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Comparative effects of aerobic training and whole body vibration on plasma adiponectin and insulin resistance in type 2 diabetic men

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ABSTRACT

Background: *Aerobic exercise has been identified as a specific and the main strategy in the treatment of patients with type 2 diabetes. However, some of diabetic patients have difficulties doing such exercise. Recently, the use of whole body vibration exercise has been recommended as a passive method for these patients. The main objective of the present study was to compare the effects of aerobic exercise and whole body vibration on glycemic control in type 2 diabetes men.* ***Materials and methods:*** *Thirty male diabetic patients were selected and randomly assigned in three groups each of ten persons: aerobic exercise, whole body vibration exercise and control group. Aerobic exercise program included three sessions of 30-60 minute walking weekly, with saved 60-70 percent of maximal heart rate. Whole body vibration exercise included 8-12 minute exercise sessions in standup position and semi squat positions, with 30 Hz frequency and amplitude of 2 mm, three times a week. No intervention was implemented for the subjects in the control group. Fasting concentrations of fasting blood sugar, insulin and plasma adiponectin were measured at the beginning, and after the 4th and 8th weeks of the study. The obtained data were analyzed by two-way analyses of variance with repeated measurements, with time and group as independent variables.* ***Results:*** *After 8 weeks of training, plasma adiponectin and insulin resistance did not change significantly in any of the groups ($P>0.05$). While there were significant changes within each exercise group ($P<0.05$), no significant difference was observed between the effects of aerobic exercise and whole body vibration on the above-mentioned two variables ($P>0.05$).*
Conclusion: *The findings indicated the same effects of the two training methods. The stimulation of metabolic system by whole body vibration was the same as aerobic exercise. Therefore, it may be recommended that the type 2 diabetics who, for any reason, are not able to perform aerobic exercise can enjoy the benefits of vibration exercises.*

Keywords: plasma adiponectin, insulin resistance, whole body vibration, aerobic exercise

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INTRODUCTION

One of the most important investigational principles in modern exercise physiology in order to treat and control diabetes mellitus is to evaluate metabolic responses to different exercise methods such as vibration. The most prominent prerequisite for reaching this goal is to acquire minute knowledge about mechanical and biochemical relations and the intensity of such an exercise in one hand, and intracellular adaptive responses formed in molecular level during the exercise in the other hand. In a study on metabolic effect of vibration exercise compared to aerobic exercise (considered as the main strategy to treat type 2 diabetics) on relevant variables of diabetes mellitus, whole body vibration has been found to less time consuming and a greater number of patients could participate in this program [1]. Therefore, it can be predicted that this method is more applicable in more passive patients. The individuals under vibration exercise have been reported to undergo higher levels of mechanic stimulation than those under daily activities[2]. Also, vibration has been shown to result in increased gravity load of >14g [3]. On the other hand, nearly all body muscles are recruited in this training method [2] while other methods employ only 40-60 percent of body muscles. By means of stimulating tendons and muscles, vibration exercise activates muscle spindles leading to muscular contraction, namely "tonic vibration reflection". Tonic vibration reflection has been reported to activate greater numbers of motor neurons and muscle spindles and consequently, increase activation of motor units leading to increased muscle power[4]. As a result of this muscular contractions, permeability of myocytes' membranes to glucose increases leading to insulin-like effect arisen from the muscle contraction[5].

Type-2 diabetes occurs mainly because body is unable to either produce sufficient insulin or to make use of produced insulin. So, when body doesn't respond suitably to insulin, a disorder called "resistance to insulin" or "insensitivity to insulin" occurs. At the cellular level, excessive circulating insulin appears to be a contributing factor in insulin resistance via down-regulation of insulin receptors [6]. This disorder leads to impaired consumption and storage of carbohydrates, increased blood sugar, stimulation of hyperinsulinemy, and consequently, overweight and obesity. Eighty percent of type 2 diabetic patients have been shown to be obese. In this case, a group of secreted peptides from fat tissue, namely adipocytokines, which are attributed to obesity, affect metabolism of glucose and lipid [7]. Compared to other adipocytokines, plasma adiponectin decreases over obesity and resistance to insulin [8]. Also, adiponectin levels in the circulation have been reported to be negatively related to fat percentage resistance to insulin, and type-2 diabetes [9].

