[Environmental Health and Preventive Medicine 2, 177-182, January, 1998]

Decreased Physical Fitness in Borderline Glucose Tolerance Men

Yasuki HIGAKI, Naoko SHONO and Masahiro NISHIZUMI

Department of Community Health Science, Saga Medical School, Saga

Abstract

To investigate the primary changes in glucose intolerance, physical characteristics and daily-life activity (pattern) were compared in the normal glucose tolerance (NGT, n=7) and the borderline glucose tolerance (BGT, n=9) subjects based on the criteria adopted by the Committee on the Diagnosis of Diabetes mellitus of Japan Diabetes Society. The basal glucose and insulin concentrations in the BGT group (90.7±4.1mg/dl, 9.2±1.1μU/ml) were slightly higher than that in the NGT group (82.0±3.2mg/dl, 6.7±1.0μU/ml), while the glucose response following an oral glucose load in the BGT group was quite different from that of the NGT group. The area under the curve (AUC) of plasma glucose level following an oral glucose load was significantly higher in the BGT group than that in the NGT group ($p<0.05$), while the AUC of plasma insulin level in the BGT group did not significantly differ from that in the NGT group ($p>0.05$). The maximal oxygen uptake was significantly lower in the BGT group than that in the NGT group (32.4±2.8 vs. 42.5±2.6ml/kg/min, $p<0.05$). Systolic blood pressure was significantly higher in the BGT group (134±3mmHg) than that in the NGT group (122±4mmHg, $p<0.05$). However, body mass index, the percentage of body fat, and waist-to-hip ratio in the BGT group did not differ from those in the NGT group. These results thus suggested that decreased physical fitness may be the primary change which induces glucose intolerance.

Key words: Maximal oxygen uptake, Life-style, Impaired glucose tolerance, College student, Systolic blood pressure

Introduction

It is well known that both physical inactivity and body fat accumulation impair glucose tolerance[1-3]. Several studies have been demonstrated that individuals with low levels of physical activity found to be at increased risk of non-insulin-dependent diabetes mellitus[4, 5]. On the other hand, excessive caloric intake results in weight gain, and the body becomes markedly resistant to the action of insulin[6]. Since body weight is determined by energy balance between consumption and intake, decrease in the consumption which is induced by physical inactivity may also lead to weight gain. Therefore, it is believed that physical inactivity is closely related to obesity in the development of glucose intolerance.

Lindgarde and Saltin[7] investigated obese subjects who have different levels of physical fitness on insulin sensitivity. Interestingly, they observed that the insulin sensitivity in the obese fit was significantly higher than that in the obese unfit. It has been reported in obese subjects that a single bout of exercise improves whole body glucose uptake without change in body fat contents[8], suggesting the potential importance of physical exercise on glucose tolerance. Since the primary sites of glucose disposal after glucose load are peripheral tissues[9], such as skeletal muscles, these results suggest that the improved or deteriorated glucose tolerance may be due to the changes in capacity for glucose uptake in skeletal muscle.

In this context, we hypothesized that decreased physical fitness which suggests a low metabolic potential of skeletal muscle may be the primary cause for impaired glucose tolerance. Therefore this study was designed to compare the physical characteristics and daily-life activity of the borderline glucose tolerance subjects with those of normal glucose tolerance subjects.

Methods

Subjects.

Twenty-two male college students participated in the program of exercise prescription in Saga Medical School. One of the characteristic trends of these subjects is that they possess an interest in health and physical activity. This study performed after giving them the informed consent. Six subjects who had a family history of diabetes or hypertension were excluded from this study.

Reprint requests to: Yasuki Higaki,
Department of Community Health Science,
Saga Medical School,
5-1-1, Nabeshima, Saga 849-8501, Japan
TEL: +81 (952) 31-6511 FAX: +81 (952) 34-2065

Nine subjects were in borderline glucose tolerance (BGT) and seven subjects were in normal glucose tolerance (NGT). The results of glucose tolerance test were classified according to the criteria adopted by the Committee on the Diagnosis of Diabetes mellitus of Japan Diabetes Society[10] based on the results of a 75-g oral glucose tolerance test. In brief, the glucose tolerance test results were defined as follows: (1) BGT: fasting plasma glucose between 110-140mg/dl, and/or 1-h blood glucose≧160mg/dl, and/or 2-h blood glucose between 120-200mg/dl; (2) NGT: fasting plasma glucose<110mg/dl, and 1-h plasma glucose<160mg/dl, and 2-h blood glucose<120mg/dl.

