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The Impact of Upper Limb Resistance Training Intervention on the Arterial Stiffness Among Patients with Type 2 Diabetes Mellitus

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Published: 25 September 2012

Ibnosina J Med BS 2012,4(5):183-191

Received: 13 July 2011

Accepted: 12 July 2012

This article is available from: <http://www.ijmbs.org>

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Abstract

Objectives: To determine the risk benefits of moderate intensity resistance training of upper limbs in type 2 diabetes mellitus patients using augmentation index as a measure of arterial stiffness. **Patients and Methods:** Twenty middle aged individuals (40-60 years) with type 2 diabetes mellitus volunteered to participate. They were assigned to two groups: an upper limb training group 51.0±6.3 years old and a sedentary group 53.7±3.1 years. The upper limb group performed 12 weeks of moderate intensity resistance training (3 days/week). **Results:** Fasting blood glucose decreased from 135±23 to 118±23 mg/dl, total cholesterol decreased from 191±14 mg/dl to 174±11 mg/dl, serum triglyceride decreased from 168±21 mg/dl to 149±23 mg/dl ($p<0.001$), high density lipoprotein increased from 51.8±4.05 mg/dl to 56.3±4.0 mg/dl ($p<0.001$) and glycosylated hemoglobin decreased from 9.3±0.8% to 8.3±0.6% ($p<0.001$) in upper limb resistance training group. The resting heart rate was increased from 78±6 bpm to 84±9 bpm ($p<0.01$) and the systolic blood pressure was increased from 122±2 mmHg

to 132±35 mmHg ($p<0.01$) and diastolic blood pressure was increased from 81±3 mmHg to 93±6 mmHg ($p<0.001$) in upper limb resistance training group. Upper limb group also showed significant increase in augmentation index (1.9±2.5 to 5.2±2.4 mmHg, $p<0.001$) and decrease in heart rate variability (17±6 to 11.6±3.5 msec; $p<0.001$). **Conclusion:** Upper limb resistance training may lead to increase in arterial stiffness in patients with type 2 diabetes mellitus. Whereas, aerobic upper limb activity could offset the increase in stiffness caused by resistance training.

Key words: upper limb resistance training, arterial stiffness, augmentation index, heart rate variability, type 2 diabetes mellitus.

Introduction

Regular physical activity is an intervention that can improve health of individuals with diabetes particularly individuals with type 2 diabetes. Lack of physical activity may cause coronary heart disease via increased adiposity,

reduced lean body mass, reduced cardiovascular fitness (1), raised blood pressure (2), decreased glucose tolerance and lowered insulin sensitivity (3). These cardiovascular complications often caused due to atherosclerotic vascular disease (4), make the patients with type 2 diabetes mellitus (T2DM) prone to heart failure (5,6). Aerobic exercises have been shown to improve glucose control, enhance insulin sensitivity and reduce cardiovascular risk factors such as visceral adiposity, lipid profile, arterial stiffness and endothelial function (7). However, many older patients with type 2 diabetes are unable to participate in the aerobic activities due to the presence of diabetic complications or certain coexisting conditions such as obesity, degenerative arthritis or cardiovascular disease (8). As resistance training is also known to enhance insulin sensitivity, daily energy expenditure and quality of life similar to aerobic exercise (7), it has been recognized as a therapeutic tool in the treatment of number of chronic diseases in elderly and obese individuals. Furthermore, resistance training has the potential for increasing muscle strength (9-11), lean muscle mass (12), and bone mineral density (13,14) which could enhance functional status and glycemic control and assist in the prevention of sarcopenia and osteoporosis. There is a debate regarding the effects of resistance training on the physiological parameters like arterial stiffness. It is recommended that the intensity of training and the type of subjects be selected carefully as acute resistance training has been proved to increase arterial stiffness in young healthy men (15,16) though in other studies moderate intensity resistance training showed no increase in arterial stiffness in middle aged women (17). Increased arterial stiffness, a marker of risk of future cardiovascular events (18) is associated with increase in mortality in patients with end stage renal failure and essential hypertension (19) Therefore, it is of paramount importance to undertake the prevention and treatment of arterial stiffness. Arm exercises leads to an increase in arterial pressure, heart rate, total peripheral resistance (20) and arterial stiffness (21,22), whereas, leg resistance training decreases arterial stiffness (23) and suppresses the increase of arterial stiffness (24). Augmentation index is described as a measure of central arterial stiffness (25,26) and peripheral vascular disease state (27). Low heart rate variability, a marker of autonomic function, is related to an increase risk of mortality (28) and may lead to incident coronary heart disease, myocardial infarction and sudden cardiac death (29-31). Considering the widely proposed benefits and the contradictory reports of an increase in arterial stiffness by resistance training, the present study was devised with view to firstly, investigating