A narrow spectrum of literature has been devoted to metabolic effects of vibration exercise on diabetes markers. To the authors' knowledge, there has been no study to evaluate the effects of vibration exercise on resistance to insulin and plasma adiponectin levels in such patients. So, the present study was performed to find whether whole body vibration, as a novel method, is effective on resistance level to insulin and plasma adiponectin in type 2 diabetic patients, as compared with aerobic exercise.

MATERIALS AND METHODS

Subjects:
Thirty type 2 diabetic males (without any history of chronic or acute diabetic complications and fasting blood sugar levels of <250 mg/dl) volunteered to participate in the study. They were informed of the purposes and methods of the study before providing written consent. The experimental protocol received approval from the local IA University, Central Tehran Branch ethics committee. The participants were randomly assigned to one of three groups, including aerobic exercise (AE), whole body vibration (WBV), and control (C). Table 1 shows the general characteristics of the subjects based on which it is clear that the studied groups have been homogeneous at the beginning of the research period.

Table1. General characteristics of the subjects

	Aerobic training	Vibration	Control	*F*	*P*
Age (year)*	53.10±6.57	49.20±3.94	52.30±6.17	*1.31*	*0.285*
Weight (kg)	82.24±12.33	75±10.92	76.43±9.22	*3.08*	*0.062*
Height (cm)	172.60±8.14	168.40±5.44	165.60±4.99	*1.31*	*0.285*

* *The data are given based on mean values ± standard deviations.*

Physiological assays:
Body Mass Index (BMI) of the subjects was measured via dividing weight (kg) by square height (m). Body fat percentage was also estimated using a caliper (Harpenden, CEO120, England) and Siri formula [10]. Maximum oxygen consumption (VO2max) was estimated through one-mile track walk test [11] to assess aerobic power using thoracic heartbeat-meter.

Aerobic exercise protocols:
Subjects in aerobic exercise (AE) group (n=10) participated in an 8-week progressively increasing aerobic exercise program with 3 sessions per week. The subjects exercised for 30 min (5 min running with 60-70% of stock heartbeat and 5 min active rest with 30-45% of reserved heart rate), 42 min (7 min running with 60-70% of reserved heart rate and 7 min active rest with 30-45% of reserved heart rate), and 60 min (10 min running with 60-70% of reserved heart rate and 10 min active rest with 30-45% of reserved heart rate) from the first to the third week, the fourth to the sixth week, and the seventh to the eighth week, respectively. Training sessions comprised warming up (stretching, turning joints, and gagging), the main program (aerobic running), and cooling down (stretching and gagging) phases. In order to prevent hypoglycemia and thirst, the subjects were asked to drink 100 ml water before onset of the exercise and to carry syrup (containing 5% sugar). All exercise sessions were performed in 50-70 min (ml/kg/min).

Whole body vibration
Patients in whole body vibration (WBV) group (n=10) also participated in an 8-week increasing exercise program with 3 sessions every week. Each exercise session was performed through the frequency of 30 Hz and the amplitude of 2 mm. The subjects stood on a whole body vibrator (Star Sport, Taiwan) and were vibrated in a 110° squat positioning (the degree was adjusted using a goniometer). The subjects exercised for 16 min (1 min vibration with 8 iterations and 1 min breaks between consecutive iterations), 20 min, and 24 min from the first to the third week, the fourth to the sixth week, and the seventh to the eighth week, respectively. It should be noted

that the control subjects were asked to do their routine activities and to participate only in biochemical and physiological assays.

