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Daily Physical Activity, Work Capacity and Glucose Tolerance in Lean and Obese Normoglycaemic Middle-aged Men

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Summary. Daily physical activity, work capacity, relative body weight and glucose tolerance were studied in 115 normoglycaemic 48 year old men selected from a health screening programme. In contrast to the reported physical activity at work, leisure time activity was significantly related to maximal oxygen uptake ($p < 0.05$), glucose ($p < 0.05$) and insulin values ($p < 0.05$) during OGTT, but not to relative body weight. The number of men with impaired glucose tolerance (glucose at 120 min > 6.9 mmol) was significantly higher among those who were physically inactive during their leisure time. The insulin glucose ratio at 0 and 120 min during the OGTT was significantly higher in the obese unfit as compared to the obese fit subjects thus suggesting an influence of moderate leisure time physical activity on glucose tolerance.

Key words: Middle-aged men, glucose tolerance, insulin sensitivity, maximal oxygen uptake, physical activity, obesity, normal body weight

Long distance runners and physically trained middle-aged men have lower circulating insulin levels than healthy sedentary men both during intravenous [1] and oral glucose tolerance tests [2]. This indicates greater insulin sensitivity in well-trained men and athletes.

The extent to which these findings apply to the general population is not obvious since few middle-aged or older individuals regularly engage in physical training or physical activity either at their jobs or during leisure time. Furthermore, body composition, particularly adipose tissue and muscle mass, fluctuates with changes in the level of physical activity [3]. Thus, some of the differences in insulin secretion between physically active and inactive subjects may be related to the degree of obesity.

In the present investigation, using a random sample of middle-aged men, we have tried to evaluate the relationships of daily physical activity and physical work capacity, specifically to determine 1) if they were interrelated, 2) if they were related to glucose tolerance, and 3) if they were dependent or independent of the degree of obesity.

Subjects

In Malmö, a town with 238000 inhabitants, a health screening programme for 47–49 year old men is performed continuously. An oral glucose tolerance test (OGTT) is a part of the screening procedure for all individuals except those who are known diabetics. In the present study men born in 1929 were investigated. A total of 1461 men were invited to be screened and 1056 of them accepted. On weekdays 6–8 men were screened and the first four coming each day during one month also performed a submaximal work test. All 115 participants were informed of the nature and risks of the study before they gave oral consent to participate. Of these individuals 42 were regular smokers, 5 had occasionally used sleeping pills during the last month, and 3 had some symptoms of chronic gastritis and were using antacids. One individual regularly took diuretics and 2 had mild hypertension but were not on medication.

Methods

All investigations were performed in the morning between 0800 and 1000 h after fasting at least 10 h. None of the subjects had smoked before any of the tests. A fasting blood sample for serum lipids was taken. The OGTT was performed with 30 g glucose per m^2 body surface area given as an aqueous solution (10 g/100 ml) and ingested within 5 min. Capillary blood glucose was measured at 0, 20, 40, 60, 90 and 120 min, and plasma insulin at 0, 40, and 120 min. Immediately after the glucose tolerance test a submaximal exercise test was performed. Two submaximal work intensities (100 and 150 or 175 w) lasting 6 min each were performed. The

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Table 1. Subject characteristics, and biochemical variables (mean ± SD) in 115 normoglycemic 48 years old men grouped according to whether they were above or below the mean for body weight and maximal oxygen uptake. The glucose and insulin values were obtained in the fasting state before and during an oral glucose tolerance test. [a], [b] and [c] denote a significant difference [a]($p < 0.05$) [b]($p < 0.01$) [c]($p < 0.001$) when comparing groups A with C and B with D, respectively. A cross denotes a significant difference when comparing groups A with B and C with D (†† $p < 0.01$; ††† $p < 0.001$). As body weight and maximal oxygen uptake were selection criteria forming the groups no significance levels for these variables are given