Body composition.

Body mass index (BMI) was calculated by dividing weight by height squared (kg/m^2). The waist-to-hip ratio (WHR), an index of the pattern of regional fat distribution, was calculated by dividing the minimal circumference of the abdomen by the circumference of the buttocks at the maximal gluteal protuberance. The percentage of body fat was estimated from the sum of the triceps and subscapular skinfolds measured with a skinfold caliper[12] using Brozek's formula[13].

Physical fitness.

The maximal oxygen uptake was measured on a cycle ergometer by the leveling off criterion[14]. The workload was increased by 15 Watts every 4min, and expired air was collected in Douglas bags at the last 3 to 4min of each stage. Fractional concentrations of oxygen and carbon dioxide in the expired gases were measured by gas analyzer (ABL3, Radiometer), and gas volumes were measured with a spirometer (Shinagawa, Tokyo, Japan).

Questionnaire on the daily-life activity pattern.

A questionnaire on the daily-life activity pattern was prepared and consisted of items as state of health, regularity of life, hours of sleep, regularity of meals, having breakfast, food preference, snacks, smoking, drinking alcohol, and habitual exercise.

Oral glucose tolerance test (OGTT).

For 3 days before the study, the subjects were refrained from any type of exercise. On the day previous to a 75-g oral glucose tolerance test, all subjects were provided a supper containing >140g carbohydrate, >30g fat, and >33g protein. OGTT was performed at 09:00 after an overnight fast. A catheter was inserted in an antecubital vein and blood was drawn for later analysis of plasma glucose and insulin concentration. Subjects were allowed to rest quietly for at least 15min before blood sampling. Basal samples for glucose and insulin were obtained before OGTT. After an oral administration of a 75-g glucose, blood samples were subsequently drawn at 10, 20, 30, 40, 50, 60, 90 and 120min. Plasma glucose concentrations were measured in duplicate using the glucose oxidase method (Yellow Springs Instruments, Yellow Springs, OH, USA). Aliquots of plasma were frozen at -80℃ until measurement of insulin levels by radioimmunoassay (SRL, Tokyo, Japan). The AUCs of plasma glucose and insulin after glucose load were calculated using the trapezoidal method[15].

The parameters of blood chemistry (lipids, serum enzymes, uric acid) were determined by Dry chemistry methods (Reflotron, Boehringer Mannheim).

Statistics.

The results were expressed as the mean±SEM. Statistical comparison between the BGT and the NGT groups was performed by Student's t-test or Mann-Whitney U-test. Univariate and multivariate stepwise regression analysis were calculated using Statview II program for Macintosh (Abacus Concepts, Inc., Berkeley, CA, USA). Differences were considered to be statistically significant at $p<0.05$.

Results

Characteristics of subjects (Table 1).

The percentage of body fat and BMI were similar in the NGT and the BGT groups. The WHR in the BGT group was slightly higher than that in the NGT group, though the difference was not statistically significant. The maximal oxygen uptake was significantly lower in the BGT group than that in the NGT group ($p<0.05$). Systolic blood pressure at rest was significantly higher in the BGT group than that in the NGT group ($p<0.05$), while diastolic blood pressure at rest was slightly higher in the BGT group than that in the NGT group, but the difference was not statistically significant.

Table 1 Characteristics of the subjects.