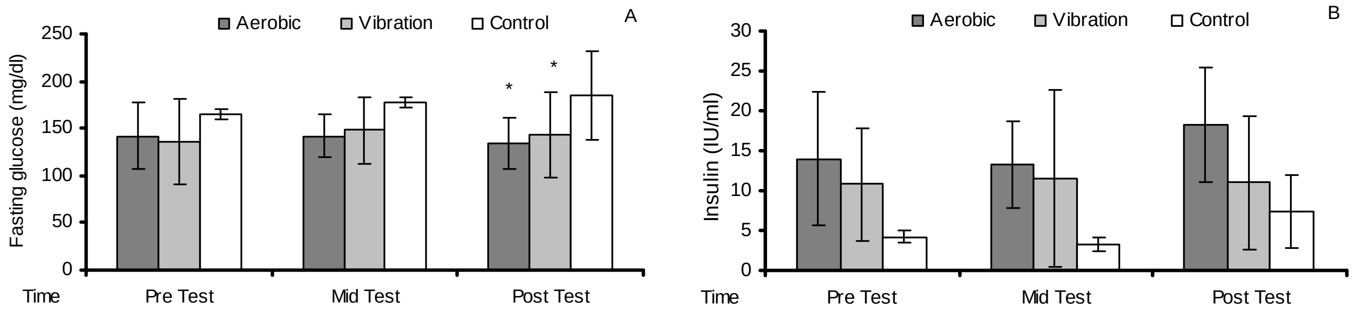
Blood Sampling:
In order to evaluate adiponectin, glucose, and insulin levels, 10 CC blood was drawn from anti-cubital vein in a time less than 1 min following bandaging with tourniquet in a sitting position after 12 hour fasting at the beginning of the trial (pre-test), at the end of the fourth week (mid-test), and at the end of the eighth week (post-test). Three CC of the obtained plasma was frozen of each sample at -80°C to be analyzed at the end of exercise period in order to measure plasma adiponectin level. All samples were obtained at 8 A.M. Subjects were asked to avoid any physical activity, except for daily routine activities, 24 hours before blood drawing.

Biochemical assays:
Concentrations of adiponectin, insulin, and glucose were measured through ELIZA method (using adiponectin kit, Biovendor Company, Italy with internal measurement degree of 6/4 and sensitivity degree of 26 ng/ml), ELISA method (using insulin kit, Diametra Company, Italy with internal measurement degree of 2% and sensitivity degree of 2 µlU/ml), and GOD Photometric Method (using glucose kit, Pars Azmoon Company, Iran with internal measurement degree of 1.28 and sensitivity degree of 5 mg/dl), respectively. After measuring fasting levels of insulin and glucose, resistance to glucose was measured through homeostasis measurement of resistance to glucose (HOMA-R) and using fasting levels of glucose and insulin in order to find resistance to insulin in type 2 diabetic patients.

Statistical analysis
Two-way analyses of variance (ANOVAs) were adopted to analyze simultaneous changes in the groups and measurement times (interactive effect of time and group, considering time as iteration). The mean values of each blood index were compared in different times between the groups. For this end, variance analyses of iterative values and Bonferroni tests were adopted. Then, variance homogeneity was assessed through Lon tests. Variance analyses and Tukey tests (if necessary) were used in the case of homogeneity. Otherwise, Welch tests were used to compare the group simultaneously and also Games-Howell (if necessary) were adopted for binary test of mean values of the groups. In order to assess the effect of the groups in mid-test and post-test regarding ununiformed basic values, covariance analyses and Bonferroni tests were adopted based on modified mean values. Significance level was considered to be $p \leq 0.05$ for all tests. All the statistical analyses were performed using SPSS Software edition 13.

RESULTS

Eight weeks of aerobic exercise had a significant effect on VO2max ($F=31.19$, $P<0.001$) so that VO2max increased significantly after 4 weeks of exercise compared to the beginning of the trial ($P=0.006$). This increasing trend continued until the end of the eighth week so that VO2max after eight weeks ($P=0.000$) was higher than that of pre-test ($P=0.01$) and mid-test ($P=0.01$) (during the second four weeks, $P=0.010$). Vibration exercise showed no significant effect on VO2max ($P>0.05$).



