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Van Dam, Rob M; Schuit, A.J.; Feskens, Edith J M; Seidell, Jaap C; Kromhout, Daan

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Physical activity and glucose tolerance in elderly men: the Zutphen Elderly study

ROB M. VAN DAM, ALBERTINE J. SCHUIT, EDITH J. M. FESKENS, JAAP C. SEIDELL, and DAAN KROMHOUT

Department of Chronic Diseases Epidemiology and Division of Public Health Research, National Institute for Public Health and the Environment, Bilthoven, THE NETHERLANDS; and Institute for Research in Extramural Medicine, Free University Amsterdam, THE NETHERLANDS

ABSTRACT

VAN DAM, R. M., A. J. SCHUIT, E. J. M. FESKENS, J. C. SEIDELL, and D. KROMHOUT. Physical activity and glucose tolerance in elderly men: the Zutphen Elderly study. *Med. Sci. Sports Exerc.*, Vol. 34, No. 7, pp. 1132–1136, 2002. **Purpose:** To determine whether physical activity is associated with glucose tolerance in the elderly. **Methods:** We examined current and 5-yr change in physical activity in relation to glucose tolerance in 424 randomly selected male inhabitants of the Dutch town Zutphen, aged 69–89 yr, without known diabetes mellitus. Physical activity was assessed by a validated questionnaire designed for retired men. Glucose intolerance was assessed by an oral glucose tolerance test and defined as impaired glucose tolerance or diabetes mellitus. **Results:** Men with 30 $min \cdot d^{-1}$ or more of physical activity of at least moderate intensity had a lower prevalence of glucose intolerance as compared to men without these activities (age-adjusted odds ratio 0.32; 95% CI, 0.18–0.57). Adjustment for family history of diabetes, smoking, alcohol intake, dietary factors, body mass index, and subscapular skin-fold thickness or exclusion of men with cardiovascular diseases or disabilities did not substantially change the results. With specific activities modeled simultaneously, bicycling (*P* for trend = 0.01) and gardening (*P* for trend = 0.02) were inversely associated with glucose intolerance. Men whose amount of physical activity had decreased during the past 5 yr had significantly higher age-adjusted 2-h glucose concentrations as compared with men who remained at least as active (difference 0.7 $mmol \cdot L^{-1}$; 95% CI, 0.1-1.3). **Conclusion:** These findings suggest that common types of physical activity such as bicycling and gardening may contribute to the prevention of glucose intolerance in elderly men **Key Words:** AGED, DIABETES MELLITUS, IMPAIRED GLUCOSE TOLERANCE, EPIDEMIOLOGY, POPULATION BASED

An inverse association between physical activity and risk of type 2 diabetes mellitus has consistently been reported in ecological (15), cross-sectional (3,16,19), and prospective (9,10,12,14,18) studies. In line with these observations, intervention studies showed that physical activity improves insulin sensitivity (10). However, most studies included middle-aged participants and data on type and duration of physical activity in relation to glucose tolerance in the elderly is sparse (3). The association between physical activity and glucose tolerance may be different in the elderly, as both glucose metabolism (1) and physical activity behavior change with age. The ability of elderly to participate in sports is decreased, and activities are generally performed at lower pace.

As Western populations are aging and the prevalence of type 2 diabetes increases strongly with age, promotion of feasible physical activity for the elderly may play an important role in prevention of type 2 diabetes. Therefore, we studied the relation between common types of physical activity and glucose tolerance in participants of the Zutphen Elderly Study, aged 69–89 yr.

METHODS

Participants. We used primarily cross-sectional data from the Zutphen Elderly Study, a cohort of elderly male inhabitants of the Dutch town Zutphen (8). The study is a continuation of the Zutphen Study, the Dutch contribution to the Seven Countries Study, including men born between 1900 and 1920 (13). In 1985, 555 members of the original cohort (N = 1088) were still alive and were invited for new examinations. In addition, a random sample (two of three) of all other men of the same age, living in Zutphen, was selected (N = 711). This resulted in a total population of 1266 men of which 939 (74%) finally took part in the 1985 survey and formed the cohort of the Zutphen Elderly Study. In 1990, 718 members of the latter cohort were still alive, of which 560 men (78%) participated in a new survey. Men with known diabetes (N = 46) were excluded as the diagnosis may have affected physical activity habits or reporting thereof. The remaining participants were unaware of their glucose tolerance status during the examinations. Data from the oral glucose tolerance test were available for 446 men without known diabetes. After exclusion of men with miss-

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TABLE 1. Characteristics by categories of physical activity in 424 men: the Zutphen Elderly Study, 1990.