	NGT group	BGT group
Age (yr)	24.1 ± 0.4	26.4 ± 0.7
Height (m)	1.72 ± 0.01	1.75 ± 0.02
Weight (kg)	71.5 ± 4.0	69.8 ± 3.6
BMI ($kg \cdot m^{-2}$)	23.3 ± 1.0	24.0 ± 1.2
WHR	0.79 ± 0.01	0.85 ± 0.02
Body fat (%)	16.7 ± 1.8	21.3 ± 2.8
VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$)	42.5 ± 2.6	32.4 ± 2.8*
SBP (mmHg)	122 ± 4	134 ± 3*
DBP (mmHg)	75 ± 3	82 ± 4
HDL-C (mg/dl)	45.0 ± 1.5	40.5 ± 3.7
TC (mg/dl)	150 ± 9	182 ± 19
GOT (μU/ml)	23.6 ± 2.1	27.7 ± 5.5
GPT (μU/ml)	24.8 ± 4.6	31.0 ± 6.6
γ -GTP (μU/ml)	16.9 ± 2.6	31.5 ± 6.4
Uric acid (mg/dl)	6.5 ± 0.3	6.7 ± 0.5

Values are represented as mean±SEM.
NGT: normal glucose tolerance.
BGT: borderline glucose tolerance.
BMI: Body mass index.
WHR: waist-to-hip ratio.
VO_2 max: maximal O_2 uptake.
SBP: systolic blood pressure at rest.
DBP: diastolic blood pressure at rest.
HDL-C: high density lipoprotein cholesterol.
TC: total cholesterol.
GOT: glutamic oxaloacetic transaminase.
GPT: glutamic pyruvic transaminase.
γ -GTP: γ -glutamyl transpeptidase.
*$p<0.05$

The daily-life activity (pattern) (Table 2).

The BGT subjects tended to prefer meat or fatty food. Regarding to habitual exercise, six of the seven NGT subjects had habitual exercise, while six of the nine BGT subjects did not perform any type of exercise.

OGTT (Fig. 1, 2, 3).

The basal glucose and insulin concentrations were slightly higher in the BGT group (90.7±4.1mg/dl, 9.2±1.1 μU/ml) than that in the NGT group (82.0±3.2mg/dl, 6.7±1.0 μU/ml), but the difference was not statistically significant. The plasma glucose and insulin concentrations during OGTT were illustrated in Figure 1

Table 2 The results of a questionnaire on daily-life activity (pettern).

	Total subjects	Group	
	(n=16)	NGT (n=7)	BGT (n=9)
The state of health			
not good	3	0	3
good	4	1	3
very good	9	6	3
Regularity of life			
irregular	6	2	4
sometimes irregular	6	3	3
regular	4	2	2
Hours of sleep			
≧9 hours	1	1	0
8 hours	7	3	4
7 hours	4	1	3
≦6 hours	4	2	2
Regularity of meals			
irregular	7	2	5
sometimes irregular	3	2	1
regular	6	3	3
Having breakfast			
rarely	5	2	3
sometimes	5	2	3
every day	6	3	3
Food preference			
fish or vegetable	0	0	0
meat or fatty food	8	1	7
all food	8	6	2
Snacks			
rarely	2	1	1
sometimes	8	3	5
every day	6	3	3
Smoking			
no	12	5	7
yes	4	2	2
Drinking alcohol			
rarely	3	1	2
sometimes	12	6	6
every day	1	0	1
Habitual exercise			
no	7	1	6
yes	9	6	3

Values are number of subjects.

and 2. The plasma glucose concentrations at 50, 90 and 120min following glucose load were significantly higher in the BGT group than that in the NGT group ($p<0.05$). While plasma insulin concentration at 120min following glucose load was significantly higher in the BGT group than that in the NGT group ($p<0.05$). The average of AUC of plasma glucose level was significantly higher in the BGT group than that in the NGT group ($p<0.05$). On the other hand, the AUC of plasma insulin level was higher in the BGT group than that in the NGT group, but the difference was not statistically significant. Since the AUC of insulin level of one subject in the BGT group showed a striking difference compared to those of other subjects, Student's t-test was also done after excluding this subject. However, there was also no significant difference between both groups. The longitudinal study included this subject could give important information regarding the process of improvement or deterioration on glucose tolerance. Therefore, this subject remained in this study. The insulin to glucose ratio was not significantly different between the BGT and the NGT groups (Fig 3).

