Effects of Vibration vs. Resistive Exercise on Endothelial Function in Type 2 Diabetic Women

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ABSTRACT

The main etiology for mortality and morbidity in patients with diabetes mellitus is atherosclerosis. A hypothesis for the initial lesion of atherosclerosis is endothelial dysfunction; which has been documented in patients with type 2 diabetes. Exercise is often recommended for patients with type 2 diabetes to improve physical conditioning and glycemic control. The aim of the current study was to investigate the effects of vibration exercise versus resistive training program on endothelial function, and glycemic control in T2DM. Forty obese type 2 diabetic women, free from respiratory, kidney, liver, metabolic and neurological disorders, were selected for this study. The patients' age ranged from 42 to 58 years, and body mass index (BMI) ranging from 31 to 35 kg/m2. The subjects were divided into two equal groups: group I received vibration exercise training. Group II received resisted exercise training; they did that three times a week for 12-weeks. The mean values of glycosylated hemoglobin (HBA1c), nitric oxide levels (NOx) and flow mediated dilatation (FMD) 8.55%, 24.1±8.4 mol/L and 4.45±2.2% respectively before the study and they showed significant difference in both groups after training. Also, there was a significant difference between the groups after treatment on all measured variables. It is suggested that in obese type 2 diabetic patients, vibration exercise may be more effective and low time consuming tool to enhance endothelial function and glycemic control than is resisted exercise training.

Keywords: *Diabetes, Vibration exercise, Resistance training, Endothelial function; HbA1c.*

INTRODUCTION

The main etiology for death and for a great percent of morbidity in patients with diabetes (type 1 or type 2) is vascular disease[1]. The endothelium is a thin layer of cells at the internal surface of blood vessels; it regulates vascular tension and maintains structure. The function of the vessel walls and interactions with adjacent blood components are included, and are endocrine organs that play important physiological roles[2]. Endothelial dysfunction has been recognized as the early event and the common feature of chronic disorders associated with increased risk for atherosclerotic heart diseases[3]. The endothelial dysfunction that is measured by flow-mediated dilation (FMD) and accompanies a number of cardiovascular disease states including hypertension, diabetes, chronic heart failure, and atherosclerosis. Regular exercise increases the numbers of smooth muscle cells and endothelial cells, expands aortic vessels, and increases arterial diameter. Smooth muscle cells and endothelial cells promote differentiation, and increases in the number of capillaries contribute to favorable outcomes in vasculature[4]. Evidence is emerging to support a role for improved nitric oxide bioavailability with training as a result of enhanced synthesis and reduced oxidative stress-mediated destruction[5].

Strength training also became an established treatment in that world-wide spreading metabolic disease[6]. However, till today only a negligible amount of patients take advantage of any sport activity. There are some reasons to explain that phenomenon, one of the most important may be that nearly all patients are obese and follow a lifelong sedentary life style. Obviously, these patients can hardly be motivated for longer lasting physical activities[7]. Vibration exercise is a new and effective measure to prevent muscular atrophy and osteoporosis[8]. It is assumed that vibrations with amplitude of 2 to 6 mm and a frequency of 20 to 30 Hz evoke muscle contractions probably induced via the monosynaptic stretch reflex[9]. Compared to traditional training regimes, VE needs significant less time and, therefore, can be expected to reach a higher compliance in previously inactive patients[10].

When Cohen et al.,[11] studied the effects of a 14-month progressive resistance exercise program (75% to 85% 1RM, 3 sets, 8 reps) on obese subjects with T2DM, they also reported improvements in endothelial function. In contrast, Wycherley et al.,[12] performed a 12-week study involving a combination of exercise and dietary therapy on T2DM subjects, and also reported no change in endothelial function. Middle brooke et al.,[13] also conducted a 6-month aerobic exercise study on T2DM subjects, and reported no significant change in vascular endothelial function. Thus, the results of studies on the effects of exercise on endothelial function in T2DM subjects are varied. In the present study we investigated the influence of a 12 weeks vibration- exercise period on glycated hemoglobin and endothelial cell function in type 2 obese diabetes patients. The results were compared to a group performing resistance exercise.