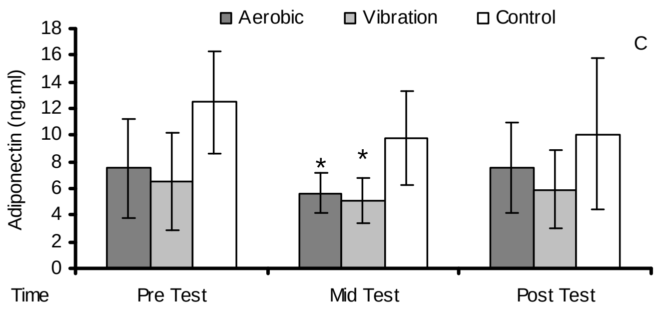


Fig.1 Concentrations of fasting glucose (mg/dl) (A), insulin (U/ml); (B) and Adiponedtin (ng.ml) at Pre, Mid and Post test in Aerobic, Vibration and control groups.* Denotes statistical differences from Control group. Values are mean ± Std.

Through comparing the groups, it was evident that the differences of VO2max among the groups were significant (F=4.06, P=0.029). Covariance analysis with adjustment on basic values showed that there were no significant differences in VO2max among the groups after 4 weeks (F=0.11, P=0.890) and 8 weeks (F=1.62, P=0.217) of training.

After 8 weeks of aerobic and vibration exercise, BMI and fat percentage of the subjects were measured and compared among the groups and in three different times and no significant differences were found among group (P>0.05) (Table 2).

Table2. Changes of physiological variables during study period. Data are expressed as mean ± standard deviation.

	Aerobic			Vibration				Control	
	Pre Test	Mid Test	Post Test	Pre Test	Mid Test	Post Test	Pre Test	Mid Test	Post Test
$Vo_{2max(ml.kg.min)}$	28.30±8.41	29.64±.52*	31.62±2.73*	31.26±2.22	32.8±2.48	39.63±4.93	37.52±5.35	38.8±6.21	39.47±5.56
BF (%)	6.61±2.46	7.52±1.2	7.03±1.17	7.18±2.36	7.48±2.43	7.03±1.17	9.53±2.23	9.63±2.18	9.68±2.32
BMI	28.43±4	27.45±2.55	27.23±2.49	26.48±3.62	26.76±3.42	26.79±3.09	27.78±3.16	27.91±3.21	28.16±3.06

* *Denotes statistical differences from Pre test.*

Eight weeks of aerobic exercise and vibration exercise had no significant effect on fasting glucose level (F=1.03, P=0.364). The results obtained from the comparison of groups showed that in the beginning of the period (F=1.05, P=0.364) and after 4 weeks (P=0.261), there was no significant difference in fasting glucose level among the groups. However, after 8 weeks, fasting glucose levels in AE and WBV groups were significantly lower than that of control group (P<0.05). No significant difference was seen between AE and WBV groups, though (P>0.05) (Fig 1, Panel A). Also, 8 weeks of aerobic exercise (F=3.50, P=0.079) and vibration exercise (F=0.041, P=0.960) had no significant effect on insulin level. Comparison of insulin levels in the groups showed a significant difference in the beginning of the period (F=12.24, P=0.002. However, there were no significant differences after 4 weeks (F=1.013 and P=0.377) and 8 weeks (F=1.01, P=0.377) (Fig 1, Panel B).

Eight weeks of aerobic exercise (F=2.80, P=0.125) and vibration exercise (F=2.71, P=0.093) had no significant influence on plasma adiponectin level. Comparison of plasma adiponectin levels among the groups showed that on the basis of covariance analysis with adjustment on basic values, the difference in the beginning of the period (F=7.38, P=0.003) was significant. However, on the basis of Bonferroni tests, although there was no significant difference between AE and WBV groups (P=0.877) after 4 weeks (F=2.71, P=0.085), significant differences were found between control and AE groups (P=0.046) and also between control and WBV groups (P=0.044). After 8 weeks, no significant differences were found among the groups (F=0.330, P=0.722) (Fig1, Panel C).

