Efficacy of Aerobic Training on Pulmonary Function and Aerobic Capacity in Type 1 Diabetic Patients

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ABSTRACT

The aim of this study was to investigate the efficacy of aerobic training on the pulmonary function, and aerobic fitness indices in patient with type 1 diabetes mellitus. Twenty male subjects diagnosed as having type one diabetes have been randomly selected to participate in a supervised 3 months aerobic exercise training 3 times/week. Pulmonary functions, the indices of the aerobic capacity, performing body composition analysis, and fasting blood glucose level were performed before and after the three months of the exercise training. The statistical analysis of the pretreatment, and post treatment variables revealed significant improvement in the indices of the aerobic capacity, and pulmonary function, with significant reduction in the total body fat, associated with significant increase of lean body mass, in addition to significant reduction of the fasting blood glucose level for these patients

Key words: *Aerobic capacity, pulmonary function, aerobic training*

INTRODUCTION

Type 1 (insulin dependant) diabetes mellitus is a chronic, progressive multifactorial disease associated with several chronic complication that result mainly from macro vascular and micro vascular damages, and predispose to excess morbidity and premature mortality.[41] Type 1 diabetes mellitus account for over 10 % of the total diabetic case, and incidence is increasing globally both in low and high frequency population[13].

Diabetes mellitus, although worldwide in distribution, are more commonly seen in the developed European countries, US and Middle- Eastern countries[16]. Abundant evidence show that patients with type 1 diabetes mellitus, or type 2 are at a high risk of for several cardiovascular and pulmonary disorders that are now the leading cause of the disease related-mortality and morbidity[39]. The disaster from the complication of the diabetes is exacerbated in the developing countries due to lack of the diabetes monitoring and the unaffordable cost of the treatment[17]. The public health impact of cardiovascular, and pulmonary diseases in diabetic patient is already enormous and is increasing. Several explanation are behind this increasing, the one that is specific to type 1 diabetes mellitus is that the insulin treatment for type 1 diabetic patient has prolonged their lives significantly, and with each year of additional life comes an increased risk for cardiopulmonary complications[24].

Diabetes can cause the development of pulmonary complication due to collagen and elastin changes.[26] It has been found also that diabetes mellitus reduces the lung volumes, pulmonary mechanism and diffusing capacity[27,36,42]. This is in addition to increasing the expression of adhesion molecules through hyperglycemia, these molecules play an important role in the pathophysiological dysfunction of the vasculature[7,8].

Histopathologic evidence of the involvement of the lungs in subject with diabetes mellitus showed thickened alveolar wall, alveolar capillary walls, and the pulmonary arterial walls, these histological changes in the lungs are becoming a cause of pulmonary dysfunction.[6,8,31] The alveolar membrane permeability is also significantly declined in diabetic patient than the normal person, that could be attributed to the presence of E.elastin. (Adhesion molecules) that cause damage to the endothelium[9,16].

The impairment in aerobic capacity indices of diabetic patients is related to the reduction of the endothelium dependant relaxation, endothelial nitric oxide production, and urinary nitrate excretion[30]. It has been also reported that VO_2 Max is reduced and the slope of ventilation –to carbon dioxide production ratio during exercise, and the dead space to tidal volume ratio at peak exercise were significantly increased and inversely correlated with the duration of the disease[21]. All of these diabetic complications have a significant impact on the quality of the life of the affected individuals.

The improvement of the pulmonary function and aerobic capacity by the exercise training is well documented in normal and patient with type 2 diabetes.[1,11] but there are few studies that investigated the effect of prolonged aerobic exercise training on the aerobic capacity and pulmonary function on patient with type 1 diabetes mellitus, so this present study has been designed to explore the relation between exercise training and physical work capacity and pulmonary function, that will assist in understanding the mechanism of how exercise training improve patient quality of life and in finding a better way to evaluate the effect of rehabilitation.

SUBJECTS, MATERIAL AND METHODS

Subjects

Eighty medical files related to patient diagnosed as type 1 diabetes mellitus has been thoroughly reviewed at outpatient diabetes clinic of, ELkaser Elany internal medicine hospital. Detailed medical history has been taken by their physician to determine whether they could be enrolled in this study or not based on the foundation of the exclusion criteria. Each subject was questioned with regard to smoking cigarettes or other tobacco products. We excluded patients who has other physician diagnosed chronic disease, as arthritis, stoke, hypertension, cancer, hear attach, chronic cough, or bronchitis, or abnormal exercise electrocardiogram findings. Also all patients with known complication of the diabetes mellitus such as diabetic neuropathy, nephropathy, and retinopathy were also excluded from the study. After this initial history taking 20 male subjects who appear healthy and diagnosed as type 1 diabetes patient has been selected. Those patients were continuously under direct clinical supervision of the staff members of the internal medicine department The mean of their age was of 38.25+3.02 year; range from 30 to 40 year old with a mean duration of the disease 10.63+.3.4 year. Table 1 shows the other general characteristics of the subjects.