Relationship of maximal oxygen uptake, WHR and the percentage of body fat to plasma glucose concentrations.

Maximal oxygen uptake was inversely related to both the percentage of body fat ($r=-0.48$, $p<0.001$) and WHR ($r=-0.88$, $p<0.001$). Glucose concentrations during OGTT were introduced in univariate and stepwise multiple regression analyses (Table 3). Glucose concentration at 120min during OGTT were inversely related to maximal oxygen uptake ($r=-0.75$, $p<0.001$), and positively related to WHR ($r=0.64$, $p<0.01$) and the percentage of body fat ($r=0.52$, $p<0.05$). The results of stepwise multiple regression analyses showed that maximal oxygen uptake is a significant vari-

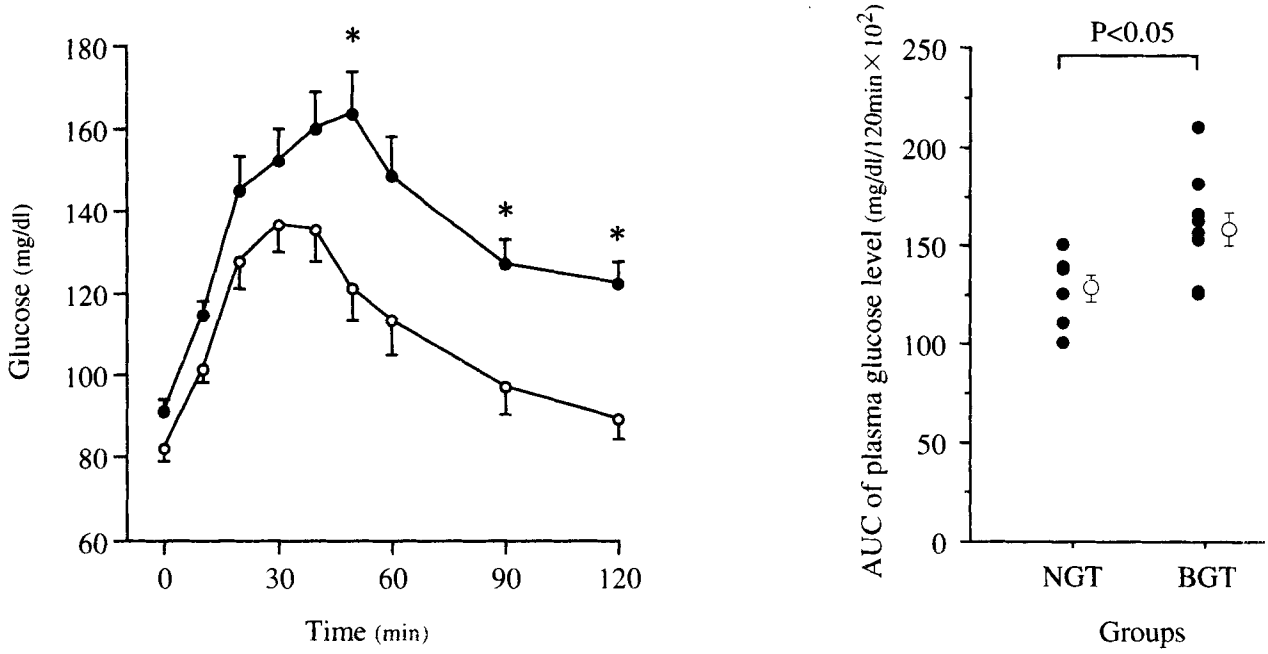

Fig. 1 Plasma glucose concentrations vs time (left) in the borderline glucose tolerance (●) and the normal glucose tolerance groups (○) during a 75-g oral glucose tolerance test. * Significantly different ($p<0.05$) from the normal glucose tolerance group. Values are represented as means±SEM. Area under the curve distribution of plasma glucose (right). Closed circle (●) and open circle (○) with bar represent individual data and the means ± SEM, respectively.