the risk benefits of moderate intensity resistance training of upper limb using augmentation index as a measure of arterial stiffness and secondly to examine the changes in the metabolic profile, body mass index, glycemic control and cardiovascular profile in middle aged individuals suffering from type 2 diabetes.

Patients and Methods

A case control experimental design with a sample size of 20 participants with T2DM for more than 1 year duration. Age range was 40-60 years with an inactive life style and undergone no strength training in the preceding one year. Individuals with subjective or objective evidence of coronary artery disease, uncontrolled hypertension, advanced retinopathy or with any severe respiratory, cardiovascular or orthopedic condition restricting physical activity were excluded. The participants were following their prescribed diabetes medication. The participants were equally assigned to two groups: upper limb training group and sedentary group (control group). Measurements were taken before training and at the end of the 12 weeks of training as described below:

Anthropometry: Body weight was measured to the nearest 0.1 kg using weighing machine (Acto inc., India) and height to the nearest 0.25 cm using anthropometric rod. Body mass index (BMI) was determined by body weight and height as kg/m^2 .

Glycemic and metabolic outcomes: Plasma glycosylated hemoglobin (HbA1c) concentration was the main outcome for glycemic control. HbA1c was analyzed using Nycocard HbA1C test (nycocard reader II). Fasting blood glucose levels were measured using glucometer (Elegance CTX 10). Serum total cholesterol, HDL (high density lipoprotein) cholesterol and triglyceride levels were measured by Minitechno's Semi Automatic Analyzer using standard procedures.

Arterial stiffness: Systolic and diastolic blood pressure was measured using Lifecare™ Sphygmomanometer (N & B Medical Products Co., India).

Heart rate variability (HRV), augmentation index (Ai), resting heart rate (RHR) and healthy heart index (HHI) were recorded using pulse analysis system by Vacumed (version 1.01 beta). A 1 minute reading was taken through finger placement with participant resting in supine position after resting for 5 minutes, strictly following the guidelines

from the manual (manual no. Y79100).

Strength testing: 1 repetition maximum was calculated using Brzynecki's equation after performing 10 repetitions warm up with low resistance.

Training program: Moderate intensity resistance training supervised by a certified physiotherapist was conducted for 12 weeks (3 days/week). The exercise intervention in upper limb group performed Biceps Curls, Triceps Curls, Chest Press, Shoulder Press and Lat Pull Down (22, 32). The sedentary group did not undergo any strength training. The load was set to be 60% of 1 RM at the start of the training and increased gradually. The training was conducted with three sets of ten repetitions with an interset rest of 2 minute and was performed for 60 minutes (33). 1RM (repetition maximum) was noted after every four weeks to set a new load for training.

Statistical analysis: The data are presented as mean \pm SD. The data was analyzed with SPSS 17.0 (Scientific Packages for Social Sciences, Inc., Chicago, IL, USA). Data was analyzed by independent t test for inter group comparison. Intra group comparison was done using related t test. Findings were considered significant at $p < 0.05$.

Results

Changes in physical characteristics and body Weight

Table 1 shows changes in physical characteristics and BMI for both the groups. There were no significant differences seen in physical characteristics and BMI after training in both the groups.

Changes in cardiovascular indices

Table 1 shows the t-values of the paired t test for cardiovascular indices of both the groups. There was a significant increase in resting heart rate ($p < 0.01$), systolic ($p < 0.01$) and diastolic blood pressure ($p < 0.001$) after training and significant decrease in healthy heart index ($p < 0.05$) after training in upper limb training group. There were no significant changes seen in the sedentary group. Independent t test showed significant differences in systolic ($p < 0.05$) and diastolic ($p < 0.05$) blood pressure between the groups.