RESEARCH DESIGN AND METHODS

Subjects characteristics and general experimental design

Study subjects

Forty obese type 2 diabetic women were selected randomly from the Cairo University Hospital. . The patients' age ranged from 42 to 58 years, and body mass index (BMI) from 31 to 35 kg/m2. The patients were diagnosed as type 2 diabetes, non insulin dependant, and not regularly involved in sport activities. All patients were under oral medication, drug dosages were maintained throughout the study. Subjects were excluded if they suffered from retinopathy or other medical problems which did not allow for participating in vibration exercises or strength training (acute thrombosis, acute inflammation, acute tendinopathy, fresh fractures, gallstones, implants (pacemaker, breast implant, buttock implant, screws, pins, pumps, wires), recent surgery, acute hernia, acute discopathy, acute migraine, fresh wound/scar, epilepsy, total knee replacement, total hip replacement, infectious disease, uncontrolled diabetes, neuromuscular disease, and osteoporosis).

Evaluated parameters

Metrics and measurement methods

Anthropometric measurements

Before the study, and after the 12-week study period, the height and weight of the subjects were measured with the subjects wearing only thin gowns. BMI was then calculated by dividing weight (kg) by height squared (m2). Waist circumference was measured at the narrowest point between the bottom of the ribs and the top of the iliac crest using a tape measure after the subject had exhaled comfortably[16].

Chemical analysis

Before and three to four days after the training period, subjects entered the laboratory after 12 h fasting. HbA1C levels were determined by a HPLC-System (Tosoh G7, Eurogenics) from a blood sample taken from the antecubital vein[17].

Endothelial cell function test

Measurement of flow-mediated dilatation of the brachial artery

To eliminate effects from the tests, the subjects maintained a fasting state for 10 hours during the examination, and were also instructed not to consume alcohol, caffeine, or smoke. Measurements were made based on the examination method recommended by Celermajer et al.,[18] using the guidelines reported by Corretti et al.,[19]. The diameter of the brachial artery will be assessed using a high-resolution ultrasound device (Siemens SG-60, USA), equipped with a 7.5 MHz linear array transducer and an integrated electrocardiography package. The ultrasound procedures will be performed with the subject resting quietly in supine position for at least 10 minutes. All measurements will be taken at end-diastole triggered by electrocardiogram. First, the diameter of the right brachial artery will be searched in a cross-sectional view and then scanned over a longitudinal section 5 to 10 cm proximal to the right elbow. The diameter of the brachial artery will be measured from the anterior to the posterior intima/ lumen interface at a fixed distance. The mean diameter will be calculated from 4 cardiac cycles. After that, a pneumatic tourniquet placed around the right forearm will be rapidly inflated to at least 50 mm Hg above the systolic blood pressure for 5 minutes. A sudden release of the cuff will induce an increase in blood flow in the brachial artery located proximal to the tourniquet. During reactive hyperemia, there will be an increase in shear stress, causing endothelium-dependent vasodilatation, mainly due to endothelial release of nitric oxide. This secondary dilation enhances and prolongs the reactive hyperaemic phase. FMD of the brachial artery will be measured 45-60 s after cuff release. The change in diameter caused by the increased flow will be calculated as the percentage change relative to the baseline measurement (FMD %). The dilator brachial artery response due to shear stress has been shown to have a good accuracy and reproducibility[20].