Table (1): general characteristics of the subjects (mean +SD)

Parameter (N=20)	Values (Mean ± SD)
Weight	72.1±8.4 Kg
Height	170±8.2 cm
BMI	24.78+0.8 kg/m^2
age	38.25+3.02 years
Duration of diabetes	10.63+3.4 years

Materials

* Weight and height scale were used to determine patient height and weight to calculate their body mass index for every patient, and also used ad a prerequisites for the exercise test.
* Body composition analyzer (Biodynamic SN 330, made in Seattle, Washington, USA) used to determine each subject's lean, and fat body weight.
* Cardio pulmonary Exercise test unit; (ZAN; MeBgerate GmbH, Germany) at the faculty of physical therapy laboratory. It consists of breath gas (O_2 and CO_2) analyzer; electronic treadmill (SN RAM; Germany). It has been used to evaluate the pulmonary function under resting condition using the built in Spiro meter, and performing the sub maximal graded treadmill test. We used the forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), and the ratio between them FEV1/FVC % to asses the pulmonary function[46] and we used the maximum oxygen uptake (VO_2 Max), anaerobic threshold (VT) and maximum treadmill test time (MTT) as an indices to evaluate the aerobic or the physical work capacity for those patient[18].
* Pulsometer, (Tunturt TPM-400, made in Japan) It was used to detect the pulse rate before, during and after exercise, and to control exercise intensity within the precalculated training heart rate.

Testing procedure

All the evaluation procedures (pulmonary function, and exercise test) and the training program have been conducted at the well equipped cardiopulmonary lab of the faculty of physical therapy, Cairo university under supervision of the physical therapy department of the cardiopulmonary disorder and geriatric. All the patients had been subjected to initial detailed investigation by their physician, including each patient's fating blood glucose level. They were under constant supervision as regard their insulin doses, and time of administration in relation to the time of the exercise test and the time of the training sessions. All the participants have signed a written informed consent before the exercise test, and the exercise programs. Body composition analysis was performed by the body fat analyzer to determine each subject's lean, and fat body weight, in addition to calculating every subject's body mass index (BMI). Body composition analysis has been done based on what reported that the improvement in pulmonary function, and VO_2 max by exercise in normal subjects, could be related to changes in body composition[9,10].

Pulmonary function test was performed by the Spiro metric part of the cardiopulmonary exercise test unit, it was carried out at affixed time of the day to minimize diurnal variation[23,29]. The apparatus was calibrated daily and operated within the ambient temperature range of 20-25^{0}C.After tacking the detailed history and the anthropometric data, the patient was informed about the test technique. The patients were encouraged to practice the test maneuver before doing the test. Pulmonary function test was conducted at relaxed sitting position. The results were printed using the printer connected to the Spiro meter. These parameters were (FVC), (FEV_1) and (FVC_1/FVC ratio).

All patient performed the sub maximal graded exercise test on electronical treadmill according to Bruce protocol with built in 12 leads ECG monitoring system.[43] The test is composed of 3 minutes multistages with gradual increase of the speed and inclination of the treadmill. During the first 2 minutes of the test, the patient was standing without walking to allow the system to analyze the ventilation characteristics under resting condition. Patients were encouraged to exercise until symptoms were intolerable. Investigator-determined exercise end points were severe ventricular tachycardia of >5 beats, ST-segment depression >3 mm, systolic blood pressure >250 mm Hg, or progressive decrease in blood pressure.[21] During the test the expired gases were investigated using breath-breath analysis through breathing mask (Oxycon B, Jaegar), to calculate the VO_2 max, and the anaerobic threshold[25,43] The anaerobic threshold for each individual was expressed in units of oxygen uptake and was determined from the computer analysis of the carbon dioxide production / oxygen uptake by the V slope method of Beaver, etal[4]. The maximal oxygen consumption, anaerobic threshold, and maximum treadmill test time have been selected from the printed results and taken as indices for evaluation of the physical fitness or the aerobic capacity[2,28,40].