	Physical Activity of At Least Moderate Intensity*			
	None (N = 122)	>0–29 min/d (N = 127)	30–59 min/d (N = 84)	60 min/d (N = 91)
Age (yr)	77	73	74	73
BMI ($kg \cdot m^{-2}$)	25.6	25.5	25.6	25.5
Subscapular skinfold (mm)	17	17	17	18
Alcohol ($g \cdot d^{-1}$)	4.2	4.3	6.1	5.7
Fibre† ($g \cdot d^{-1}$)	24	24	27	25
Saturated fat† ($g \cdot d^{-1}$)	39	37	36	38
Current smoking (%)	23	27	15	22
Family history diabetes (%)	9.0	11	3.6	8.8
Cardiovascular diseases‡ (%)	40	29	15	20
Disabilities§ (%)	31	13	6.0	1.1
Activities				
Bicycling ($min \cdot d^{-1}$)	0	10	22	43
Gardening ($min \cdot d^{-1}$)	0	8.6	21	34
Walking ($min \cdot d^{-1}$)	14	11	15	17
Odd jobs (%)	19	47	52	62
Sports (%)	1.6	13	14	16

Values are medians, unless stated otherwise.
* Activities with an energy cost of at least 4 $kcal \cdot kg^{-1} \cdot h^{-1}$.
† Adjusted for total energy intake by regression analysis [21].
‡ History of myocardial infarction, stroke, angina pectoris, or intermittent claudication.
§ Disabilities in basic activities of daily living or mobility; refers to 420 men with complete information on disabilities.

ing data for physical activity or potential confounders (age, family history of diabetes, smoking, body mass index, subscapular skin-fold thickness, and intake of saturated fat, fiber, and alcohol) in 1990, 424 men remained for this analysis. All participants signed an informed consent form, and the Zutphen Elderly study was approved by the Medical Ethical Committee of the Leiden Academic Hospital.

Assessment of physical activity and covariates. In 1985 and 1990, between March and June, physical activity was assessed with a validated self-administered questionnaire specifically designed for retired men (5). The questionnaire included questions on the frequency, duration, and intensity of bicycling and taking a walk during the previous week, and the average amount of time spent on gardening in summer and winter, sports, hobbies, and odd jobs. Open-ended questions were used to assess the duration and frequency of activities and the kind of hobbies and sports. Apart from minutes per day spent on separate activities, we calculated the total minutes per day spent on physical activities of at least moderate intensity (requiring an energy expenditure $\geq$ 4 $kcal \cdot kg^{-1} \cdot h^{-1}$, e.g., brisk walking, bicycling at normal or high speed, or gardening). To assess whether a participant performed occupational physical activity of at least moderate intensity, we used survey questions on having a paid job and type of job.

Data on usual food intake were collected by trained dieticians with the cross-check dietary history method adapted to the Dutch situation (4). Information on disabilities in basic activities of daily living and mobility (11), cigarette smoking, and family history of diabetes was collected using standardized questionnaires. Information on history of cardiovascular diseases (myocardial infarction, angina pectoris, stroke, and intermittent claudication) was obtained by a physician-administered standardized medical questionnaire and verified with hospital discharge data. Anthropometric measurements were conducted by trained physicians with participants dressed in underwear only, using a calibrated balance for weight, a Microtoise for height, and calibrated Harpenden calipers for subscapular skin-fold thickness (measured twice).

Assessment of glucose tolerance. In 1990, an oral glucose tolerance test was conducted according to the 1985 World Health Organization guidelines (22). For glucose determination, samples were collected in tubes with sodium fluoride. Plasma glucose was determined using the hexokinase method; within- and between-run coefficients of variation were lower than 2%. Men with a fasting glucose concentration of at least 7.0 $mmol \cdot L^{-1}$ or a 2-h postload glucose concentration of at least 7.8 $mmol \cdot L^{-1}$ were categorized as glucose intolerant (impaired glucose tolerance or diabetes mellitus (7)).

