

Original Research

The Effects of Moderate Intensity Treadmill Exercise with Gradual Increase of Speed and Inclination on VO₂max in Men with Type 2 Diabetes Mellitus

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ABSTRACT

Background: The American College of Sport Medicine (ACSM) recommends cardiorespiratory fitness training in people with diabetes mellitus (DM) for 3-7 days a week, total duration 150 minutes a week with moderate intensity using large muscle groups. Treadmill training is the best cardiorespiratory fitness training because it involves large muscle group compared to static cycle and arm crank.

Aim: To determine the effect of moderate intensity treadmill exercise with gradual increase of speed and inclination on VO₂max in men with T2DM.

Material and Methods: Randomized group design in 22 men with T2DM, suitable with inclusion criteria was divided into 2 groups, the experimental and control group. The experimental group received moderate intensity treadmill exercise, 3 times a week with gradual increase of speed and inclination for 4 weeks. The control group underwent standard therapy. Measurement of VO₂max was performed before and after program in both groups.

Results: A significant increase of VO₂max in the experimental group (p = 0.003). Compared to the control group, alteration of VO₂max also significant among the experimental group (p = 0.000).

Conclusion: Moderate intensity treadmill exercise with gradual increase on speed and inclination for 4 weeks increase VO₂max in men with T2DM.

Keywords: *Treadmill exercise, moderate intensity, gradual increase on speed and inclination, T2DM, VO₂max.*

Introduction

Diabetes mellitus (DM) is a group of metabolic disease characterized by hyperglycemia that primarily threat the human health in the 21st century. T2DM resulting from defects in insulin secretion, insulin action, or both, which is 90-95% of all types of DM. WHO predicts an increase of people with DM in Indonesia by 8.4 million in 2000 to around 21.3 million in 2030.^{1,2}

Treatment modalities of hyperglycemia consist of a triad of drugs, diet, and exercise. Each has a specific role in promoting glucose uptake and hence balancing blood glucose levels. DM is a major public health issue because it has high impact on quality of life, and decline life expectancy.

Endothelial dysfunction is a key abnormality found in insulin resistance state and vascular dysfunction. Maximum oxygen consumption (VO₂max) is strongly correlated with insulin sensitivity and endothelial dysfunction. Individuals with T2DM have previously been shown to have 20% lower VO₂max compared to healthy subjects.^{3,4,5,6}

Regular aerobic exercise in DM improves glycemic control, insulin sensitivity, VO₂max, and prevent the progression of DM. VO₂max reflects person's maximum aerobic capacity to absorb, transport, and consume oxygen during dynamic exercise using large muscle groups. Practically, VO₂max is considered to be equivalent to the highest VO₂ value obtained in peak exertion which usually classified as measure of cardiorespiratory fitness. Treadmill training is the best cardiorespiratory fitness training because it involves large muscle group compared to static cycle and arm crank. Treadmill can also be used for a stress test to estimate VO₂max. Modified Bruce Protocol treadmill test is frequently used with lower incremental workload and preferable for sedentary patients.^{7,8} The purpose of the present study is to determine the effect of

moderate intensity treadmill exercise with gradual increase of speed and inclination on VO₂max in men with T2DM.

Material and Methods

Subjects

This single-blinded, randomized controlled study was carried out in gymnasium at Medical Rehabilitation Installation of RSUD Dr. Soetomo Surabaya from July to August 2019 for 4 weeks. The total subjects were 22 men diagnosed with T2DM based on World Health Organization's (WHO) criteria.⁹ All subjects met the inclusion criteria and did not have any of the exclusion criteria. The inclusion criteria were men with T2DM, aged 35-55 years old, random blood glucose >100 - <250 mg/dL, BMI 23 – 24,9 kg/m², normal cognition function evaluated using Mini Mental State Examination, systolic blood pressure 110-130 mmHg, diastolic blood pressure 70-80 mmHg. The exclusion criteria were women, presence of erythema, ulcer, or gangrene on one/both side of lower extremity, peripheral neuropathy, ankle range of motion limitation at both side, regular aerobic exercise, heart disease, pulmonary disease, musculoskeletal disease that disturb ambulation, visual and balance disturbance. Drop out criteria were when subject unable to complete treadmill exercise according to the protocol as much as 2 sessions consecutively in one week from the total session