Treatment procedure

All the patients participated in the aerobic exercise training program on electrical treadmill 3 days/week for a total 36 exercise sessions, starting at hear rate 50-70% of the maximum heart rate (40-60% of VO_2 max) for 30 minutes. This was progressively increased to heart rate> 60% of the maximal heart rate (75% of VO_2 max) for 50 minutes session, which was maintained for the last 4 weeks. The heart rate for each patient was monitored by the pulsometer fixed to patient index finger.[29,33,44]. All the evaluation procedures including body composition analysis, pulmonary function, and graded exercise test were repeated for all subjects at the end of their treatment program. All the program of exercise was under supervision of the patients physician as regards adjusting the doses of the insulin, and carbohydrates during the day of the exercise session to avoid hypoglycemia, which is a common complication of exercise in type 1 diabetes mellitus, specially with high dose of insulin with low intake of carbohydrates[17].

Statistical analysis

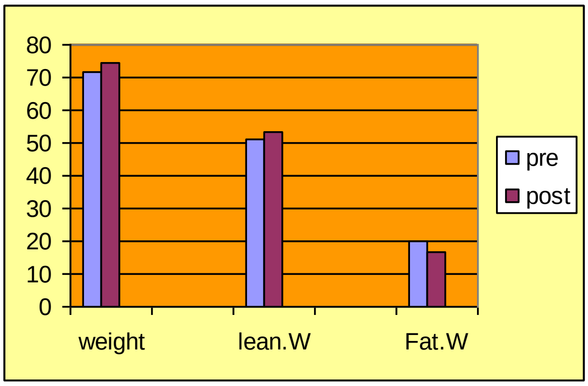
Results were expressed as mean + SD. Statistical analysis on baseline differences between pre, and post treatment variables was performed using an unpaired student-t test. A bivariate correlation analysis was performed to investigate the linear relationship between variables of changes in pulmonary function, aerobic capacity indices, and body composition. All P values less than 0.05 were considered statistically significant.

RESULTS

In the present study the efficacy of aerobic exercise training for 3 months on the pulmonary functions, and the indices of aerobic capacity have been investigated in-patient with type 1 diabetes mellitus. All the collected data were statistically treated by mean, standard deviation, and paired t test to investigate the effect of aerobic training on the pulmonary function, and the aerobic capacity indices As revealed from table {2}, and figure {1} there was a significant increase in the mean values of the BMI, total body weight, and the lean body weight (P<0.05) as a result of the exercise training for 3 months, this is in addition to significant reduction in the mean values of the fasting blood glucose level, and the fat body weight (P<0.05).

Table (2): Comparison between the pre, and post treatment values for the weight related variables, and fating blood glucose level and the significance of the results

Parameter Mean + SD	Pre value	Post value	Mean difference	t-value	P value
BMI Kg/m^2	24.78±0.8	26.6±0.4	2.52±0.5	20.4	(P<0.05)
Weight kg	71.9±2.1	74.6±3.4	2.6±2.25	5.28	(P<0.05)
Lean weight	51±0.9	53.6±1.4	1.75±1.0	7.5	(P<0.05)
Fat weight	20.2+1.4	16.83±0.9	3.3±1.4	10.5	(P<0.05)
Blood glucose ml	220.6±92	150.3±13.3	70±35	3.2	(P<0.05)



Weight: total body weight Lean. W: Lean body weight Fat.W : Fat body weight

Fig. (1): Comparison of the mean value for the pre and post treatment weight, Lean, and fat body weight.

Table 3 and figure 2 show the changes in the pulmonary function indices produced by the exercise training, as there were significant increase in the FVC, FEV_1, and the FEV_1/FVC ratio (P<0.05).This is in addition to significant reduction in the fasting blood glucose level for the most of the patients(P<0.05). Eight patients has their insulin doses reduced by 25% as decided by their physician a result of that significant reduction of the fasting blood glucose level after the 3 months of the exercise training

Table (3): Comparison between the pre, and post treatment values pulmonary function test, and the significance of the results.

