2.74
Hobbies	Inactive vs. active	1.62	0.88–2.99	0.89	0.45–1.80	Inactive vs. active	0.77	0.31–1.90	0.68	0.26–1.75
Odds jobs	Inactive vs. active	1.12	0.63–2.00	0.65	0.35–1.20	Inactive vs. active	0.97	0.40–2.33	0.53	0.18–1.58
Gardening	Inactive vs. active	1.16	0.64–2.10	0.56	0.29–1.06	Inactive vs. active	0.86	0.43–1.74	0.46	0.21–1.01
Sport	Inactive vs. active	0.70	0.35–1.41	0.28	0.11–0.74	Inactive vs. active	0.82	0.38–1.75	0.59	0.26–1.35

\* CI, confidence interval.

† By tertile of activity.

‡ Reference category.

To see whether a dose-response relationship can be observed between physical activity and glucose intolerance, the effect of physical activity on glucose level as a continuous variable was estimated. All physical activities seem to be inversely associated with a lower glucose level (both fasting and post-load). Significant associations were found between lower glucose level and vigorous activity ( $p < 0.01$  for both men and women), bicycling ( $p < 0.01$  for both men and women), and sports ( $p = 0.03$  for men) after adjustment for the main confounders (data not shown).

## DISCUSSION

Physical activity is known to reduce the risk of non-insulin-dependent diabetes mellitus (NIDDM) in younger and middle-aged populations (3, 7, 16). The purpose of this study was to estimate the association between physical activity and presence of glucose intolerance in elderly subjects. A significant inverse association between physical activity and presence of newly diagnosed diabetes was observed. For impaired glucose tolerance, the association was less clear. Of special note was the finding that more vigorous activity was inversely associated with the presence of nDM, independent of age, overweight, waist-hip ratio, family history of diabetes mellitus, and smoking. This observation is in accordance with the findings of sev-

eral prospective studies performed among middle-aged subjects (3–5), in which vigorous exercise was shown to be effective in reducing the risk of NIDDM. The literature is less consistent (3, 7, 16) in regard to activities of moderate intensity. In the present study, moderate activities were not associated with presence of nDM or IGT. This might be a consequence of measurement error due to inaccurate recall. Several studies have demonstrated low accuracy in recalling low-intensity behaviors, but higher accuracy with vigorous-intensity activity (17).

The questionnaire we used was originally designed and validated for elderly men (13). However, for use in this study, the questionnaire was modified by including questions about housekeeping and work. The correlation between physical activity and resting heart rate may give an impression of the validity of the questionnaire used (18). Although the correlation in the present study was comparable with that obtained in the original questionnaire (15), the results must be interpreted with some caution because the correlation is generally quite low ( $-0.08$ ,  $p = 0.04$  for women and  $-0.04$ ,  $p = 0.39$  for men). The estimates obtained through the activity questionnaire are, however, valuable in relative terms and can be used to rank individuals or groups within a population. By categorizing the variables into tertiles or as active/inactive, misclassification is reduced.

Physical activity behavior can be biased by the diagnosis of diabetes. Therefore, subjects with known diabetes mellitus were excluded from this study. Subjects with nDM or IGT were most likely unaware of the diagnosis at the time of examination, which makes it less likely that they have altered physical activity behavior through treatment interventions or their own efforts to change life-style factors.

Because diabetes is a clear risk factor for cardiovascular disease and persons with cardiovascular disease may be less physically active because of their disease, some of the association between physical activity and diabetes might be artifactual. However, an analysis excluding subjects with known coronary heart disease or stroke yielded virtually the same findings. In other studies the results similarly remained essentially unchanged following the exclusion of subjects with prevalent coronary heart disease, hypertension, or stroke (3, 4, 6). Although this study is cross-sectional, which makes a definitive conclusion about cause and effect impossible, it seems that the observed association was not due to coexistent disease.