Changes in glycemic control and metabolic risk factor

Table 2 shows the t-values of the paired t test and changes in glycemic control and metabolic risk factors before and after training. There were significant changes ($p < 0.001$)

in fasting blood glucose, glycosylated hemoglobin (HbA1C), total cholesterol, serum triglyceride and high density lipoprotein in the upper limb training group. There were no significant changes seen in the sedentary group. Independent t test showed significant differences in fasting blood glucose ($p < 0.05$), HbA1C ($p < 0.05$) and serum triglyceride ($p < 0.05$) between the groups.

Changes in augmentation index

Figure 1 shows changes in augmentation index in the two groups before and after training. There were three readings taken at the time of measuring changes in the augmentation index and out of the three readings the mean was considered the final reading. There were significant changes observed in the upper limb training group. In upper limb training group, augmentation index increased significantly ($t = 7.06$; $p < 0.001$) from 1.9 ± 2.5 mmHg to 5.2 ± 2.4 mmHg after training. No significant changes were seen in the sedentary group. There was a significant difference noted in augmentation index between the groups with independent t test. Interaction was $t = 2.49$; $p < 0.05$.

Change in heart rate variability Figure 2 shows changes in heart rate variability in the two groups before and after training. Upper limb training group showed significant ($t = 6.08$; $p < 0.001$) decrease in heart rate variability from 16.8 ± 5.1 msec to 11.6 ± 3.4 msec after training. No significant changes were observed in heart rate variability in sedentary group. There was no significant difference seen in heart rate variability between the groups with independent t test.

Discussion

The objective of this study was to analyze the effect of upper limb moderate intensity progressive resistance training on arterial stiffness of patients suffering from type 2 diabetes mellitus. After 12 weeks of resistance training, fasting blood glucose decreased from 135 ± 23 mg/dl to 118 ± 23 mg/dl with training group closing the normal range of 70-100 mg/dl and glycosylated hemoglobin (HbA1C) decreased 10.6% in upper limb training group closing the normal level ranging from 4 to 5.9. With upper limb training, total cholesterol decreased by 9.14%, serum triglyceride decreased by 11.5% and HDL increased by 8.6%. There were beneficial changes seen in the metabolic (total cholesterol, serum triglyceride and high density lipoprotein) and glycemic (fasting blood glucose and glycosylated hemoglobin) profile in upper limb training group. Shenoy et al. (32) studied Indian population

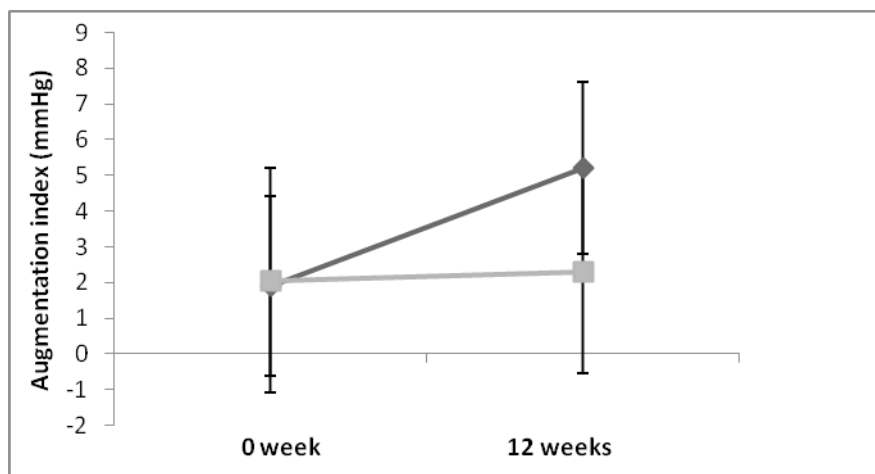
Table 1. Intra group comparison of physical characteristics and cardiovascular indices before and after training.				
Variables	Upper limb group (n=10) (m=8; f=2)	Interaction	Sedentary group (n=10) (m=7;f=3)	Interaction
Age (years)	51±6.2		53.7±3.1	
Height (cm)	165.3±10.4		167.5±4.5	
Duration of diabetes (yr)	5.7 ±2.5		6.3 ± 2.2	
Weight (kg)				
Before	75.1±9.3	t=1.8	79.01±15.9	t=1.8
After	75.1±9.3	p=0.102	80.3±14.5	p=0.104
BMI (kg/m²)				
Before	27.8±4.7	t=1.8	27.9±3.6	t=1.9
After	27.3±4.4	p=0.101	28.4±3.1	p=0.095
Resting Heart Rate (bpm)				
Before	77.8±6.3	t=5.3	85.4±12.02	t=0.9
After	83.4±8.7	p=0.001	84.9±12.7	p=0.397
Healthy Heart Index				
Before	86.7±6.7	t=2.3	79.02±9.7	t=1.9
After	78.05±9.4	p=0.044	79.9±9.6	p=0.095
Systolic BP (mmHg)				
Before	122.3±2.3	t=4.24	126.3±5.7	t=1.5
After	132.5±35.4	p=0.002	125±6.1	p=0.164
Diastolic BP (mmHg)				
Before	81.2±2.7	t=6.3	84.5±4.5	t=0.00
After	92.6±5.5	p=0.000	84.5±6.6	p=1.00
BMI: body mass index; BP: blood pressure; values are mean±SD				