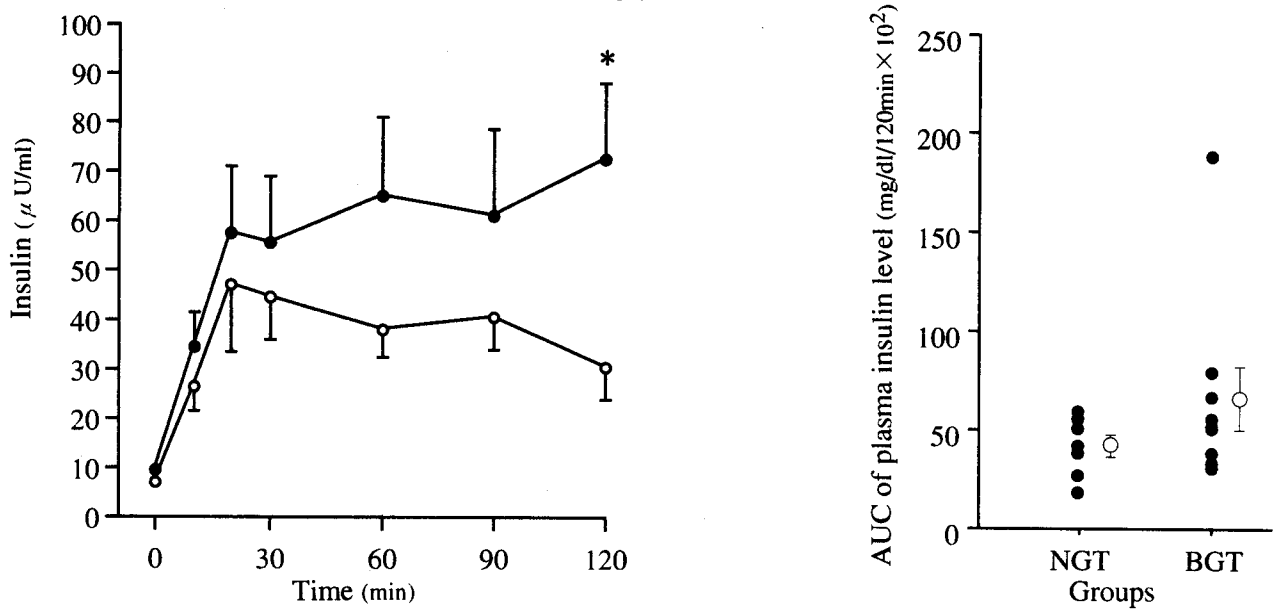

Fig. 2 Plasma insulin concentrations vs time (left) in the borderline glucose tolerance (●) and the normal glucose tolerance groups (○) during a 75-g oral glucose tolerance test. * Significantly different (p<0.05) from the normal glucose tolerance group. Values are represented as means±SEM. Area under the curve distribution of plasma insulin (right). Closed circle (●) and open circle (○) with bar represent individual data and the means ± SEM, respectively.

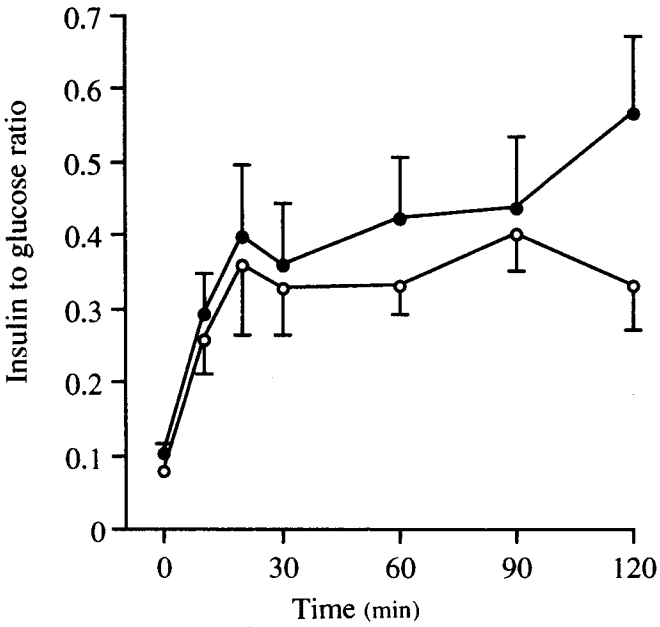

Fig. 3 Insulin to glucose ratio during oral glucose tolerance test in the borderline glucose tolerance (●) and the normal glucose tolerance (○) groups. Values are represented as means ± SEM.

able to plasma glucose concentrations during OGTT (P<0.01).