Group	A	B	C	D
Number of subjects	27	41	27	20
Body weight, kg	71.7 ± 6.5	70.5 ± 5.9	88.8 ±11.7	84.0 ± 10.8
Relative body weight	1.00± 0.07	1.01± 0.07	1.25± 0.14[c]	††† 1.22± 0.11[c]
Skinfold thickness, unit	186 ±17	188 ±22	214 ±15[c]	†††203 ± 18[c]
Maximal oxygen uptake l/min	3.19± 0.4	2.13± 0.3	3.27± 0.6	2.16± 0.3
Blood glucose mmol/l fasting 120 min	4.19± 0.6 4.8 ± 1.1	5.1 ± 0.6 5.3 ± 1.4	5.2 ± 0.5 6.1 ± 1.7[b]	5.4 ± 0.5 6.8 ± 1.6[c]
Sum of 0, 40, 60, 80, 100 and 120 min	42.5 ± 4.8	44.9 ± 6.8	45.2 ± 7.0	†† 50.3 ± 5.2[b]
Plasma insulin mU/l fasting 120 min	6.5 ± 3.8 18.0 ±13.9	7.6 ± 4.6 28.1 ±23.7	10.3 ± 6.0[b] 37.3 ±24.2[c]	†† 19.4 ± 14.7[c] †††102.1 ± 89.8[c]
Sum of 0, 40 and 120 min	121 ±46	140 ±59	153 ±61[a]	††272 ±180[b]
Serum cholesterol mmol/l	5.63± 0.92	5.77± 0.94	5.88± 0.80	†† 6.42± 0.47[b]
Serum triglycerides mmol/l	1.56± 0.86	1.73± 0.85	1.92± 0.92	2.22± 1.15

heart rate was monitored continuously and the mean heart rate during the last 2 min of work at each load were used for calculation of the maximal oxygen uptake [4]. Comparison between this indirect measure of maximal oxygen uptake and a direct measurement of oxygen uptake was made on 15 of the men. The agreement between the methods was found to be within ±6% (coefficient of variation) with the mean values being the same. A questionnaire was used to classify daily physical activity during work and leisure time into four [1–4] categories [5]. Office work with no or very little physical demands was classified in category 1 and those jobs with heavy manual labour as category 4. Similarily, if an individual undertook no physical activity during his spare time he was placed in category 1, whereas weekly bouts of endurance activity were required for placement in category 4. One hundred and seven of the men answered the questionnaire adequately.

Relative body weight was calculated according to the formula: measured weight/ideal weight for body height [6]. Skinfold thickness was measured with a caliper over the right brachial triceps 5 cm above the elbow [7]. Blood glucose was measured with a hexokinase method [8] and plasma insulin by radioimmunoassay [9]. Assays were done in triplicate. The limit of detection was 3 mU/l. Cholesterol and triglycerides were analyzed according to routine methods [10, 11, 12].

Statistical Methods

The data are presented as the mean ± SD. Statistical comparisons were by the unpaired t-test or using χ^2 [13].

Results

The mean values for relative body weight and predicted maximal oxygen uptake were 1.11 ± 0.15 and 2.66 ± 0.66 l/min, respectively. In order to separate the influence of the relative body weight and physical fitness the 115 subjects were divided into four groups using these mean values as dividing lines. In this way two groups of lean subjects, one with high (group A) and one with low physical capacity (group B) and two analogous groups of overweight men, one with a high (group C) and one with a low physical capacity (group D) were formed (Table 1). The number of men in the respective groups were 27 (A), 41 (B), 27 (C) and 20 (D). Job physical activity did not differ significantly between groups, but the reported mean physical activity in leisure time was 2.1 (range 1–3), 1.9 (1–3), 2.0 (1–3) and 1.1 (1–2) in groups A to D respectively, the difference between group D and group C being significant. Mean values for body weight for men in groups C and D were 13–19 kg or approximately 20% higher than for men in groups A and B. Similarly mean maximal oxygen uptake was 1.0 to 1.1 l/min higher in groups A and C as compared with groups B and D. The overweight men who had a good physical work capacity (group C) were about 5 kg heavier and had a skinfold thickness which was higher than the mean of group D. In the lean subjects mean values for body weight and skinfold thickness were very close. In addition the mean maximal oxygen uptake was the same in groups A and C as well as B and D.