Statistical analysis. Statistical analyses were carried out using SAS software (release 6.12). We used ANCOVA to calculate adjusted mean glucose concentrations and linear regression analysis to calculate regression coefficients. Logistic regression analysis was used to calculate age and multivariate adjusted odds ratios of glucose intolerance. To test for linear trend, physical activity was modeled as a continuous variable. The reported P-values were two-sided.

RESULTS

In 1990, the mean age of the participants was 75 yr (range 69–89 yr). Inactive men (activity assessed in 1990) were older and were more likely to have disabilities or a history of cardiovascular diseases (Table 1). Men in the highest category of physical activity of at least moderate intensity were characterized by a high amount of bicycling and gardening. Sport participation was low (N = 45; 11%), and few men reported occupational physical activity of at least moderate intensity (N = 8; 1.9%).

The amount of physical activity of at least moderate intensity was inversely associated with plasma 2-h glucose concentrations (age-adjusted $\beta = -0.31$ $mmol \cdot L^{-1}$ per 30 $min \cdot d^{-1}$, SE 0.09, P = 0.0005). Men with more than 30 $min \cdot d^{-1}$ of this type of physical activity had a lower

TABLE 2. Two-hour plasma glucose concentration and odds ratio for glucose intolerance by categories of physical activity in 424 men; the Zutphen Elderly Study, 1990.

Range (median)	Physical Activity of At Least Moderate Intensity* None	>0–29 min·d^{-1} (13)	30–59 min·d^{-1} (40)	60 min·d^{-1} (90)	*P*-Trend
Number	122	127	84	91	
2-h glucose (mmol·L^{-1})					
Age-adjusted	7.1	6.7	6.2	5.7	0.0005
Multivariate†	7.1	6.7	6.3	5.7	0.0005
(95% CI difference‡)	0 (ref.)	(−1.2, 0.3)	(−1.7, 0.01)	(−2.3, −0.6)	
No. glucose intolerance (%)	42 (34)	23 (18)	16 (19)	9 (10)	
Odds ratio (95% CI)					
Age-adjusted	1	0.43 (0.23–0.78)	0.32 (0.18–0.57)		0.0002
Multivariate†	1	0.36 (0.19–0.69)	0.30 (0.16–0.55)		0.0002

Glucose intolerance includes impaired glucose tolerance and newly diagnosed diabetes mellitus.
* Physical activity of at least moderate intensity includes activities with an energy cost of at least 4 kcal·kg^{-1}·h^{-1}.
† Adjusted for age (yr), family history of diabetes (yes/no), smoking (current, past, never), intake (g·d^{-1}) of saturated fat, fiber, and alcohol, body mass index (kg·m^{-2}), and subscapular skin-fold thickness (mm).
‡ Difference in 2-h glucose as compared with lowest category of physical activity.

prevalence of glucose intolerance as compared with men in the lowest category (age-adjusted odds ratio 0.32; 95% CI, 0.18–0.57). Additional adjustment for family history of diabetes, smoking, body mass index, subscapular skin-fold thickness, and intake of alcohol, saturated fat, and fiber did not substantially change the results (Table 2). Furthermore, associations were similar when isolated postload hyperglycemia (fasting glucose < 7.0 mmol·L^{-1}; $N = 59$) was examined as an endpoint (OR 0.36; 95% CI 0.17–0.76). Physical activity was inversely associated with 2-h glucose concentrations in both men with ($\beta = -0.35$, SE 0.13, $P = 0.01$) and without ($\beta = -0.28$, SE 0.11, $P = 0.01$) a subscapular skin-fold thickness above the median.

To address the possibility that high glucose concentrations affected physical activity through deteriorated health, we conducted additional analyses. Adjustment for presence of cardiovascular diseases and disabilities in basic activities of daily living or mobility did not materially change the results (β for 2-h glucose -0.30, SE 0.09, $P = 0.0009$; OR for glucose intolerance 0.30, 95% CI 0.16–0.59). Furthermore, physical activity remained significantly inversely associated with 2-h glucose concentrations after exclusion of men with cardiovascular diseases or disabilities ($\beta = -0.32$, SE 0.09, $P = 0.0008$) or men in the lowest category of activity ($\beta = -0.25$, SE 0.09, $P = 0.004$).