showing better changes in total cholesterol and triglyceride levels with resistance training than with aerobic training in middle aged type 2 diabetes patients. Resistance training

leads to increase in skeletal muscle mass which is related to decrease in HbA1C (33-36) by augmenting the skeletal muscle storage of glucose and improving the glycemic

Table 2. Glycaemic control and metabolic risk factor before and after training.

Variables	Upper limb group	Interaction	Sedentary group	Interaction
Number (M; F)	8; 2	-	7, 3	-
Fasting Glucose				
Before	135.4±22.8	t=5.5	152±35.7	t=0.7
After	118.4±22.5	p=0.000	149±29.1	p=0.512
Total Cholesterol				
Before	191.3±13.5	t=5.3	184.1±15.1	t=1.99
After	173.8±11.2	p=0.000	177.4±15.2	p=0.77
Serum Triglyceride				
Before	167.8±21.3	t=5.3	170.6±19.1	t=0.5
After	148.5±23.1	p=0.000	169±13.7	p=0.617
HDL Cholesterol				
Before	51.8±4.1	t=13.2	54.1±4.8	t=0.12
After	56.3±4.03	p=0.000	54.3±4.5	p=0.905
Hb A1C (%)				
Before	9.3±0.8	t=7.9	9.2±0.6	t=1.3
After	8.3±0.6	p=0.000	9.6±0.6	p=0.216
FBG: fasting blood glucose (mg/dl); HDL: high density lipoprotein; values are mean±SD, Lipids are measured as mg/dl.				

**Figure 1.** Changes in augmentation index in upper limb (filled diamond) and sedentary group (filled square). Values are mean±SD.

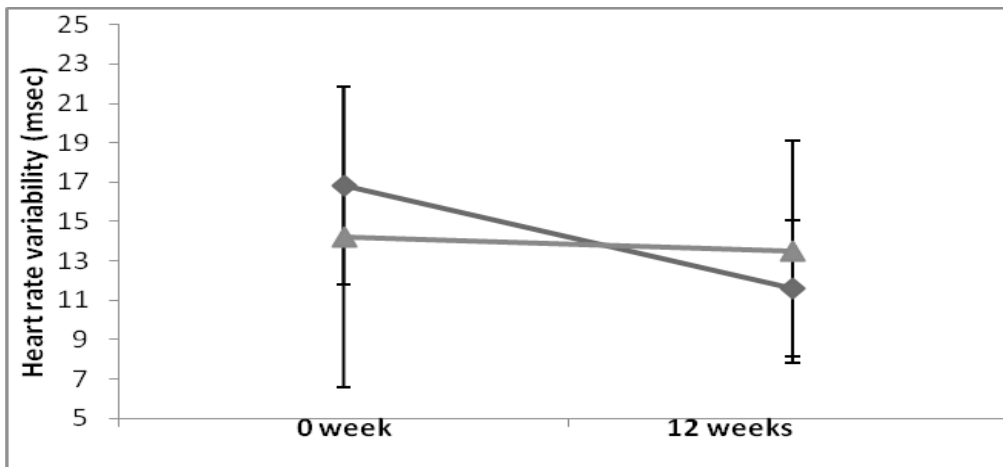


Figure 2. Changes in heart rate variability in upper limb (filled diamond) and sedentary group (filled triangle). Values are mean+SD.