The mechanism by which physical activity affects the occurrence of diabetes mellitus has not yet been clearly established. There is evidence that physical activity increases peripheral sensitivity to insulin, especially in skeletal muscle and adipose tissue (19–21). Besides, physical activity may improve weight reduction by increasing the energy expenditure associated with exercise (22), and obesity is a risk factor for developing diabetes mellitus (23). Indeed, in the present study, body mass index was inversely associated with physical activity. However, the crude odds ratios were very similar (data not shown) to the adjusted odds ratios. This would suggest that the effect of physical activity is at least partly independent of obesity.

Elderly persons, both men and women, who cycled had a lower risk of having undiagnosed diabetes mellitus, whereas walking, an activity ideally suited for older persons (24), showed no association with nDM or IGT in the present study. It may well be that elderly persons with a lower level of ADL (activities of daily living) are more willing to continue walking, instead of, for example, bicycling. As we stated earlier, the intensity of an activity seems to be related to the effectiveness in reducing the risk of NIDDM. Bicycling is more intense than walking, which might partly explain why it is more associated with the occurrence of nDM or IGT. Walking is certainly to be advocated, but, at least in this study, showed no effect on diabetes mellitus.

Sports were significantly associated with nDM among men, but not among women. While women reported spending less time on sporting activities, this

could also be explained by the differences in the type of sport practiced; men participated in more vigorous sports. Because the numbers concerned were so small, no analysis was performed to estimate the effect of the different types of sports.

Two other studies have reported associations between physical activity and diabetes mellitus in elderly subjects (9, 10). In the Honolulu Heart Study (9), a single index for physical activity was used in 4,560 Japanese-American subjects aged 71–93 years. The authors did not describe how this index was obtained nor which activities were included. Contrary to our results, no difference in physical activity between subjects with NGT and newly diagnosed diabetes was found. In the Dutch “Hoom” Study (10), 1,029 men and women aged 50–75 years reported on their physical activity, using the same questionnaire that we used in the present study. The level of the physical activity was expressed as a score ranging from 0–9. As in our study, both men and women with nDM had a lower physical activity score than subjects with NGT, which was significant in women.

In addition to an association with nDM, vigorous physical activity seemed to be inversely associated with the presence of impaired glucose tolerance, although not significantly. A few other studies (1, 9, 10, 25) have examined the association between IGT and physical activity, and their results are conflicting. In the Hoom Study (10), significant differences in physical activity score were found between men and women with IGT and NGT. The number of subjects with IGT in the Hoom Study was twice as high as in our study, which might explain the significance reached. Dowse et al. (1) reported equal relative risks for impaired glucose tolerance and diabetes mellitus, although the risks were not significant. In two other studies (9, 25), no association was observed between physical activity and IGT.

In our study, diagnosis of IGT was made by a single OGTT, which is prone to intra-individual variation (26, 27). Using two OGTTs to diagnose IGT is likely to yield a more homogeneous group and may reveal a clearer association of IGT with physical activity. Lending support for the association between IGT and physical activity is the fact that, at least for the more vigorous activities, a dose-response relationship was observed. The more vigorous the activity, such as sports and bicycling, the lower the fasting or postload glucose levels.

Because this study is cross-sectional in design and there were no questions asked about past physical activities, we could not analyze whether physical activity throughout life is important or whether physical activity initiated at an older age is also protective.



Several studies have shown that the benefits of physical activity disappear within several days after exercising, which implies a need for regular exercise (28). Adults who have previously been sedentary require a period of training to increase their fitness to a level where they can perform the necessary duration and intensity of exercise that will be effective. Because this level of training may be difficult or impossible to achieve in older subjects, exercise optimally should be initiated at much younger ages and should be continued throughout life.

In conclusion, regular exercise may protect against diabetes mellitus in older adults as it does among middle-aged adults. This finding therefore serves to strengthen the grounds for encouraging physical activity in elderly subjects.

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