Serum cholesterol was significantly higher when comparing group D with groups C, B and A. The mean triglyceride concentration was only significantly higher when comparing group D with group A.

In the fasting state and during the OGTT, plasma insulin and blood glucose levels were similar in groups A and B. Thus, physical work capacity had no influence on these variables among the lean subjects. However, definite differences were seen not only between overweight and lean subjects, but also between the two groups of overweight men. Group C had lower glucose and insulin sums during OGTT than group D ($p < 0.05$). Further, the fasting as well as the 120 min values for both insulin and glucose were lower in the physically fit overweight men (C vs D; $p < 0.05$). Comparing group C with group A or B, fasting blood glucose values as well as the sum of glucose values were not different, whereas the glucose level at 120 min was higher in group C (group C vs A, $p < 0.05$; group C vs B, $p < 0.05$). A comparison of groups A and C for plasma insulin showed differences in the fasting state and for the sum of insulin values during the OGTT ($p < 0.01$). Only the 120 min insulin values were different when comparing group B with group C ($p < 0.05$). The insulin/glucose ratio at rest and during OGTT revealed that group D (obese and unfit men) had higher values than the other groups ($p < 0.001$) whereas there were no differences between groups A, B and C (Fig. 1).

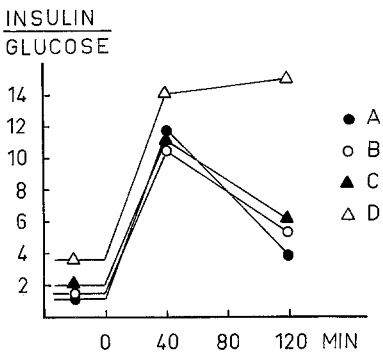

Fig. 1. The plasma insulin (mU/l) to blood glucose (mmol/l) ratio in groups A–D (see text) during OGTT (30 g/m²). The ratio for group D (above mean ideal weight and below mean physical capacity) was significantly different from groups A, B and C ($p < 0.001$) at 0 and 120 minutes

Mean values for the various groups based on reported physical activity levels at their jobs and during leisure time were also compared. The results are summaried in Table 2. Regardless of activity level at work, mean values for glucose and insulin sums during the OGTT, as well as body weight, relative body weight and maximal oxygen uptake were not significantly different. In contrast, those who reported some leisure time physical activity (categories 2 and 3; none of the subjects qualified for group 4) had higher maximal oxygen uptake and lower glucose and insulin sums during the OGTT ($p < 0.05$). It is of note that body weight and relative body weight were the same for the different leisure time activity groups

Table 2. Observations (mean ± SD) for variables studied in one hundred and seven 48-years old normoglycaemic men grouped according to reported daily activity (group 1 very little, to group 4 very high) at work and during leisure time. Blood glucose > 6.9 mmol/l after 120 min in the OGTT was used as the criterion for impaired glucose tolerance (IGT). The sum during the OGTT for glucose (0, 40, 60, 80, 100, 120 min) and for insulin (0, 40, 120 min) are given. There were no significant differences comparing groups based on job activity levels. An [a] or [b] donote a significant difference when comparing the activity levels during leisure time (1 vs 2 and 1 vs 3) ([a], $p < 0.05$; [b], $p < 0.01$). No statistically significant differences were found between group 2 and 3. A χ^2 test revealed that the number of men with IGT was significantly ($p < 0.01$) higher among those who were physically inactive in leisure time. No such relationship was found when comparing job activity levels