Biomarkers of the endothelial function. Measurement of the NO in serum:

Subjects were prescribed with low nitrite/ nitrate diets (no spinach, beets or cured meats, the most ample sources of alimentary nitrite and nitrate) for 24 hours before the test day. All medications which can influence the test were discontinued 1-3 days before the test. Each patient underwent antecubital vein cannulation for the collection of plasma samples. Samples for NO determination were collected before (basal) and immediately after cessation of exercise. Blood samples were collected in EDTA tubes and centrifuged immediately at 1000x g (30 min). Plasma were placed in 0.5-1 ml portions into Eppendorf tubes and kept at – 20 ºC until used. The Griess reaction was used for the measurement of plasma nitrite (NO2-) and nitrate (NO3-) concentrations (NOx), two end products of nitric oxide metabolism as the half life of NO is very short. Specifically, NO3 was reduced to NO2 by 0.1U nitrate reductase, 5x10–6 mol/l flavin adenine dinucleotide and 250x10–6 NADPH. The samples were incubated at 37 ºC for 3 h, then 8.8U lactic dehydrogenase and 10–2 mol/l pyruvate was added, and the samples were incubated for an additional 90 min at 37 ºC. Finally the Griess reaction was added to each well, and the samples were read at 540nm. Results are given as mol/L[22].

Patients were randomly divided into two groups: Group I: a vibration training group, group II: strength training group. They trained for 12 weeks at three days per week. All sessions were supervised and participation assessed. All patients were free to withdraw from the study at any time. A written consent form was obtained from them before participating in the study. If any adverse effects had occurred, the experiment would have been stopped and the Human Subjects Review Board would have been informed. However, no adverse effects occurred, and so the data of all the patients were available for analysis. The detailed training regimen was as follows:

Vibration exercise

Patients were asked to remain in a standing position on a whole body vibration device. The purpose built device produced a synchronous vibration. All patients were instructed to stand on the vibration platform with their feet shoulder width apart, knees locked, and hands by their side to receive maximum vibration exposure, the protocol was performed with patients' shoes removed to prevent any attenuation of vibration that may result from footwear. Subjects exercised on a horizontal swinging platform with an amplitude of 2 mm (Vibrogym Professional©). Vibration frequency was set to 30 Hz from weeks 1 to 9 and to 35 Hz during the last three weeks. Subjects were encouraged to work isometricaly against the swinging platform. The number of sets was identical with the strength training regimen. It took about 20 minutes to fulfill a training session[10].

Strength training

Commercially available weight machines (Conex© multiform) were used for strengthening muscle groups of the upper and lower body. Eight stations were included in each session, e.g. leg extension, seated leg flexion, leg press, seated calf raise, lat pulley, horizontal chest press, butterfly, and rowing. Subjects performed dynamic contractions with intermittent relaxations after each concentric-eccentric phase in order avoid critical blood pressure responses. The subjects were in-structed to start with a 10-minute warm-up, perform 40 minutes of resistance training, and cool-down for 10 minutes. After familiarization with the correct movements, the one repetition maximum (1RM) was established prior to the training period. During the first six weeks of training, 1 set with 12 repetitions at 70 % of 1 RM was performed. From week 7 to 9 volume was increased by an additional set. In weeks 10 to 12, 3 sets with 10 repetitions at 80 % of 1 RM were realized[14,15].

Statistical Analysis

The mean values of HBA1c, NOx levels (mol/L), and FMD obtained before and after three months in both groups were compared using the paired "t" test. An independent "t" test was used for the comparison between the two groups ($P < 0.05$).

RESULTS

The study involved forty obese type 2 diabetic women. Their age ranged from 42 to 58 years and the mean duration of diabetes mellitus of both groups was 5.6±3.9 years. The subjects were divided into two equal groups: the first group (I) received vibration exercise training. The second group (II) received resisted exercise training three times a week for 12- weeks in order to compare the effect of vibration and resisted exercise intensity on glycated hemoglobin (HBA1c), nitric oxide levels (NOx) and flow mediated dilatation(FMD) in obese type 2 diabetic women. (Table 1) represented non significance difference between both groups. The mean values of HBA1c, NOx and FMD were significantly decreased from7.86±0.4, 24±8.4, 4.5±1.6 to 6.44±0.3, 28.8±11.8, 6.4±1.9 respectively, in group I and from 7.88±0.4, 24.2 ±8.44.9±2.5 to 6.84±0.3, 27.1 ±11.8, 6.1 ±2.8 respectively, in group II (Tables 2 and3). Also, there was a significant difference between the groups after treatment (Table 4). So, it can be concluded that both vibration exercise and resistance exercise have a positive effect on glycemic control and endothelium function but vibration exercise training was more appropriate than resistive exercise training.