control. This could be a possible explanation for changes in glycemic control in upper limb training group.

The key findings were that upper limb training group showed high increase in the augmentation index and decrease in heart rate variability after training. These findings signify that upper limb resistance training increases central arterial stiffness by increasing augmentation index (25,26) and reducing arterial compliance by reduction in heart rate variability (32-39). Hypertension causes profound change in arterial pressure waves leading to increase in augmentation index (40). Therefore, it could be a possible cause for increase in augmentation index in upper limb training group as upper limb training led to increase in systolic and diastolic blood pressure by 8.3% and 14.0%.

A decrease in heart rate variability changes the sympathetic nervous system activity (41,42) and an increase in sympathetic nervous system activity with resistance training (43,44) had a powerful vasoconstrictor effect on the arterial walls. Thus, arterial stiffness may increase in upper limb training group via greater sympathetic vasoconstrictor effect (43). Older studies suggested either no increase in sympathetic nerve activity (45) or increased sympathetic nerve activity with upper limb exercise leading to a vasoconstrictor effect on lower limbs (46).

A higher heart rate and perceived exertion has been noted in performing arm exercise when compared with leg exercise at the same absolute work rate (47). Arm exercise has also been reported to produce increase in arterial pressure, heart rate and total peripheral resistance (20). Similar changes were seen in upper limb training group with resting heart rate increasing by 14.5% and systolic and diastolic blood pressure increased by 8.3% and 14.04%. Upper limb resistance training increased the cardiovascular system work load as shown by the product of high blood pressure

and heart rate. Activities involving upper body work, such as gardening and snow shoveling, have been identified as triggering myocardial infarction (48). However some studies reported increase in mean arterial pressure during arm cranking when compared to leg exercise (49). Increase in blood pressure reduces arterial elasticity (50) and it has been found that arm exercises increases the blood pressure when compared to leg exercise (48,51). Therefore, although elevation of heart rate, blood pressure and augmentation index during arm exercises may contribute to arterial stiffness, intermittent decrease in heart rate, augmentation index and blood pressure may suppress arterial stiffness.

It was indicated previously that regular upper extremity aerobic exercise leads to a marked reduction on systolic and diastolic blood pressure and an improvement in small artery compliance (52). They also indicated a decrease in augmentation index by 2.1 ± 7.3 with aerobic exercise. This is at variance from Tabara et al. (53) who found that long term exercise-induced changes were significant in augmentation index and recommended that healthy and sedentary elderly subjects with higher augmentation index may benefit from mild to moderate aerobic exercise to improve arterial stiffness. Previous studies stated that regular resistance training increases arterial stiffness (21,54,55). Whereas, Okamoto et al. (21) reported increase in systemic arterial stiffness with single arm resistance training intervention. With high intensity of resistance training of 10 weeks, Okamoto et al. (22) suggested that upper limb training increases arterial stiffness in young healthy subjects. The present study showed similar findings in upper limb training group with moderate intensity progressive resistance training in type 2 diabetes participants.

Our results are limited by the fact that we did not incorporate pulse wave velocity, a gold standard, for measuring arterial

stiffness (56) as augmentation index is set to vary with changes in the arterial blood pressure and only predicts changes in central arteries. We conclude that the upper limb training group showed highly significant increase in the augmentation index and decrease in heart rate variability which led us to believe upper limb training causing an increase in arterial stiffness. We therefore propose that perhaps another program incorporating moderate amount of aerobic exercise is likely to offset these negative consequences of upper limb resistance training. Future studies could be done by incorporating both forms of exercise interventions to predict changes in arterial stiffness in diabetes patients.

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