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Does endurance training affect IGF-1/IGFBP-3 and insulin sensitivity in patients with type 2 diabetes?

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***Aim*. The aim of the present study was to determine whether six weeks of submaximal endurance training using a cycle ergometer would result in a modified serum insulin-like growth factor-1 (IGF-1), an insulin-like growth factor binding protein 3 (IGFBP-3), and insulin resistance in middle-aged men with type 2 diabetes (T2D).**

***Methods*. Twenty male patients with T2D voluntarily participated in this study and were randomly divided into two groups: the training group (N.=10) and the control group (N.=10). The training protocol consisted of a 45-minutes cycling session/day, three days/week for six weeks with intensity 60-70% of the maximum heart rate. To examine the IGF-1 and the IGFBP-3, fasting blood glucose levels, and insulin resistance, blood sampling was performed before and immediately after the first and 18th sessions. The homeostatic model assessment (HOMA-IR) method was used to determine insulin resistance.**

***Results*. Before the study began, no significant difference between the two groups was observed in the anthropometric and blood factors. After a session of aerobic exercise, IGF-1 and IGFBP-3 levels were significantly increased (153.79% and 64.3%, respectively), and fasting glucose and insulin resistance levels were significantly decreased (15.82% and 27.82%, respectively); however, the changes resulting from a six-week training period were not significant.**

***Conclusion*. According to the present study, one session of aerobic exercise for middle-aged men with T2D leads to increased IGF-1 and IGFBP-3, and to decreased fasting glucose and insulin resistance. Considering the lack of changes after a six-week training, it seems that the amount of change depends on subjects' fitness level and exercise parameters. From a clinical point of view, the beneficial effects of acute exercise inT2D subjects show that such exercises should be part of the daily program for them.**

KEY WORDS: Diabetes mellitus - Resistance training - Insulin-Like Growth Factor I - Insulin-Like Growth Factor Binding Protein 3 - Insulin resistance.

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The insulin-like growth factor-I (IGF-I) is the main endocrine and paracrine regulator of metabolism and growth.[1] In fact, IGF-1 mediates most of the anabolic effects of the growth hormone (GH) in the target tissues.[2] The IGF-1 has a structure similar to that of insulin. The IGF-1 stimulates insulin-like actions and enhances insulin sensitivity.[3] The liver produces most of the IGF-1 in the circulatory system, and the GH, through a negative feedback mechanism, regulates the IGF-1 levels.[4] In addition to the liver, many extrahepatic tissues synthesize and secrete this factor as well.[5] The circulating IGF-1 is of hepatic origin and acts in an endocrine way, while the extrahepatic IGF-1 acts locally in a paracrine way.[6] More than 99% of the IGF-1 is bound to members of a family of six IGF-binding proteins (IGFBP).[3] In the circulatory system, most of the IGF-1 is present in complexes with the IGFBP-3 and subunits (ALS); this complex prolongs its half-life in plasma and provides IGF-1 storage for the target tissue.[7] The IGFBP-3 concentration, which reflects growth hormone secretion, has been investigated as an appropriate marker for evaluating the growth hor-

mone/IGF-1Axis.[8] The IGFBP-1 is a local modulator of the IGF-1, and production in the liver is inhibited by increasing the insulin level.[9] The IGF-1 is engaged in a wide variety of biological phenomena, including metabolic disorders, such as diabetes, that influence glucose metabolism.[10] Diabetes mellitus is a group of metabolic diseases that occur because of the deficiency of the function or the secretion of insulin, that increases the amount of blood glucose.[11] The hyperglycemia in diabetes causes damage and dysfunction in different organs, including the liver.[12] Diabetes impairs growth and may modify the IGF-1 concentration.[13] Dills *et al.* (1999) have shown that the IGF-1 levels in T2D are 25% lower than those in non-diabetic subjects.[15] Other studies showed that the IGF-1 levels in patients with T2D compared with those of normal subjects are significantly different.[16] The precise mechanisms involved in the decrease in the circulating and hepatic IGF-1 levels are unclear, but may be related to a reduction in the circulating GH levels or in the tissue responsiveness to GH.[12, 13, 17]