Table (1): Clinical characteristics of study subjects of both groups at baseline.

Characteristic	VEG group I (n=20)	REG group II (n=20)	P value
Age, yr	50.5±8.6	51.3±6.1	0.720
DM duration, yr	6.6±6.7	4.6±2.7	0.889
Weight, kg	82.2±7.3	81.8±4.6	0.639
BMI, kg/m2	33.7±2.6	33.6±2.1	0.407
Waist, cm	90.4±6.0	92.8±4.8	0.480
HbA1c, %	7.86±0.4	7.88±0.4	0.770
NOx levels (mol/L)	24 ±8.4	24.2 ±8.4	0.307
FMD %	4.5±1.9	4.9±2.5	0.964

VEG, Vibration exercise group; REG, resistance exercise group; DM, diabetes mellitus; BMI, body mass index; HbA1c, glycosylated hemoglobin; NOx levels , nitric oxide levels and FMD, flow-mediated vasodilatation.

Table (2): Mean value and significance of HbA1c, NOx levels (mol/L), and FMD in group I before and after treatment.

Value	Mean ±SD		t value	P- value
	Before	After		
HbA1c, %	7.86±0.4	6.44±0.3	5.2	.006
NOx levels (mol/L)	24 ±8.4	28.8 ±11.8	4.5	.001
FMD, %	4.5±1.6	6.4±1.9	4.451	.002

HbA1c, glycosylated hemoglobin; NOx levels, nitric oxide levels and FMD, flow-mediated vasodilatation

Table (3): Mean value and significance of HbA1c, NOx levels (mol/L), and FMD in group II before and after treatment.

Value	Mean ±SD		t value	P- value
	Before	After		
HbA1c, %	7.88±0.4	6.84±0.3	3.3	.032
NOx levels (mol/L)	24.2 ±8.4	27.1 ±11.8	2.437	.038
FMD, %	4.9±2.5	6.1±2.8	2.941	.016

Table (4): Mean value and significance of, NOx levels (mol/L), and FMD in group I and group II after treatment.

Value	Mean ±SD		t value	P- value
	Group I	Group II		
HbA1c, %	6.44±0.3	6.84±0.3	3.52	0.034
NOx levels (mol/L)	28.8 ±11.8	27.1 ±11.8	3.548	0.076
FMD, %	6.4±1.9	6.1±2.8	2.726	0.012

DISCUSSION

There has been only limited research on the effects of vibration exercise on endothelial function in individuals with type 2 diabetes. The aim of this study was to compare changes in HbA1c, NOx levels and FMD after vibration and resistance exercise training in obese type 2 diabetic women. The mean values of HbA1c, NOx levels and FMD were significantly decreased in both group I and group II. Also, there was a significant difference between the groups after treatment. This means that in obese type 2 diabetic patients vibration exercise is appropriate for improving endothelium function as well as is resisted exercise training.

Plasma volume in muscle increases during exercise and the nitric oxide produced in endothelial cells plays an important role in vasodilatation. Leukocytes and monocytes prevent things from attaching to the blood vessel walls and interfering with the interaction between platelets and the blood vessel walls. The permeability of endothelial cells is then reduced, and the proliferation of vascular smooth muscle cells is blocked, causing a reduction in intensity from the blood vessels. Endothelial cell dysfunction accompanies aging, and as cardiovascular disease risk factors become accelerated and physical activity decreases, atherosclerosis is exacerbated. Aging is also accompanied by T2DM, dyslipidemia, hypertension, and endothelial cell dysfunction in obese subjects[22]. In this study, changes in glycated hemoglobin and endothelial cell function were seen as a result of vibration and resistance exercise.