Discussion

This study was designed to investigate the primary changes in impaired glucose tolerance. In order to examine this question, the NGT and the BGT subjects were selected based on the criteria of the Committee on the Diagnosis of Diabetes mellitus of Japan Diabetes Society[10]. The BGT subjects had significantly lower maximal oxygen uptake compared with NGT subjects, while BMI, WHR and the percentage of body fat in the BGT subjects did not differ from those in the NGT subjects significantly. These results thus suggested that decreased physical fitness may be the primary change which induces glucose intolerance.

Table 3 Univariate and stepwise multiple regression analyses with plasma glucose consentrations during OGTT.

	basal glucose	120min
Univariate regression analysis		
Maximal oxygen uptake	r= -0.63(p< 0.01)	r=-0.75 (p<0.001)
WHR	r= 0.50(p= 0.06)	r= 0.64 (p<0.01)
% body fat	r= 0.31 (NS)	r= 0.52 (p<0.05)
Stepwise multiple regression analysis		
Maximal oxygen uptake	p<0.01	p<0.001
WHR	NS	NS
% body fat	NS	NS
Model R^2	0.40	0.56

NS: not significant; WHR: waist-to-hip ratio.

Maximal oxygen uptake in the NGT group was similar to that in previous studies (means: 40.9～44.6, ml·kg^{-1}·min^{-1}) which were measured using the same exercise protocol in the sedentary male subjects who have a normal response to a 75-g oral glucose tolerance[16, 17], while that in the BGT group (32.4ml·kg^{-1}·min^{-1}) seemed to be lower than that of similar aged sedentary subjects. The association between low maximal oxygen uptake and glucose intolerance may be explained as follows: Since the primary sites of glucose disposal after glucose load are peripheral tissues, such as skeletal muscles[9], the differences between two groups on glucose tolerance could be resulted from the ability of glucose uptake in muscles. It is well known that skeletal muscle with excellent capacity of glucose uptake was characterized in an increase in capillary density[18] and glucose transporter protein[19, 20], and enhanced glycogen synthase activity[19], and that muscles consisted primarily of slow-twitch oxidative fibers predominate in these factors compared to that of fast-twitch glycolytic fibers[18, 20]. Magnusson et al.[21] observed that the subjects who had low physical activity indicated lower values of maximal oxygen uptake, capillary density, and aerobic enzyme capacity compared to healthy controls. Therefore

the low values of maximal oxygen uptake in the BGT subjects may suggest deterioration of functional capacity in skeletal muscle for glucose uptake. In the NGT group, six of the seven subjects engaged in habitual exercise, while six of the nine subjects in the BGT group did not perform any exercise. This suggested that maximal oxygen uptake may be influenced by physical activity. Therefore, we thus speculated that low metabolic potential of skeletal muscle, as reflected in the decreased maximal oxygen uptake and/or inactive lifestyle might be primary cause for impaired glucose tolerance.

It has been reported that essential hypertension is associated with resistance to the action of insulin to stimulate glucose uptake in skeletal muscle[22, 23]. Baron et al.[24] demonstrated that attenuated insulin-mediated skeletal muscle blood flow appears to be a major cause of insulin resistance in subjects with elevated mean arterial pressure. Since systolic blood pressure in the BGT group was significantly higher than that of the NGT group, there is a possibility that impairment in the action of insulin to increase skeletal muscle blood flow may result in glucose intolerance. Recently, it has been reported that insulin-stimulated blood flow is positively correlated to maximal oxygen uptake[25]. Overall, metabolic conditions, such as decreased maximal oxygen uptake and elevated blood pressure, may thus induce the dysfunction of glucose tolerance.