The effects of aerobic exercise are well established and the relevant evidence on interrelationships between exercise and metabolic outcomes in healthy subjects well defined.[18] Exercise interventions generally improve glucose homeostasis in diabetics and prevent some damage by increasing the sensitivity and responsiveness to insulin.[18] The circulating levels of the IGF-1 are regulated by the GH and insulin. However, other factors, such as exercise, may potentially affect the IGF-1 levels.[19] Previous studies have examined the effects of exercise training on the IGF-1 and its binding proteins in healthy subjects or in diabetic animals, but, so far, no study has been conducted on patients with T2D.

The effects of exercise and training on the IGF-1and the IGFBP-3 remain not completely understood. The best-studied protein of the IGF system is the IGF-1, which has repeatedly been found to increase after both endurance and resistance training.[9, 21-24] However in some studies, a decrease [25] or an unaltered [26] IGF-1concentration has been reported. The disagreement among these studies is probably explained largely by differences in the subject's training variables, body composition status, age or sex.[22] Most training protocols have resulted in a higher level of IGFBP-3,[27, 28] but this protein is reduced in situations of increased proteolysis (inflammation, under-nutrition, and overtraining). Changes in IGFBP-3 proteolysis are believed to represent a compensatory mechanism inducing the increase of free IGF-1 concentration by lowering IGFBP-3 ligand affinity.[22] Therefore, the aim of the present study was to investigate the effects of six weeks of submaximal endurance training on the plasma IGF-1 and IGFBP-3 concentration, with the control of confounding factors in middle-aged men with T2D.

TABLE 1.—*Clinical and anthropometrical characteristics of the study population.*

	Training group (N.=10)	Control group (N.=10)	Non-diabetic subjects (N.=13)
Age (years)	50.3±4.2	52.1±4.01	52.4±3.09
BMI(kgm^{-2})	28.9±1.7	28.02±1.4	27.9±1.3
Percent Fat(%)	23.5±4.3	22±3.4	22±4.2
HbA_{1c} (%)	6.6±0.7	6.9±0.8	5.4±0.6

Values are the means±SD. BMI: body mass index.

Materials and methods

Subjects

Twenty middle-aged men with T2D, with duration of the disease of diabetes of less than 10 years, voluntarily participated in this study and were randomly divided into two groups: the training group (N.=10) and the control group (N.=10). The study was approved by the committee on research ethics at the institution in which the research was conducted and any informed consent from human subjects was obtained as required.

Participants were matched for age, body mass index (BMI), percent body fat, hemoglobin A_{1C} (HbA1c) level, and physical activity. No patients had a history of hypertension, kidney disease, diabetic foot ulcers, smoking, or using alcohol. No subject exhibited electrocardiogram abnormalities at rest or during a maximal cycle ergometer test, which was performed by a cardiologist. Anders (2003) concluded that besides the anthropometric determinants and physical activity, "*life style habits*" and " t*ype of ethnic population*" could affect the IGF system levels.[29] Hence, the levels of these factors before training among the diabetic and non-diabetic population (Iranian middle-aged men) was compared for evalu-

ation of efficacy of exercise, it was necessary to see how much the values measured in intervention group would close to these norm value of population after training. Thus blood samples were taken from 13 non-diabetic middle-aged men, and the normal value for each variable was obtained for comparison. The characteristics of both T2D groups and non-diabetic subjects are presented in Table I. The T2D subjects in the present study were treated with both metformin (500 mg after 3 meals) and glibenclamide (5 mg before 2 meals) with same doses, but no oral treatments were taken on the morning of the exercise test. To control for the impact of nutrition during the study period, the subjects were given a diabetic diet that they were instructed to follow. The subjects were asked to report any change in medication as soon as possible. Participants who did not cooperate in completing the course of study or experienced medical problems were excluded, the details of study procedures is shown in Figure 1. Informed consent was obtained from all study participants after the nature of and the risks involved in participating in the experiment were explained.