Protocols

The duration of intervention was 4 weeks. Subjects from both groups were examined for the vital signs (blood pressure, heart rate, respiratory rate, oxygen saturation, body mass index (BMI), diabetes duration, history of smoking, hypertension, dyslipidemia, and random blood glucose levels at the beginning. Subjects were recruited by consecutive sampling method and randomly assigned to the experimental ($n = 11$) and control group ($n = 11$) using

computerization lottery.

Subjects in the control group underwent standard therapy for DM, consists of education for diet, oral antidiabetic drugs and insulin, and physical activity at least 3 times/week while the experimental group received standard therapy and aerobic exercise with the motor driven treadmill (BTL), 3 times/week for 4 weeks, moderate intensity with target heart rate of 75% maximal heart rate. Each session consists of 5 minutes warm up, 20 minutes core workout, and 5 minutes of cooling down. In core session, subjects trained using the stages of protocol with gradual increase of speed and inclination until the target heart rate (THR) achieved and maintained until the end of core session. When the rate exceeds the THR, the exercise stage decreased and the THR maintained until the time finished.

Table 1. Protocol for gradual increase of speed and inclination in the experimental group

Stage	Speed (mph)	Inclination (%)	Duration (min)
1	1.5	0	2
2	2.0	3.5	2
3	2.0	7	2
4	2.0	10.5	2

Measurement of VO₂max was performed before and after the therapy period in both groups using Modified Bruce Protocol stress test and calculate estimated VO₂max using formula;⁸

$$\text{Men: VO}_2\text{max (ml/kg/minute)} \\ = 2.94 \times T + 7.65$$

T: total time completed stress test (in minutes)

All subjects already provided their written informed consent. This study was approved by The Ethics Committee of RSUD Dr. Soetomo Surabaya, East Java, Indonesia (1266/KEPK/VI/2019).

Data Analysis

Data distribution of all variables was tested with Shapiro-Wilk test. For normal distributed data, paired *t*-test was used for comparisons in the same group, and independent *t*-test was used for comparisons between two groups. For non-normally distributed data, the non-parametric Chi Square test and Mann-Whitney U test were used for comparisons between two groups. Differences were considered significant at $p < 0.05$. All distributed data are reported as mean \pm standard deviations (SD) or percentage (%). All data were analyzed using SPSS (version 23).

Results

All 22 subjects completed the sessions and study protocol, with no dropout throughout study. None of the subjects reported any adverse effect during or after the program. The homogeneity test of subject characteristics for BMI, smoking, hypertension, dyslipidemia, random blood glucose, diabetes duration, Oral Anti Diabetic, insulin and VO₂max before program between two groups were not significantly different ($p > 0.05$), except age met the inclusion criteria (Table 2), so all subjects could participate in this study.

The results of this study indicate a significant increase in VO₂max in the experimental group after 4 weeks, $p=0.003$ (Table 3). Compared to the control group, changes (delta) VO₂max also significant among the experimental group, $p = 0.000$ and the effect size in this study was 1.85 (Table 4).

Discussions

To our knowledge, no studies have been conducted to evaluate the effect of moderate intensity treadmill exercise with gradual increase of speed and inclination on

VO₂max in men with T2DM. The mean age in the experimental group was 50.36 ± 4.43 years old, while the control group was 46.55 ± 3.93 years old (Table 2), indicating that the mean age of subjects was within the range of productive age which allowed for cardiorespiratory fitness training.¹⁰ The mean of BMI in the experimental group was 23.32 ± 3.88 kg/m², and the control group was 25.93 ± 4.88 kg/m², which indicate that BMI of both groups was overweight to obese.¹¹ Obesity causes a decrease in the ability of insulin to inhibit the release of glucose from liver and uptake of glucose in fat and muscle cells that cause insulin resistance and becomes a major risk for T2DM.