Bweir et al.,[23] reported that the group receiving resistance exercises had a significantly lower HbA1c level than the group receiving the treadmill intervention at the end of 10 weeks ($P < 0.006$), these findings are in agreement with Cauza et al.,[24] showing a greater improvement in blood glucose control following 4 months of strength training as opposed to endurance exercise. Given that the etiology of type 2 diabetes consists of insulin resistance within skeletal muscle, perhaps it is not surprising that resistance exercises had more of a positive effect on glucose control than aerobic exercise. Resistance exercises have been shown to have a significant impact on insulin sensitivity in people with type 2 diabetes[25]. Caution should be noted as not all resistance training appears to be beneficial. Training program using resistance exercise bands was not sufficient to improve glycemic control[26]. We report a decrease of HbA1c levels over the course of a 12 week vibration and resistance training program. More in line with our study, Christos et al.,[27] showed a reduction of HbA1c levels with 4 months of combined exercise. Our large drop in percentage points is likely due to the fact that the subjects enrolled in this study had baseline HbA1c levels that were dramatically higher than those reported in the other studies.

The current study show an improvement in endothelial function after vibration and resistance exercise, this come in agreement with study performed by Hwi et al.,[20] for 12 weeks at a maximum intensity of 40% to 50% 1RM, and resulted in some improvement to endothelial cell function. In contrast Cohen et al.,[11] conducted a resistance exercise study on obese T2DM subjects in which progressive resistance exercise (75% to 85% 1RM, 3 sets, 8 reps) was employed. No significant change in endothelial cell function was observed after 2 months; however, after 14 months they reported an improvement in endothelial cell function.

Rittweger et al.[28] conducted VE was performed in two sessions, with a 26 Hz vibration on a ground plate, in combination with squatting plus additional load (40% of body weight. Thus, VE can be well controlled in terms of these parameters. Surprisingly, an itching erythema was found in about half of the individuals, and an increase in cutaneous blood flow (SBF) hence improvement in endothelial function.

Sackner & Adams[29] reported a descent in the dicrotic notch, similar to the effects of active exercise, from periodic acceleration. This cardiovascular change may be due to a significant increase in circulating NO concentrations resulting in vasodilatation of resistant blood vessels. The underlying mechanism for the significant increase in the skin blood flow (SBF) following vibration may be due to pulsatile endothelial stress resulting in increased circulating NO concentration as a result of increased eNOS activity. Findings in the current study showed improvement in NO in both groups combined with the findings of Sackner & Adams in an older Population with circulatory pathology provides evidence of the efficacy of clinical application of vibration as an intervention in populations where aerobic exercise is contraindicated or is not feasible.

A logical explanation for endothelial function improvement after vibration exercise might be that the mechanical vibration forces on the endothelial cells have their effect due to friction at a cellular level. Another vibration study concluded that the increased blood flow (SBF) was due to significant increases in nitric oxide (NO). Increased NO produced by an increase in endothelial NO synthase (eNOS) due to increased NOS messenger RNA expression and eNOS promoter as a direct function of pulsatile sheer mechanical forces to the endothelium[30].

Everett et al.,[31] reported that despite the short term reduction in skin blood flow (SBF) following isometric exercise, the benefits of vibration exercise program to the cardiovascular system are well documented including : 1) endothelium-dependent vasodilatation , 2) bone density, 3) physical fitness , and 4) muscle hypertrophy . During active exercise blood flow is directed away from areas where it is not immediately needed and redirected to areas where it is needed. When short duration, high intensity demands are placed on the human musculoskeletal system; blood is shunted away from organs, including the integumentary system, and redirected to the musculature.

Hutcheson & Griffith[32] reported that the peak response of endothelium derived NO was 250–360 cycles per minute (4.17–6.00 Hz); however, a good response was provided at 180–210 cycles per minute (3.00–3.60 Hz).