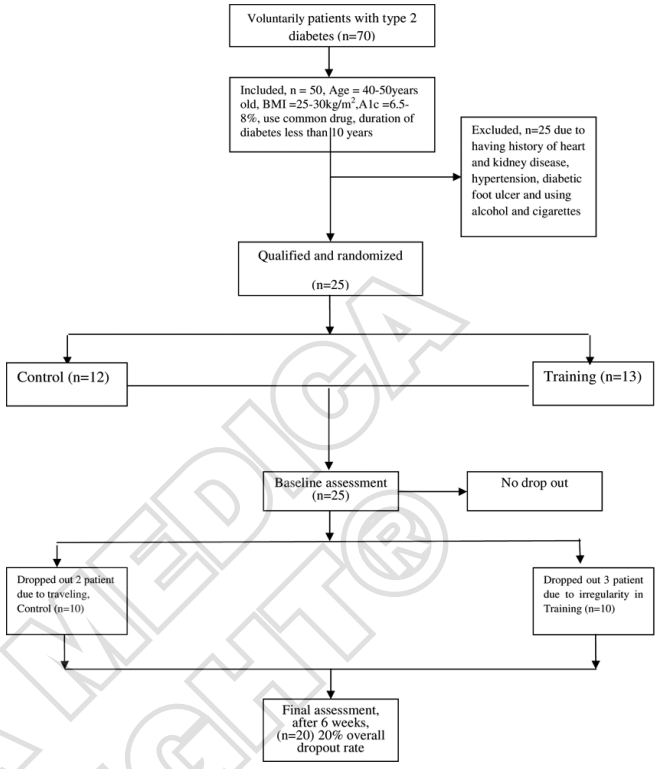

Figure 1.—Flow chart of the study.

Protocol

The most important factor is to design a program for individuals that will provide the proper amount of exercise to attain the maximum benefit at the lowest risk. According to studies on the effects of aerobic exercise on patients with T2D,[17] and with the advice of a cardiologist based on the results of the exercise test, an intensity level equal to 60-70% of the maximum heart rate was selected. The training program consisted of 18 sessions of submaximal aerobic cycling (45min/day, three days/week, for 6 weeks). The progressive exercise protocol was as follows: 1) pedal for 5 minutes at the desired RPM and zero workload; 2) pedal at an RPM of 60 to 70 and constantly increase the workload as long as the person's target heart rate was achieved (HR_{max}=220-Age, HR_{target}=60-70%HR_{max}); 3) pedal for 30 minutes at an RPM of 60 to 70 and a variable workload, so that the heart rate remained in the target range; 4) pedal for 5 minutes at the desired RPM and zero workload. Heart rate was monitored by an experienced nurse throughout the exercise with a heart rate monitor (Bearer PM40). According to the effectiveness of the progressive exercise protocol, in each training session the degree of the resistance cycle ergometer to achieve the target heart rate was increased. As a result, the time needed to reach the target heart rate was gradually increased.

Blood sampling and analyses

To examine IGF-1, IGFBP-3, fasting blood glucose, and insulin resistance levels, blood sampling was done 4 times: before and immediately after the first and 18th sessions of training for diabetics intervention group and before and immediately after the first and 18th sessions of "passing the time" without any intervention for diabetics control group. The passing time in control group was exactly similar to the "training time"(45 minutes) in the intervention group. In 13 weight and age-matched healthy male subjects, blood sampling was done only one time. The subjects were asked to fast overnight before the blood sampling. They entered the laboratory at 8 am and then sat to adapt to the environment. Sampling was placed in cephalic vein at the level of the cubital

TABLE II.—*The pre, post and the mean (±SD) changes in IGF-I, IGFBP-3 glucose and insulin resistance, in the first session of endurance training in diabetics subjects.*