Lifestyle modifications including physical activity, exercise, and diet have positive effects in patients with T2DM.^{7,12} Exercise plays a major role on DM treatment because of its imitation of insulin properties which increase the muscle capacity to intercept plasma glucose due to intramuscular fat storage degradation.

Aerobic exercise with moderate intensity can increase the number of β cell and average area size of Langerhans islets.¹³ The mean value of random blood glucose in both groups did not show a significant difference. Random blood glucose levels >100 - <250 mg/dL is not contraindicated for cardiorespiratory fitness training.^{8,14}

Table 2. Clinical characteristic and laboratory investigations of subjects at baseline

Variable	Experimental group (n=11)	Control group (n=11)	p value
Age (years)	50.36 ± 4.43	46.55 ± 3.93	0.045 ^a
Body Mass Index (kg/m ²)	23.32 ± 3.88	25.93 ± 4.88	0.181 ^a
Smoking (%)			
• Yes	4 (36.4)	3 (27.3)	1.000 ^b
• No	7 (63.6)	8 (72.7)	
Hypertension (%)			
• Yes	2 (18.2)	2 (18.2)	1.000 ^b
• No	9 (81.8)	9 (81.8)	
Dyslipidemia (%)			
• Yes	1 (9.1)	1 (9.1)	1.000 ^b
• No	10 (90.9)	10 (90.9)	
Oral Anti Diabetic (%)			
• Yes	10 (90.9)	11 (100)	1.000 ^b
• No	1 (9.1)	0	
Insulin (%)			
• Yes	6 (54.5)	4 (36.3)	0.670 ^b
• No	5 (45.5)	7 (63.7)	
Random blood glucose (mg/dL)	181.91 ± 43.22	174.64 ± 34.64	0.921 ^c
Diabetes duration (years)	7.09 ± 6.09	6.05 ± 4.77	0.659 ^a
VO ₂ max before intervention (mg/kg/min)	20.56 ± 2.95	23.4 ± 5.66	0.161 ^a

Data are presented as the mean ± standard deviations (SD) or percentage (%).

^a = Independent *t*-test; ^b = Chi-Square Test; ^c = Mann-Whitney Test. *significant if *p* < 0.05.

Table 3. Comparisons of VO₂max between the experimental and control groups after 4 weeks

Group	n	Before intervention (mg/kg/min) Mean ± SD	After intervention (mg/kg/min) Mean ± SD	p value
Experimental group	11	20.56 ± 2.95	31.57 ± 5.75	0.003*
Control group	11	23.40 ± 5.66	23.23 ± 9.46	0.938

*paired *t*-test; Significant: *p* < 0.05

Table 4. Comparisons of Changes VO₂max between the experimental and control groups after 4 weeks

Delta sKlotho (pg/mL)	n	Mean ± SD	p value	Effect size
Experimental group	11	11.01 ± 4.93	0.000*	1.85
Control group	11	-0.17 ± 7.01		

*Independent *t*-test; Significant: *p* < 0.05

The mean of duration suffering from diabetes in the experimental group was 7.09 ± 6.09 years, and in the control group was 6.05 ± 4.77 years. Patients suffering from DM in this time of length commonly suffer from deconditioning in cardiorespiratory fitness and physical activity which is risk of complications in DM. T2DM is usually asymptomatic in many patients for a prolonged duration, and is diagnosed with the emergence of complications after 5-6 years.^{7,15}