The principal new finding of this study was that vibration exercise training improved indices of endothelial function in patients with type 2 diabetes. These findings suggest that resistance and conduit vessel vasodilator function are enhanced by exercise training in type 2 diabetic patients. This adaptation appears to be predominantly endothelium dependent, although other mechanisms, such as increased smooth muscle sensitivity to NO or structural changes, cannot be ruled out[33].

The beneficial effects of an exercise program on vascular function probably relate to increasing flow and shear stress on the endothelium, although general metabolic effects may also contribute. There is evidence that FMD in conduit vessels is largely dependent on endothelial release of NO, as is resistance vessel dilation and hence exercise-induced hyperemia. Experimentally, repeated exercise induces a sustained increase in endothelial NO-synthase, implying chronic adaptation of the NO-vasodilator system. It might be expected that an increase in shear stress would not only result from increased blood flow but also from other hemodynamic variables such as increased HR and blood pressure, as well as metabolic effects that would be imposed throughout the vasculature[34,35].

Conclusion

In summary, both vibration and resistance exercise protocols were effective in reducing HbA1c levels and improving endothelial function but vibration exercise produced a more significant reduction in HbA1c level as compared to resistance exercise. Since the time to treat is far beyond traditional training forms, patients without any affinity to traditional sports activities may prefer vibration training as a part of an intended lifestyle modification. It was proposed that an optimal exercise program for individuals with diabetes should include a vibration training component to be effective in improving the overall endothelial function, and thus reduces the risk for long term diabetic complications in type 2 diabetes.

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الملخص العربي

مقارنة تأثير التمارين الاهتزازية وتمارين المقاومة على وظيفة الغشاء المبطن لجدار الاوعية الدموية في السيدات مرضى السكري النوع الثاني

ان السبب الرئيسي للوفاة في المرضى المصابين بمرض السكري هو تصلب الشرايين وينتج ذلك عن الخلل الوظيفي في الغشاء المبطن لجدار الاوعية الدموية . ولذا قد تم توثيق هذا الخلل في المرضى المصابين بمرض السكري من النوع الثاني وكثيرا ما يوصى بممارسة التمارين لمرضى السكري النوع الثاني لتحسين القدرة الفيزيائية ونسبة السكر في الدم. أجريت هذه الدراسة لاختبار دور برنامج التمارين الاهتزازية مقارنة ببرنامج تمارين المقاومه على وظيفة ا الغشاء المبطن لجدار الاوعية الدموية ونسبة التحكم في السكر في الاناث المصابه بمرضى السكري النوع الثاني . تمت هذه الدراسة على 40 سيدة مصابه بالسكري النوع الثاني وتتراوح اعمارهم من 42 الى 58 سنة ومعدل كتلة الجسم من 31-35 كجم/م2 وقد تم تقسيمهم عشوائيا إلى مجموعتين متساويتين في العدد . تلقى المرضى في المجموعة الأولي برنامج علاج طبيعي من التمارين الاهتزازيه و تم علاج المجموعة الثانية بتمارين المقاومه ثلاث مرات اسبوعيا لمدة 12 اسبوع لكلتا المجموعتين . وقد تم قياس جلايكوز الهيموجلوبين ومستوى اكسيد النيتريك في الدم ومستوى تدفق الدم في الشرايين قبل وبعد ثلاثة اشهر ووجد فروق ذات دلالة احصائية عند مقارنة النتائج المسجلة قبل وبعد ثلاثة شهورفي جلايكوز الهيموجلوبين و مستوى اكسيد النيتريك في الدم ومستوى تدفق الدم من برنامج العلاج الطبيعى في كلا الفريقين هذا ويوصى باستخدام التمارين الاهتزازيه حيث انها تحتاج لوقت ومجهود أقل من تمارين المقاومة في تحسين وظيفه الغشاء المبطن لجدار الاوعية الدموية والتحكم في نسبة السكر في الدم .

الكلمات الدالة : مرض السكري- التمارين الاهتزازيه- تمارين المقاومة – وظيفة الغشاء المبطن لجدار الاوعية الدموية - جلايكوز الهيموجلوبين .