	Pre	Post (First session)	%Mean change	P-value
IGF-1				
Exercise group(N.=10)	5.67±1.28	14.39±2.57	153.79%	P=0.009
Control group(N.=10)	6.6±0.93	7.21±1.07	9.24%	P=0.07
IGFBP-3				
Exercise group(N.=10)	9.33±2.28	15.33±3.3	64.3%	P=0.01
Control group(N.=10)	14.8±3.77	17.01±4.43	14.93%	P=0.2
Glucose				
Exercise group(N.=10)	158±7.2	133±6.8	15.82%	P=0.001
Control group(N.=10)	171±10.6	183±15.3	7.01%	P=0.1
Insulin resistance				
Exercise group(N.=10)	3.45±0.4	2.49±0.4	27.82%	P=0.00
Control group(N.=10)	3.18±1.16	2.88±0.7	9.43%	P=0.5

Exercise group: they were diabetics subjects with endurance exercise training intervention. Control groups: they were diabetics subjects with no intervention.

TABLE III.—*The pre, post and the mean (±SD) changes in IGF-I, IGFBP-3 glucose and insulin resistance, in 18th session of endurance training.*

	Pre	Post (18th session)	Mean change	P-value
IGF-1				
Exercise group(N.=10)	5.89±0.9	10.16±1.08	72.49%	0.008
Control group(N.=10)	7.4±1.1	9.16±1.19	23.7%	0.5
IGFBP-3				
Exercise group(N.=10)	7.21±1.91	14.7±2.66	103.8%	0.03
Control group(N.=10)	12.8±1.5	15.66±3.3	22.34%	0.3
Glucose				
Exercise group(N.=10)	152±8.6	131±6.2	13.8%	0.002
Control group(N.=10)	182±8.37	168±9.24	7.69%	0.1
Insulin resistance				
Exercise group(N.=10)	3.15±0.4	2.17±0.3	31.11%	0.003
Control group(N.=10)	3.33±1.11	3.18±1.03	4.5%	0.9

Exercise group: they were diabetics subjects with endurance exercise training intervention. Control groups: they were diabetics subjects with no intervention.

fossa. After 10 minutes of incubation of the blood samples at room temperature, the serum was separated from clots by centrifugation (10 minutes, 3500 rpm). Serum IGF-1 and IGFBP-3 were measured with a Sandwich Enzyme-linked immunosorbent assay (ELISA) kit (Cusabio Biotech, Wuhan, China). The sensitivity of the assays was 2 and 0.195 ng/mL, respectively. Insulin was measured with a Sandwich ELISA kit (Mercodia, Uppsala, Sweden). The sensitivity was 1 mU/L. Serum glucose was measured using a Colorimetric Enzymatic kit (Parsazmun, Tehran, Iran). The intra assay coefficient of variation percent (CV%) and sensitivity of the assays were 1.3 and 5mg/dL, respectively. The HOMA-IR method was used to measure insulin resistance.

$$\text{HOMA-IR} = \frac{\text{Glucose (mmol/L) x Insulin}}{22.5}$$

Statistical analyses

Statistical analyses of the data were performed by using a statistics software, SPSS version 16. Descriptive statistics of the data are presented as means±SD. For the comparison of different terms and groups, the data were examined using two-way repeated-

TABLE IV.—*The mean (±SD) changes in IGF-I, IGFBP-3, glucose and insulin resistance after 6 weeks training in diabetics subjects.*

	Baseline	6 week	Mean change	P-value
IGF-1				
Exercise group(N.=10)	5.67±1.28	10.16±1.08	79.1%	0.9
Control group(N.=10)	6.6±0.93	9.16±1.19	38.78%	0.3
IGFBP-3				
Exercise group(N.=10)	9.33±2.28	14.7±2.66	57.55%	0.5
Control group(N.=10)	14.8±3.77	15.66±3.3	5.81%	0.6
Glucose				
Exercise group(N.=10)	158±7.2	131±6.2	17%	0.3
Control group(N.=10)	171±10.6	168±9.24	1.75%	0.3
Insulin resistance				
Exercise group(N.=10)	3.45±0.4	2.17±0.3	37.1%	0.4
Control group(N.=10)	3.18±1.16	3.18±1.03	0%	0.8