Parameter Mean + SD	Pre value	Post value	Mean difference	t-value	P value
FVC liter	3.07+0.5	4.03±0.4	0.95±0.33	12.8	(P<0.05)
FEV1 liter	2.38+0.15	3.73±0.12	1.35±0.33	34.4	(P<0.05)
FEV1/FVC	66.95+13.04	82.05±7.5	15.1±8.9	7.58	(P<0.05)

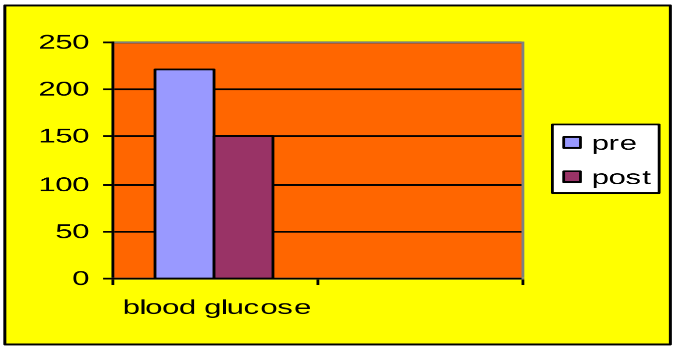
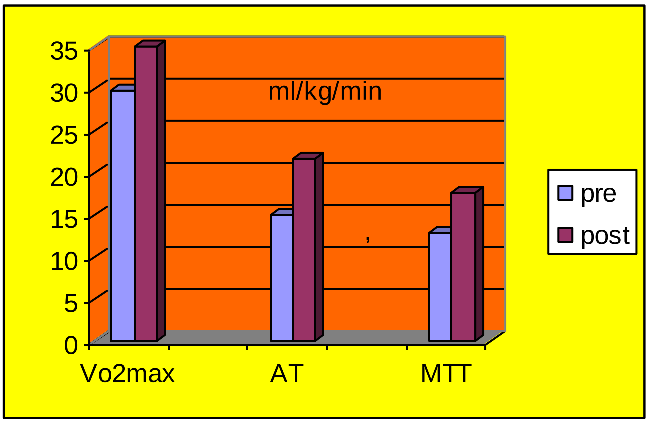


Fig. (2): Comparison between the mean values of the pre and post treatment blood glucose level.

The results of the present study had also showed a significant increase in the indices of the treadmill test that represent the improvement of the aerobic fitness or capacity by aerobic exercise training for 3 months, as it produced significant increase in the VO_2 max, AT, and the MTT ($P<0.05$). In the bivariate correlation analysis only the reduction in the fat body weight was significantly correlated with the maximum oxygen consumption, where the reduction in the total body fat was responsible for 17% of the increase in the oxygen consumption.on the other hand the increase in the total body weight, and lean body weight were only partially correlated to the increase in the VO_2max with non-significant correlation between the other investigated variables. (Correlation statistics is not presented).

Table (4): Comparison between the pre, and post treatment values for the indices of the aerobic or the physical work capacity and significance of the results

Parameter Mean + SD	Pre value	Post value	Mean difference	t-value	P value
VO_2 max/ml/kg/min	29.7+1.05	34.96+1.8	5.2+2.1	10.9	(P<0.05)
AT /ml/kg/min	15.1+0.9	21.65+2.04	6.5+1.8	15.7	(P<0.05)
MTT/minute	12.74+1.4	17.6+1.3	4.91+1.7	12.7	(P<0.05)



VO_2 max: maximum oxygen consumption AT: Anaerobic threshold MTT: Maximum m treadmill time

Fig. (3) Comparison between mean values of the pre and post training aerobic capacity indices.

DISCUSSION

The present study showed a significant improvement in the pulmonary function, and the indices of the aerobic capacity after three months of moderate exercise training in-patient with type 1 diabetes mellitus. Regular exercise training had also reduced the fasting blood glucose level significantly, in addition to significant reduction of the total body fat, coupled with significant increase in the lean or muscle mass and the total body weight.

The result of the present study indicated that intensive aerobic exercise training is able to induce an anabolic response even in normal weight type 1 diabetic patients. This results are in accordance with a study by Bernard, etal, who reported that prolonged aerobic training for 12 weeks had enhanced the bilateral mid thigh muscle cross-sectional area, a measure of skeletal muscle mass, assessed by computerized topography[5]. The significant reduction in the total body fat showed in this study could be attributed to the fact that moderate exercise training {used in this study} is associated with increase in the fat oxidation as reported by previous studies as they explained this fact by increasing the energy expenditure coupled with greater fatty acid availability, the increase in the fatty acid availability is due both to increases in lioplysis and decreased resterification of non estrified fatty acids {NEFA} to triglyceride[18, 43,45].

In the present study the changes in the pulmonary function and the aerobic capacity, indices {VO_2max, AT. And MTT} were only in part related the change in the lean body mass, so the increase in the lean body mass ($P<0.05$) was insufficient to be responsible for the improvement in the aerobic capacity. Despite the lack of correlation,, the most majority of the patients had showed significant improvement of the aerobic capacity, lean body weight or both.