Increase in body fat, especially abdominal fat accumulation is associated with glucose intolerance[26, 27]. In the present study, there are no significant differences between the BGT and the NGT group in both the percentage of body fat and WHR. However, the glucose concentration at 120min following glucose load was positively associated with both the percentage of body fat and WHR. The percentage of body fat and WHR were inversely associated with the maximal oxygen uptake, suggesting that these two anthropometric variables-glucose concentration association might be due to an relationship between these two anthropometric variables and the maximal oxygen uptake. Results from stepwise multiple regression analyses showed that maximal oxygen uptake was a significant variable to plasma glucose concentration at 120min following glucose load. We have previously reported that subjects who showed insulin resistance had both lower maximal oxygen uptake and higher fat accumulation[11]. In the present study, the insulin to glucose ratio as an index of insulin resistance was not significantly different between the BGT and the NGT groups, but it is of obvious interest, in view of the effect of fat accumulation on the development of insulin resistance.

In conclusion, our study showed that maximal oxygen uptake was significantly related to plasma glucose concentrations following oral glucose load. These results suggest that decreased maximal oxygen uptake may be at least in part the primary event in the process in the development of impaired glucose tolerance. Furthermore, we speculated that inactive life-style, as reflected in the decreased maximal oxygen uptake, may also deteriorate the capacity for glucose disposal in skeletal muscle.

Acknowledgments

This research was supported in part by a grant from the ONO Sports Science Foundation and a grant from the Ministry of Education, Science, Sports and Culture of Japan (No.06780086).

References

1) DeFronzo RA, Ferrannini E. Insulin resistance: A multifaceted syndrome responsible for NIDDM, obesity, hypertension, dyslipidemia, and atherosclerotic cardiovascular disease. Diabetes Care 1991; **14**: 173-94.
2) Kriska AM, LaPorte RE, Pettitt DJ, Charles MA, Nelson RG, Kuller LH, Bennett PH, Knowler WC. The association of physical activity with obesity, fat distribution and glucose intolerance in Pima Indians. Diabetologia 1993; **36**: 862-9.
3) Pereira MA, Kriska AM, Joswiak ML, Dowse GK, Collins VR, Zimmet PZ, Gareeboo H, Chitson P, Hemraj F, Purran A, Fareed D. Physical inactivity and glucose intolerance in the multiethnic island of Mauritius. Med Sci Sports Exerc 1995; **27**: 1626-34.
4) Eriksson KF, Lindgarde F. Poor physical fitness, and impaired early insulin response but late hyperinsulinaemia, as predictors of NIDDM in middle-aged Swedish men. Diabetologia 1996; **39**: 573-9.
5) Helmrich SP, Ragland DR, Leung RW, Paffenbarger RS. Physical activity and reduced occurrence of non-insulin-dependent diabetes mellitus. N Eng J Med 1991; **325**: 147-52.
6) Sim EAH, Danford E, Horton ES, Bray GA, Glennon JA, Salans LB. Endocrine and metabolic effects of experimental obesity in man. Recent Prog Horm Res 1973; **29**: 457-96.
7) Lindgarde F, Saltin B. Daily physical activity, work capacity and glucose tolerance in lean and obese normoglycaemic middle-aged men. Diabetologia 1981; **20**: 134-8.
8) Marin P, Krotkiewski M, Holm G, Gustafsson C, Bjorntorp P. Effects of acute exercise on insulin and non-insulin-dependent glucose uptake in normal and moderately obese women. Eur J Med 1993; **2**: 199-204.
9) Ferrannini E, Bjorkman O, Reichard GA, Pilo A, Olsson M, Wahren J, DeFronzo RA. The disposal of an oral glucose load in healthy subjects. Diabetes 1985; **34**: 580-8.
10) Kosaka K. Report of the Committee on the Diagnosis of Diabetes mellitus. J Jap Diab Soc 1982; **25**: 859-66. (in Japanese)
11) Higaki Y, Shono N, Nishizumi M. Effects of aerobic capacity and body fat accumulation on the insulin response after an oral glucose load. Jap J Hyg 1997; **52**: 504-10. (in Japanese)
12) Nagamine S, Suzuki S. Anthropometry and body composition of Japanese young men and women. Human Biology 1964; **36**: 8-15.
13) Brozek JFG, Anderson JT, Keys A. Densitometric analysis of body composition: Revision of some quantitative assumptions. Annals of the New York Academy of Sciences 1963; **110**:113-40.
14) Astrand PO, Rodahl K. Textbook of Work Physiology (3rd. ed.). New York: Mcgraw-Hill, 1988.
15) Press WH, Flannery BP, Teukolsky SA, Vetterling WT. Numerical Recipes. New York: Cambridge Univ. Press, 1986.
16) Higaki Y, Kagawa T, Fujitani J, Kiyonaga A, Shindo M, Taniguchi A, Nakai Y, Tokuyama K, Suzuki M, Tanaka H. Effects of a single bout of exercise on glucose effectiveness. J Appl Physiol 1996; **80**: 754-9.
17) Tokuyama K, Higaki Y, Fujitani J, Kiyonaga A, Tanaka H, Shindo M, Fukushima M, Nakai Y, Imura H, Nagata I, Taniguchi A. Intravenous glucose tolerance test-derived glucose effectiveness in physically trained humans. Am J Physiol 1993; **265**: E298-303.
18) Lillioja S, Young AA, Culter CL, Ivy JL, Abbott WGH, Zawadzki JK, Yki-Jarvinen H, Christin L, Secomb TW, Bogardus C. Skeletal muscle capillary density and fiber type are possible determinants of in vivo insulin resistance in man. J Clin Invest 1987; **80**: 415-24.
19) Ebeling P, Bourey R, Koranyi L, Tuominin JA, Groop LC, Henriksson J, Mueckler M, Sovijarvi A, Koivisto V. Mechanism of