Baseline: the values of "pre of first session"; 6 week: the values of "pre of 18th session"; mean of changes: the values of "pre of first session" – "pre of 18th session". Exercise group: they were diabetics subjects with endurance exercise training intervention. Control groups: they were diabetics subjects with no intervention.

measures ANOVA, with significant differences assessed by applying the *post hoc* Tukey test. Assumptions of homogeneity and sphericity in the data were checked, and, where appropriate, adjustments in the degrees of freedom for the ANOVA were made. Statistical differences were considered to be significant for $P<0.05$.

Results

Subjects were matched for age, BMI, fat (%), HbA1c, and duration of diabetes (Table I). The baseline serum IGF-1 and IGFBP-3 concentrations were not different between the two groups, but when compared with the values obtained from non-diabetic subjects, they were significantly lower (P=0.009). Comparing the values before and immediately after the first session for the training group indicated that the IGF-1 and the IGFBP-3 increased 153.79% and 64.3% (P=0.009, P=0.01 respectively) (Table II, III). No significant difference was observed in the control group. In first session, the IGF-1 and IGFBP-3 levels ranged respectively, from 5.67±1.38 to 14.39±2.57, and from 9.33±2.28 to 15.33±3.3, which were a little closer to those obtained from healthy subjects (35±4.8 and 48.2±5.45, respectively). Also, comparing the values before and immediately after the 18th session for the training group indicated that the IGF-1and the IGFBP-3 increased, 72.49% and 103.88%, respectively, (P=0.008, P=0.03). No significant difference was observed in the diabetic control group.

In 18 sessions, the IGF-1 and IGFBP-3 levels ranged, respectively, from 5.89±0.09 to 10.16±1.08, and from 7.21±1.91 to 14.7±2.6, which were a little closer to those obtained from healthy subjects (35±4.8 and 48.2±5.45, respectively). But comparing the values of the IGF-1 and the IGFBP-3 before the first session with those before the 18th session indicate that the six-weeks training effect or the lasting effect of training was not significant (P=0.8, P=0.5).

Before intervention, the baseline fasting values for serum glucose and insulin resistance were not different in the two groups.

Comparing the values before and immediately after the first session for the training group indicated that fasting glucose and insulin resistance decreased, 15.82% and 27.82%, respectively (P=0.001, P=0.00) (Table II). No significant difference was observed in the control group. In first session, fasting glucose and insulin resistance levels ranged, respectively, from 158±7.2 to 133±6.8, and from 3.45±0.4 to 2.49±0.4. Also, comparing the values before and immediately after the 18th session for the training group indicated that glucose and insulin resistance decreased, respectively, 13.81% and 31.11% (P=0.002, P=0.002) (Table III). No significant difference was observed in the control group.

In the 18th session, fasting glucose and insulin resistance levels ranged, respectively, from 152±8.6 to 131±6.2, and from 3.15±0.4 to 2.17±0.3. But comparing the values of glucose and insulin resistance

after six weeks of training (before the 18th session — before the first session) was not significant (P=0.3, P=0.4) (Table IV). As well as in the present study, an improvement in the patients' fitness was shown by the decrease (8.7%) in systolic blood pressure and (3.7%) diastolic blood pressure, and a significant increase 20.8% (P=0.01) in the degree of the resistance cycle ergometer and 40.4% (P=0.04) in the time to achieve the target heart rate. Thus, our results very likely reflect the effectiveness of training. Regular exercise improves metabolic control in diabetic animals and humans, and is an important component in the treatment of diabetes mellitus.[25, 26]

Discussion

For many years, physical activity, along with diet and medication, has been considered to be basic in the treatment of diabetes. Based on numerous large, randomized, controlled trials, physical activity and exercise have recently been recommended to prevent and treat diabetes, according to the Americans With Disabilities Act (ADA), the American College of Sports Medicine (ACSM), and other national guidelines.[18] Based on the results of present study, one session of aerobic exercise led to an increase in the IGF-1 and theIGFBP-3, and a decrease in fasting glucose and insulin resistance in patients with T2D. However, changes resulting from a six-week training period were not significant.