DISCUSSION

Plasma adiponectin levels in the present study showed no significant variations in between and within group assessments. Although the variable has insignificantly decreased in control (21.7%), AE (24.50%), and WBV (21.23%) groups after the first 4 weeks. It was also insignificantly increased in the second 4 weeks (3.27%, 33.69%, and 15.23%, respectively). Despite insignificant decrease in plasma adiponectin after 8 weeks in control (19.14%) and vibration (9.23%) groups, it was reverse in AE group and increased very insignificantly (0.93%). However, despite insignificant differences between AE and WBV groups in within group comparison, there were significant differences in comparison of these groups with control group.

Unlike other adipocytokines, adiponectin levels decrease in obese diabetic patients[8,12]. Diabetic and non-diabetic subgroups have been reported to have higher difference in adiponectin concentration relative to BMI [13] which can reflect the fact that diabetes mellitus is more associated with lower adiponectin production relative to obesity. On the other hand, some studies have shown that the variations in blood adiponectin level is reversely related to body fat percentage and its positive effects are owing to lower body weight and increased muscular mass [14,15]. Japanese studies, also showed that plasma adiponectin level is reversely and significantly attributed to BMI and that plasma adiponectin levels in obese people are higher than those of thin people [16]. An alternative assumption is that lower metabolism actions of adipocytes occur at the same time with their hypertrophy [17].

Mitochondria biogenesis has been recently reported to increase during separation. The number of mitochondria, however, decreases in adipocytes of obese rats db/db. This indicates that mitochondria biogenesis may strongly need adipose separation (metabolic activities) and adipocyte hypertrophy may result in decreased number of mitochondria[18].

The size of separated cells will decrease with higher numbers of mitochondria which is due to increased oxidation of fatty acids and lower accumulation of intracellular triglycerides. Authors have postulated that adiponectin synthesis levels increase in small fat cells[19] which springs from higher performance of mitochondria. On the contrary, in hypertrophied fat cells, adiponectin synthesis decreases due to impaired activity of mitochondria. In the present study, the lack of significant decrease in BMI and BF% was accompanied by the lack of significant increase in adiponectin level in both groups. In AE group, it is consistent with the results of previous studies [20,21]. Insignificant variations of BMI and BF% in this study may arise from no observed glycemic and lipidemic options in the foods used by the subjects due to dissimilar nutritional program. While obese individuals follow a high glycemic and lipidemic nutritional program and get obese and because obesity brings about impaired performance of mitochondria, defective circle irritates and dysfunction of mitochondria halts increased adiponectin synthesis. While plasma adiponectin levels in the three groups of the present study have not experienced any significant variation, fat biosynthesis, did not decrease which is shown by insignificant variation of BMI and hypodermic fat and body weights of the subjects. On the other hand, the results of the present study are not consistent with those of some other investigations which designated the effect of aerobic exercise on highly increased plasma adiponectin level [22,23,24]. In a review study on the effects of exercising on adiponectin concentration, Kraemer et al. (2007) suggested that intensity of exercise may affect adiponectin response so that long and intense exercise affects adiponectin level [25]. Despite insignificant difference in plasma adiponectin level among the groups of the present study and high (but insignificant) increase in plasma adiponectin level in AE (33.69%) and WBV (15.23%) groups compared to control group (3.27%) in second 4 weeks in comparison with the first 4 weeks, longer term of exercise in the second 4 weeks may affect the variations.

Impaired performance of mitochondria, one of the main organelles causing ROS oxidative stress, due to obesity can bring about decreased synthesis of adiponectin with increased ROS production [26]. During muscle contraction, calcium translocation and protein folding in endoplasmic reticulum with close contact with mitochondria require ATP and on the other hand, impaired performance of mitochondria in hypertrophied adipocyte results in endoplasmic reticulum stress leading to decrease in some adiponectin translocation reactions. Also, in diabetes where lack of glucose and hypoxia evacuate ATP of cell stimulate endoplasmic reticulum stress [18]. Endoplasmic reticulum stress in the present study due to the lack of glucose, also, might have prevented significant variations of adiponectin in various stages of exercise among the groups. However, highly increased VO2max in both exercise groups might have ceased the effect of hypoxia as one of stimulators of ER stress. This may be more evident via high (but insignificant) increase in plasma adiponectin of the groups in the second 4 weeks compared to the first 4 weeks.