enhanced insulin sensitivity in athletes: Increased blood flow, muscle glucose transporter protein (GLUT-4) concentration, and glycogen synthase activity. J Clin Invest 1993; **92**: 1623-31.

20) Houmard JA, Egan PC, Neufer D, Friedman JE, Wheeler WS, Israel RG, Dohm GL. Elevated skeletal muscle glucose transporter levels in exercise-trained middle-aged men. Am J Physiol 1991; **261**: E437-43.
21) Magnusson G, Kaijser L, Rong H, Isberg B, Sylven C, Saltin G. Exercise capacity in heart failure patients: Relative importance of heart and skeletal muscle. Clin Physiol 1996; **16**: 183-95.
22) Natali A, Santoro D, Palombo C, Cerri M, Ghione S, Ferrannini E. Impaired insulin action on skeletal muscle metabolism in essential hypertension. Hypertension 1991; **17**: 170-8.
23) Capaldo B, Lembo G, Napoli R, Rendina V, Albano G, Sacca L, Trimarco B. Skeletal muscle is a primary site of insulin resistance in essential hypertension. Metabolism 1991; **40**: 1320-2.
24) Baron AD, Brechte-Hook G, Johson A, Hardin D. Skeletal muscle blood flow: A possible link between insulin resistance and blood pressure. Hypertension 1993; **21**: 129-35.
25) Utriainen T, Makimattila S, Virkamaki A, Lindholm H, Sovijarvi A, Yki-Jarvinen H. Physical fitness and endothelial function (nitric oxide synthesis) are independent determinants of insulin-stimulated blood flow in normal subjects. J Clin Endocrinol Metab 1996; **81**: 4258-63.
26) Fujioka S, Matsuzawa Y, Tokunaga K, Tarui S. Contribution of intraabdominal fat accumulation to the impairment of glucose and lipid metabolism in human obesity. Metabolism 1987; **36**: 54-9.
27) Krotkiewski M, Bjorntorp P, Sjostrom L, Smith U. Impact of obesity on metabolism in men and women. Importance of regional adipose tissue distribution. J Clin Invest 1983; **72**: 1150-62.

(Received Jun. 10, 1997/Accepted Nov. 18, 1997)