Most previous studies that assessed the effects of training on the IGF axis in non-diabetic subjects suggested that training could increase the IGF-1 and improve glucose disposal.[9, 21] Recently, Gomes [13] and Leme,[30] who examined the effects of training on the IGF-1 in diabetic rats current study, investigated for the first time the effects of acute and long-term training on the IGF-1 and the IGFBP-3 in patients with T2D. This current study tried to match all possible confusing factors, such as age, gender, BMI, nutritional status, drug regime, and levels of physical activity. In the training group, the subjects, in addition to following the dietary guidelines and the drug regime, performed exercise with the same intensity and volume. The diabetic control group did not exercise at that time and just followed their medication and diet guidelines.

In addition to the liver, which is responsible for producing large amounts of the IGF-1, a small amount of the IGF-1was produced in the type 2 fibers of skeletal muscles in response to mechanical loading, even in the absence of the stimulation of the GH and in the type 1 fibers through the stimulation of the GH.[31, 32] The IGFBP-3 is a marker of physical fitness [22] and taken to be an integrated index of GH action.[33] The effects of exercise and training on the IGF-I and the IGFBP-3 remain incompletely understood. The best-studied protein of this system is the IGF-1, which has repeatedly been found to increase after endurance and resistance training;[9, 21-24] however, some studies have reported a decrease [25] or no change [26] in the IGF-1 after training. Most training protocols in non-diabetic subjects have resulted in a higher level of IGFBP-3.[9, 27, 28] However, several studies [21, 23] have reported conflicting results that are caused by differences in the age of participants or in training status (intensity and duration). Our results show that one session of aerobic exercise led to an increase in the IGF-1 and the IGFBP-3 (P<0.05) (Tables II, III), while the changes resulting from a six-week training period were not significant (Table IV), which could be caused by the low-intensity training.

Rezai *et al.* have indicated a significant increase in the IGF-1 in response to one session of exercise in healthy male subjects.[34] The increased levels of the IGF-1 after exercise were consistent with the results of Schwarz and Gomes.[35, 36] Therefore, given the GH response following exercise, and considering the IGF-1-dependent response to the GH and the independent of the GH in response to the mechanical loads after exercise, IGF-1increased, even with a session exercise that was expected. Contrary to the results of Manetta,[9] there were no long-lasting changes in the IGF-1 and the IGFBP-3. Indeed, this revealed that compared with prolonged, acute exercise training has a stronger effect on the levels of the IGF-1and the IGFBP-3. As the results of the first and 18th sessions, a significant increase in the IGF-1 and the IGFBP-3 were observed. Despite this positive effect of acute training on these parameters, these changes yet are lower than norm value, that it can emphasize the IGF axis impairment in these patients. In this context, the appropriate exercise program is unknown. After 15 weeks/three days a week of aerobic exercise, it could get significant changes in the IGF-1 and the IGFBP-3 in postmenopausal women with breast cancer.[37] Whereas these increases in the IGF axis are transient and typically return to the baseline level,[25] it is logical that these changes disappeared in the serum after the termination of the exercise. Maybe with increasing the duration

and intensity of endurance training, we could get statistically significant results, after exercise training, on the IGF-1 and the IGFBP-3. Given that in previous studies, subjects were healthy [22] or professional athletes,[28] exercise was performed at a high intensity. However, in this study, because participants were diabetics who had no history of professional sports activities, high-intensity exercise was not possible. Indeed, the long-lasting effect of training could not have cumulative effects on improving the responses in subjects with T2D. Plasma volume correction was not calculated in all groups after training, and it could be considered a common effect. However, based on the Anders study,[29, 38] the effect of plasma volume correction was around 7%, but the changes in glucose and insulin were 16% and 21.5%, respectively. Thus, it can be called into question whether or not correction for plasma volume is advisable in this context. It is worth noting that this study examined the changes in the systematic IGF-1 level and that changes in local production were not assessed; therefore, this study could not capture the potential effect of exercise on the IGF-1 changes at the tissue level. So far, studies on the effect of exercise on the IGF-1and IGFBP-3 levels in people with T2D have not been done, and studies in this field were performed on animal models. Perhaps to take advantage of the beneficial effects of exercise, diabetic patients should have exercise as a regular part of the daily program.