Lower numbers of GLUT4 for any reason leads to its lower activity so that glucose cannot find its way into target tissues of type 2 diabetics. This increases blood glucose level higher than that of normal statue leading to stimulation of pancreas and secretion of insulin and consequently, to hyperinsulinemy[27] which is accompanied by resistance to insulin. Thus, oxidative stress can be considered as one of the factors promoting resistance to insulin. Although resistance to insulin increased insignificantly in all the groups after 8 weeks, this increase in WBV group (1.37%) was very low and remissible compared to AE (21.29%) and control (97.04%) groups. On the other hand, despite high (but insignificant) decrease of resistance to insulin in WBV group (11.24%) compared to high (but insignificant) increase in AE group (30.45%) in the second 4 weeks, vibration exercise may be postulated to be more effective in decreasing oxidative stress and consequently, decreasing resistance to insulin compared to aerobic exercise.

Yamauchi et al. (2001) showed that induction of obesity through increased consumption of fatty foods decreases expression and blood adiponectin levels and consequently, brings about resistance to insulin [9]. This means that adiponectin leads to lower resistance to insulin in type 2 diabetics with obesity and reduces basic level of blood glucose which springs from lower glucose produced in liver and other body cells. One of the most prominent circumstances about effect of adiponectin on reduction of glucose level is that this hormone halts hepatic glucose production via reductive regulation of key enzymes of gluconeogenesis process such as phspoenolpyruvate, carboxykinase, and glucose 6-phosphatas. This amplifies the effects of insulin [9,28,29]. Bluher et al. reported significant increase in blood adiponectin level after 4 weeks of aerobic exercise as a consequence of increased sensitivity to insulin [30]. This is not consistent with our findings in the second 4 weeks of aerobic exercise because insignificant increase in resistance to insulin can be seen despite insignificant increase in adiponectin level. The findings of the present study suggest that there is no causality between this hormone and resistance to insulin in AE group.

However, there is a very slight and insignificant causality in WBV group in the second 4 weeks compared to the first 4 weeks which can be due to adaptation of body to the exercise or improved performance of mitochondria leading to increased adiponectin level. This may bring about lower oxidative stress in one hand, and lower glucose level and higher performance of insulin and consequently, lower resistance to insulin on the other hand.

Increased resistance to insulin at the fourth and eighth weeks of vibration exercise can be justified by this fact that mechanical properties of vibration can be considered as a convenient stimulator for secretion of the special hormone in addition to providing effects of sense reflection. Previous studies stress the interaction between deep? receptors and hormonal responses. Glucocorticoids, thyroid hormones, growth hormone, and angiotensin II result in impaired tolerance of glucose and resistance insulin. For instance, adjustment of avran hypophyseal axis of a muscle has been reported to affect biological measurement of secretion of growth hormone after activities of special muscles exposed to vibration [31]. Bosco et al. (2000), also reported increased growth hormone after 10 minutes of vibration [3]. Because increased blood glucose, the most important regulating factor of insulin secretion, is a metabolic consequence of growth hormone, the observed increased growth hormone in the present study may bring about increased glucose and higher insulin secretion leading to increased resistance to insulin.

Finally, considering high (but insignificant) variations of indices of both exercise methods, volume (intensity and time) of each exercise might not be enough to make significant differences. On the other hand, insignificant statistical results in the present study may be attributable to small sample size leading to lower statistical power.
In conclusion, considering insignificant differences between AE and WBV groups in between-group comparisons of the present study, whole body vibration exercise can be considered to have identical effects on plasma adiponectin level and resistance to insulin as aerobic exercise does.

However, vibration exercise, thank to exposing body to whole body vibration in standstill situation, can be used as a convenient training method for the diabetic patients suffering from obesity due to their passive lifestyles and shorter exercising time (Baum et al, 2007).

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