The improvement in the pulmonary function noted in this study, could be attributed to increased pulmonary ventilation, as the lung can take in more air with each respiration.[9] This improvement could result also from increasing efficiency of the external respiration where oxygen and carbon dioxide are interchanged more efficiently between the lung and the capillaries on the alveoli. This in addition to increasing efficiency in absorption of oxygen per liter of the ventilation during exhausting work with increasing efficiency to eliminate carbon dioxide[18].

The improvement of the aerobic capacity could be attributed to the fact that exercise training induces intrinsic alteration in the skeletal muscle including the diaphragm, and the intercostals muscle, such as increments in mitochondria, or oxidative enzyme, which contribute to the improved physiological functions[22,32,46]. This is could also explain the lack of correlation between the aerobic capacity, pulmonary function, and the lean body weight. Furthermore the diabetic patient might have developed the ability to increase motor unit recruitment during exercise, and thereby performance might have increased more than muscle mass[3,15,20].

Exercise training is associated with substantial increase in both fatty acid, and carbohydrates oxidation in the skeletal muscle, with the relative use of the 2 fuels varying with exercise intensity. Thus, during low – intense exercise {30-40 % of VO_2 max}the fatty acids is the principle oxidative substrate, where during some what more intense exercise {60-70% of VO_2 max}, the absolute rates of fatty acids and carbohydrates oxidation increase, but the oxidization of fatty acid relative to carbohydrates is decreased[10,22]. This could explain the significant reduction pf the fasting blood glucose level ($P<0.05$) noted in this study after more intense exercise training.

The significant control of the blood glucose level by exercise training in type 1 diabetes mellitus could be attributed to increased skeletal muscle glucose uptake due to marked increase of the muscle blood flow during exercise, as it has been reported that the increased perfusion of the blood to the isolated rat hind limb is necessary for full contraction-induced glucose uptake[10,32,35]. Aerobic exercise training also increase glucose transport by stimulating GLUT 4 translocation to the muscle cell surface, which involve sensing an increase in the muscle adenosine monophosphate {AMP}, which in turn stimulate AMP kinasae.[14,19,37,38] In addition to AMP kinase activation, data suggest that nitric oxide {NO} may mediate contraction-induced glucose uptake[12], as is also documented by several studies as they found that electrical stimulation increase muscle NO synthesis and the pharmacological inhibition of NO synthesis decreases uptake of glucose.[17,19,25] This is in addition to increasing liver and muscle sensitivity to the action of the insulin that increase the insulin use of the cells, and accelerates the utilization of glucose by liver and muscles[15,25,34].

Conclusion

The practice of the regular aerobic training is recommended to type one diabetic mellitus, but the emphasis must be in adjusting the therapeutic treatment {insulin, and diet} to allow for the safe participation in aerobic training according to the individual goal and his predisposition. Regular exercise training improves the lung function, and the functional aerobic capacity that in turn improves the quality of life, and at least delay the onset of the serious diabetic complication.

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الملخص عربى

تأثير االتدريبات الهوائية على الوظائف الرئوية والكفاءة البدنية لدى مرضى البوال السكرى من النوع الأول

أجريت هذه الدراسة بهدف بحث تأثير التمرينات الهوائية على الوظائف الرئوية والكفاءة الفيزيائية لدى مرضى البوال السكرى من النوع الأول. تم اختيار عشرون رجلاً من الذين يعانون من مرض البوال السكرى من النوع الأول ليشتركوا فى برنامج تمرينات هوائية تحت الملاحظة لمدة ثلاثة اشهر بموجب ثلاث جلسات فى الأسبوع . وقد تم تقييم الوظائف الرئوية والدلائل الخاصة بالكفاءة الفيزيائية بإضافة إلى تقييم مستوى السكر فى حالة الصيام وتقييم مكونات القسم الدالة على وزن الجسم الدهنى ووزن الجسم الخالى من الدهون وذلك قبل وبعد برنامج العلاج . أظهرت النتائج الإحصائية وجود تحسن ذو دلاله إحصائية فى جميع العوامل الخاصة بالكفاءة الفيزيائية والوظائف الرئوية كما أظهرت الدراسة تحسن ذو دلالة إحصائية فى مستوى السكر الصائم ووزن الجسم الدهنى ووزن الجسم الخالى من الدهون لدى هؤلاء المرضى .