Activity group	At work 1	2	3	4	During leisure 1	2	3	4
Number of subjects	38	36	30	3	35	54	18	0
Men with IGT	5	10	6	0	13	5	3	
Blood glucose SUM mmol/l	45.3 ± 7.3	46.4 ± 7.4	44.6 ± 4.5	40.8 ± 2.4	47.4 ± 7.4	[a]44.6 ± 5.6	[a]43.7 ± 7.2	
Plasma insulin SUM mU/l	175 ±99	176 ±137	140 ±68	112 ±73	199 ±113	[a]152 ±108	[b]124 ±54	
Relative body weight	1.10± 0.15	1.09± 0.10	1.13± 0.20	1.10± 0.20	1.14± 0.16	1.08± 0.14	1.10± 0.16	
Maximal oxygen uptake l/min	2.55± 0.6	2.56± 0.7	2.72± 0.6	2.86± 0.2	2.40± 0.6	[a]2.66± 0.5	[a]2.90± 0.8	
ml/kg · min	32.7 ± 6	33.1 ± 7	33.9 ± 6	36.6 ± 4	29.6 ± 7	[a]34.7 ± 6	[a]37.1 ± 7	

($p < 0.05$). Further, the number of men who had a blood glucose concentration above 6.9 mmol/l at 120 min of the OGTT was significantly higher for leisure time physical activity group 1 than for groups 2 and 3 ($p < 0.05$).

Discussion

There are many indices indicating that the present group of men is representative of the total Swedish population of 48 year old men. The relative frequencies of subjects in the various activity groups in the present data are similar to those found in slightly younger and older middle-aged men [14]. The estimated mean value and range for maximal oxygen uptake are also quite close to the expected as based on measurements of other random samples of men in various age groups [15, 16]. Furthermore, body weight and relative body weight are the same as found in a larger group of men of this age [17].

The interesting new observation in this study is that among these men, of whom none are especially physically active either at work or during leisure time, an effect can be found on glucose tolerance and insulin sensitivity in relation to small differences in physical activity pattern and work capacity. This is in line with the findings in some age groups of the Tecumseh study [18] and is also an extension of the high insulin sensitivity observed in well-trained subjects and athletes [1, 2, 19].

The serum insulin level at rest and during the OGTT in the present study was normal or higher for a given blood glucose concentration, suggesting that the subjects' β cells were functioning appropriately. It is well established that adipose tissue is a major site for the insulin insensivity in overweight subjects, although the cause for this reduced insulin action is not clearly defined. An interesting question is whether adipose tissue has a different insulin sensitivity in physically fit subjects than in unfit subjects, or whether the other insulinsensitive tissues, liver and muscle, compensate with increased insulin sensitivity. Little data is available on these subjects. A difference in uptake of glucose and insulin by the liver does not appear likely. In all groups the blood glucose curves are very similar during the first third of the OGTT, that is during the time when absorption of glucose from the gut and its uptake by the liver play dominant roles for the observed glucose level. In contrast it appears likely that muscle tissue may play a role. Skeletal muscle is the largest tissue mass of the body (except in very obese individuals). Thus, small changes in the metabolic capacity of muscle could markedly influence the overall metabolic response of the body. During an OGTT such an influence will be most apparent during the later part of the 2 h observation period. It is also during this period that the most marked differences in both blood glucose and serum insulin are observed. Another and probably the most important factor explaining the insulin insensitivity of the unfit subjects is the finding that marked changes of the metabolic potential of the muscle occur with small variations in the level of physical activity [20]. We also know that men with impaired glucose tolerance (IGT) can normalize their glucose tolerance by some increase in their weekly physical activity pattern [21]. This occurs without any changes in body weight or lean body mass [21].

We thus suggest that a low metabolic potential of the skeletal muscles is in part the cause for insulin insensitivity and IGT and that physical inactivity should therefore be considered an independent risk factor in the development of these problems. Men with IGT have a higher risk of developing overt diabetes and also a higher risk of cardiovascular illnesses [22]. There is thus good evidence for recommending an increased level of physical activity in the population as a supplement to advice about dietary intake. To what extent changes in life-style can help is unknown, but in a continuing study, 238 middle-aged men with IGT have improved their glucose tolerance and insulin sensitivity by increased physical activity. Further, over a mean observation period of 2 years, only one of them has developed overt diabetes [23].

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