Table 3 shows the association between common types of physical activity and glucose tolerance after simultaneous modeling of specific activities. Regular bicycling and gardening were both associated with a lower prevalence of glucose intolerance. The time spent on taking walks was not significantly associated with glucose tolerance. Additional adjustment for family history of diabetes, smoking, body mass index, subscapular skin-fold thickness, and intake of saturated fat, fiber, and alcohol did not appreciably change these results.

We also examined whether physical activity in 1985 and 5-yr change (1985–1990) in physical activity were predictors of glucose tolerance in 1990. The Spearman correlation coefficient for physical activity in 1985 and 1990 was 0.52. Physical activity in 1985 was associated with glucose tolerance in 1990, even after correction for physical activity in 1990 ($P = 0.01$). As shown in Table 4, men with at least 30 min·d^{-1} of physical activity of at least moderate intensity in 1985 who maintained that amount of activity in 1990 had the lowest 2-h glucose concentration and prevalence of glucose intolerance. Furthermore, men whose amount of physical activity had decreased had higher 2-h glucose concentrations as compared with men whose physical activity had remained stable or had increased (difference 0.7 mmol·L^{-1}; 95% CI, 0.1–1.3 adjusted for age and baseline activity). These results were similar after exclusion of men with cardiovascular diseases or disabilities.

DISCUSSION

In this study, physical activity was strongly associated with lower plasma glucose concentrations and a lower prevalence of glucose intolerance in elderly men, aged 69–89 yr. This

TABLE 3. Two-hour plasma glucose concentration and odds ratio for glucose intolerance by specific activities in 424 men*; the Zutphen Elderly Study, 1990.

	None	>0–19 min·d^{-1}	20 min·d^{-1}	*P*-Trend
Bicycling (%)	27	32	41	
Median (min·d^{-1})	0	11	43	
2-h glucose (mmol·L^{-1})	7.2	6.2	5.8	0.01
Odds ratio (95% CI)	1	0.47 (0.25–0.87)	0.37 (0.20–0.70)	0.01
Gardening (%)	42	30	28	
Median (min·d^{-1})	0	8.6	34	
2-h glucose (mmol·L^{-1})	6.7	6.5	6.0	0.12
Odds ratio (95% CI)	1	0.57 (0.31–1.05)	0.33 (0.16–0.66)	0.02
Taking a walk (%)	20	45	36	
Median (min·d^{-1})	0	8.6	34	
2-h glucose (mmol·L^{-1})	6.3	6.7	6.2	0.36
Odds ratio (95% CI)	1	1.48 (0.75–2.88)	0.92 (0.46–1.88)	0.70

* Estimates for 2-h glucose and odds ratios are derived from a multivariate model including age (yr), sport (yes/no), work (yes/no), hobbies (yes/no), and bicycling, gardening, odd jobs, and taking walks (none, >0–19 min·d^{-1}, 20 min·d^{-1}); *P*-values for trend were calculated with these parameters modeled as continuous variables; glucose intolerance includes impaired glucose tolerance and newly diagnosed diabetes mellitus.

TABLE 4. Change in physical activity between 1985 and 1990 in relation to 2-h plasma glucose concentrations and glucose intolerance in 412 men*; the Zutphen Elderly Study, 1985–1990.

30 min·d^{-1} Physical Activity†						
1985	1990	*N*	2-h Glucose‡ (mmol·L^{-1})	Difference in 2-h glucose‡ (mmol·L^{-1})	Glucose Intolerance (*N*)	Odds Ratio‡
No	No	164	7.1	0 (ref.)	29% (47)	1 (ref.)
Yes	No	85	6.5	−0.6 (−1.4, 0.2)	21% (18)	0.68 (0.36–1.26)
No	Yes	46	6.4	−0.8 (−1.7, 0.2)	15% (7)	0.46 (0.19–1.11)
Yes	Yes	129	5.8	−1.3 (−2.0, −0.6)	14% (18)	0.41 (0.23–0.76)

* 12 men with missing values for physical activity in 1985 were excluded.
† Physical activity of at least moderate intensity (energy cost 4 kcal·kg^{-1}·h^{-1}).
‡ Estimates adjusted for age (95%CI).

inverse association with glucose tolerance was observed for bicycling and gardening but not for taking walks. Men who had maintained their physical activity over a 5-yr period had a higher glucose tolerance as compared with men who reduced their activity with aging.