The mean of VO₂max before intervention in the experimental group was 20.56 ± 2.95 ml/kg /min, while the control group was 23.40 ± 5.66 ml/kg/min. VO₂max value before program between two groups was not significantly different (Table 2). These results indicate that VO₂max before intervention in men with T2DM in this study was very poor compared to healthy men of the same age.⁸ O'Connor et al.¹⁶ showed a significant decrease of O₂max in men and women with T2DM than healthy subjects. An early step in the development of insulin resistance in patients with T2DM is impaired mitochondrial activity. Insulin plays an important role in the regulation of mitochondrial anion transporter function during the Krebs cycle Oxygen consumption for oxidation of Acetyl-CoA produced by glycolysis. VO₂max is a gold standard measurement of cardiorespiratory fitness. The better the VO₂max, the better the person's cardiorespiratory fitness and insulin sensitivity, the better prevention to the complication of DM.^{8,17,18}

In this study, smoking, hypertension, dyslipidemia, use of insulin and Oral Anti Diabetic had no difference

between two groups. The variables of BMI, random blood glucose, smoking, hypertension, dyslipidemia, Oral Anti Diabetic, insulin, diabetes duration, and VO₂max before intervention are homogenous in all subjects (Table 2). After 4 weeks, there was a significant increase of VO₂max (*p* < 0.05) in the experimental group, while no difference of VO₂max in the control group (Table 3). The increase in VO₂max in the experimental group was 53.55%, while a decrease in VO₂max in the control group was 0.73%. Compared to the control group, VO₂max changes was also significant among the experimental group (*p* = 0.000) (Table 4).

Aerobic exercise is a therapeutic strategy in T2DM which can improve glycemic control, insulin sensitivity and VO₂max. The more intense the aerobic exercise the better the glycemic control and insulin sensitivity.⁷ Moderate intensity aerobic exercise regularly can induce an increase in skeletal muscle mitochondrial density up to 40% which correlates with an increase in slow-twitch muscle fiber. Aerobic exercise also increases the number of capillaries blood vessels in the skeletal muscles that cause increase blood flow in the skeletal muscles.^{19,20}

Upon the onset of muscle contraction, homeostasis perturbate within skeletal muscle, such as increase AMP/ATP ratio, Ca²⁺, reactive oxygen species (ROS), lactate, reduced glycogen availability result in the activation of number of regulatory protein kinases, AMPK, p38MAPK, and CaMKII that stimulates PGC-1α which is the main transcription coactivator in the

mitochondrial biogenesis. Mitochondrial biogenesis is a metabolic adaptation to aerobic exercise that causes an increase in size, number, density, and oxidative enzyme activity in the mitochondria that

The effect size after treadmill exercise was 1.85 (Table 4), which means moderate intensity treadmill exercise for 4 weeks with gradual increase of speed and inclination give large effect on VO₂max in men with T2DM. This result is consistent with Gholaman²³ and Rehman et al.⁸ in people with T2DM that showed a significant increase in VO₂max after aerobic exercise ($p < 0.05$). Treadmill exercise with gradual increase of speed and inclination will increase the body's metabolism, involving more muscles working rhythmically, requiring more energy that needs greater oxygen consumption, so gradual increase of speed will increase heart rate along with the load speed. The higher the speed, the muscles work harder that cause oxygen demand also increases. This increase in oxygen demand help the source of energy to maintain performance in completing exercise duration.⁸ The increased of inclination indicates an increase in heart rate slowly that will increase the work rate which causes an increase in VO₂max. Increasing speed and inclination gradually on treadmill exercise will increase VO₂max.²⁴

Conclusions

This study showed that aerobic exercise using treadmill with gradual increase of speed and inclination can increase VO₂max in sedentary men with T2DM with moderate intensity, 3 times a week for 4 weeks, 30 minutes for each session. There is a difference in changes in VO₂max in men with T2DM who get intervention compared with the control group. The American Diabetes Association (ADA) recommends lifestyle modifications including diet and regular exercise could improve blood glucose

produces ATP and oxygen as a source of energy in cardiorespiratory fitness to increase VO₂max.^{21,22}

control, insulin sensitivity, muscle strength and cardiorespiratory fitness that can reduce cardiovascular risk, normal body weight, and improve quality of life.²⁵

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