It has been proved that blood glucose in diabetic patients is reduced by a single bout of exercise [39] and by training.[40] In this study, comparing fasting blood glucose and insulin resistance levels before and after the first and18th sessions, it showed a significant decrease that indicates the acute effect of exercise on blood glucose and insulin resistance in these patients. But when we examined the lasting effect of training (before the 18th session and before the first session), results showed no significant change. In the present study, the acute effect of exercise resulted in a significant decrease in fasting glucose and insulin resistance in patients with T2D. In line with this study, the blood glucose and insulin sensitivity were not significant after 15 weeks of training for postmenopausal women with breast cancer.[37]It seem that these two factors were transient and typically returned to the baseline level after the patients ended exercise. Consistent with this conclusion, many studies have also suggested that the improvement in glucose uptake by insulin after exercise training was due to the effect of the last session of exercise.[41, 42]

Since the subjects in both groups used the same drug regimen and diet under the supervision of an endocrinologist and nutritionist, the changes in fasting glucose levels in the training group can be attributed to the exercise training. Previous studies have also shown that exercise training decreases serum glucose in diabetic animals and humans.[30, 40] Most of the blood glucose uptake in response to insulin occurs because of skeletal muscle, so it seems that this improvement is caused by adaptations when exercise is induced in muscles.[43] The benefits of exercise in reducing blood glucose levels in patients with T2D are due to improved muscle blood flow (capillary recruitment) and increased GLUT4 (an form of the glucose transporter in skeletal muscle) translocation.[44] It seems that the mechanism by which exercise may lead to an increase is insulin responsiveness. The relation between exercise and increase in muscle insulin sensitivity is established as well by Holloszy *et al*.[45] The basic mechanisms for increasing muscle insulin sensitivity have not been proven, but some evidence proposes that it may be mediated by the enhanced insulin signaling pathway at different molecular levels, especially through the insulin receptor substrate (IRS)/phosphoinositol-3 (PI3)-kinas pathway associated with the activation of glucose transport and glycogen synthesis in muscles.[46]

The IGF-1 could be involved in insulin sensitivity. IGF-1 binds to insulin receptors, stimulates insulin-like actions, and increases insulin sensitivity. The direct effects of the IGF-1 are stimulating glucose transport, particularly in skeletal muscle cells. However, because the circulating IGF-1 binds to high-affinity binding proteins and has less ability to bind to insulin receptors, thus, indirectly through the suppression of the GH, it increases the ability of insulin to suppress liver gluconeogenesis.[3] In the present study, the increased serum IGF-1 through exercise training may have contributed to increased insulin sensitivity. In studies conducted in non-diabetic subjects, a positive correlation between the IGFBP-1 and insulin sensitivity,[9, 24] and a negative correlation between the IGFBP-1 and a fasting insulin level have been demonstrated.[9] In this study, for reasons of limitation, the serum IGFBP-1 concentration was not examined, and future studies are needed to clarify the relationship between the IGFBP-1 concentration and insulin sensitivity in diabetic subjects after endurance training in T2D subjects.

Conclusions

According to the present study, a single bout of exercise increases the IGF-1 and the IGFBP-3, and decreases the fasting blood glucose and insulin resistance. Thus, it can be assumed that performing exercise as regular physical activity by patients with T2D can be more effective from a clinical point of view. However, this hypothesis will require further investigation because of the absence of changes induced by a six-week training,

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