Few studies reported on the relation between physical activity and glucose tolerance in the elderly. Total physical activity was associated with newly diagnosed diabetes in Dutch women aged 50–75 (16) but not in Japanese-Americans aged 71–93 yr (19). These studies focused on a single global physical activity score and did not present information on type and duration of physical activity. Although the time spent on activities was not assessed, Folsom et al. (9) observed an inverse association of the frequency of both moderate and vigorous physical activities with diabetes risk in women aged 55–69 yr. Our findings also agree with results of the Rotterdam study (aged 55–75 yr) that observed a lower prevalence of newly diagnosed diabetes observed in participants who reported any bicycling (3). In addition, the present results are consistent with the inverse association between physical activity and hyperinsulinemia in this population (8).

The amount of physical activity of at least moderate intensity in our study was mainly determined by gardening and bicycling; sport participation was low. Cycling or gardening was reported by 84% of the study participants, suggesting that activities of this intensity are feasible for the majority of persons of this age group. However, in many countries, fewer facilities for bicycling (e.g., cycle tracks) exist than in The Netherlands, which may reduce the possibilities to perform this activity. Walking is probably more accessible and easy to adopt but was not associated with glucose tolerance in the present study and the Rotterdam study (3). Still, we cannot exclude the possibility that differences in accuracy of assessment explain the lack of association with walking. Also, the relatively low contribution of walking to total physical activity in this population may have reduced the power to detect an association with glucose tolerance. Another possibility is that physical activity is only be beneficial beyond a certain limit of intensity, as walking is generally of lower intensity than gardening or bicycling (2). Among female nurses aged 40–65 yr, walking was inversely associated with risk of type 2 diabetes mellitus (12). However, women with a brisk usual walking pace had a 41% lower risk of type 2 diabetes as compared with women with an easy walking pace (12), and brisk walking was probably rare in our study of elderly men.

The association between physical activity and glucose tolerance was observed in both men with and without high body fatness. Also, adjustment for body mass index and subscapular skin-fold thickness did not weaken the observed association, suggesting that the effect of physical activity on glucose tolerance was not mediated by an effect on body fatness. This agrees with small intervention studies showing that regular exercise improves insulin sensitivity in older persons (6), independent of changes in weight or body composition.

The advantages of our study included the extensive information collected on potential confounders, the availability of two identical detailed assessments of physical activity, and the possibility to examine men at a very high age. Also, in contrast to most studies of physical activity that used diagnosed diabetes mellitus as an endpoint, we used an oral glucose tolerance test to restrict under-ascertainment of glucose intolerance. Our physical activity questionnaire was specifically designed for retired men. Among 21 participants, the 4-month test-retest correlation for total physical activity was 0.93, and the correlation with total energy expenditure as measured by the doubly labeled water technique was 0.61 (20).

In theory, the reported cross-sectional associations might also be explained by an effect of glucose tolerance on physical activity behavior. As awareness of having diabetes may affect physical activity habits or reporting thereof, we excluded men with diagnosed diabetes. High plasma glucose concentrations may also affect physical activity through deteriorated health. However, the prospective association between physical activity 5 yr before the oral glucose tolerance test and glucose tolerance was consistent with our cross-sectional findings. Moreover, adjustment for cardiovascular disease and disabilities in basic activities of daily living or mobility, or exclusion of men with these conditions did not weaken the observed associations. Also, the association between physical activity and glucose tolerance remained after exclusion of men in the lowest category of physical activity, indicating that the association was not due to specific characteristics of the inactive group. These analyses suggest that the observed association was not due to confounding by health status, and that modifiable physical activity may affect glucose tolerance.

Various health agencies recommend to accumulate 30 min or more of moderate intensity physical activity on most, preferably all, days of the week (17). Our results suggest that this amount of activity increases glucose tolerance substantially in elderly men, even without a decrease in body fatness. Specifically, bicycling and gardening may be beneficial. Our findings support public health advice to maintain or increase physical activity in elderly men for prevention of glucose intolerance.

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Address for correspondence: Rob M. van Dam, Department of Chronic Diseases Epidemiology, National Institute for Public Health and the Environment, P.O. Box 1, 3720 BA Bilthoven, The Netherlands; E-mail: rob.van.dam@rivm.nL.

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