Immediate Effects of Buerger's Exercise on Vascular Diameter and Leg Blood Flow in Type 2 DM Compared with Sedentary Healthy Individuals

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Abstract

Type 2 diabetes mellitus (T2DM) is one of the chronic diseases, which is required a long-term care. Peripheral arterial disease is the common complication of T2DM caused by abnormal vascular function. Aerobic exercise is recommended to improve peripheral perfusion. However, there are many barriers to restrict patient's compliance to aerobic exercise program. Buerger's exercise has been reported as a treatment to improve limb circulation for arterial occlusive patients. Therefore, it is possible to apply this form of exercise to improve peripheral circulation for diabetes patients. However, it is lack of studies to support the Buerger's exercose. Accordingly, the objective of the present study was to investigate the immediate effects of Buerger's exercise on vascular diameter, blood flow velocity and blood volume in type 2 diabetes compared with healthy individuals. **Methods:** Eighteen type 2 diabetes and 18 healthy subjects aged between 40-70 years were participated in this study. Smoking, obesity and underlying disease that might affected cardiovascular functions were excluded. Three steps of Buerger's exercise consisted of leg elevation, ankle movement in sitting position and supine lying were applied to both groups. Vascular diameter, blood flow velocity and blood volume of popliteal and posterior tibial arteries were measured at baseline and after one session of Buerger's exercise. **Results:** At baseline, popliteal and posterior tibial diameters, blood flow velocity and blood volume in diabetes were higher than healthy subjects. After one session of Buerger's exercise, there were significant differences between baseline and post-exercise of popliteal diameter and blood velocity of posterior tibials in the healthy group ($p<0.05$). Diabetes patients showed the trend of increased in diameter, blood velocity and blood volume of popliteal artery after exercise. Posterior tibial blood flow velocity was decreased post-exercise in both healthy and the diabetes groups ($p<0.05$). There were significant differences between groups in popliteal and posterior tibial diameters after Buerger's exercise ($p<0.05$).

Keywords: Diabetes, Buerger's exercise, Vascular diameter, Leg blood flow

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Introduction

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder characterized by elevated blood glucose. (Kharroubi & Darwish, 2015). Pathophysiologies of diabetes are either abnormal of receptor cell response to insulin called “insulin resistance” or lack of insulin secretion called “insulin deficiency” (B Olokoba, A Obateru, & Lateefat, 2012). In Thailand, the prevalence of type 2 diabetes increased from 7.0% in 2004 to 9.7% in 2014 and trends to increase every years (Aekplakorn et al., 2018). Diabetes is a leading cause of premature mortality and morbidity associated with micro- and macro-vascular complications such as blindness, kidney, nerve disease and peripheral artery problem (Nickerson & Dutta, 2012). The goals of T2DM treatment are to maintain optimal blood glucose, blood lipid and blood pressure levels and to prevent or delay chronic complications. ("Standards of Medical Care in Diabetes—2010," 2010)

Exercise is highly recommended as treatment strategy to achieve the treatment goals. Walking exercise has been reported to enhance mobility, functional capacity, exercise pain tolerance and quality of life in diabetes with peripheral arterial disease (Lyu et al., 2016). However, T2DM showed reduction in maximal aerobic capacity compared with healthy individual (Lalande, Gusso, Hofman, & Baldi, 2008). The possible mechanism is leg blood flow reduction during aerobic exercise in diabetes when compared with healthy individuals. Lower blood flow could result from impaired endothelium function and elevated peripheral vascular resistance observed in diabetes patients (Kingwell, Formosa, Muhlmann, Bradley, & McConell, 2003; Lalande et al., 2008)

Buerger’s exercise or Buerger-Allen exercise, one of alternative form of exercise, has been reported for improving peripheral circulation in diabetes patients (Chang et al., 2015). Buerger exercise is the use of gravitational effects applied in different positions included 1) legs elevate, 2) sitting with foot exercise and 3) supine lying (Chang, Chang, & Chen, 2015; Lin et al., 2018). Therefore, Buerger’s exercise is qualitatively different from any others mode of physical activity or exercise. Much less is known if type 2 diabetes patients with impaired endothelial function and elevated peripheral resistance shows different in peripheral blood flow responses to this mode of exercise compared with healthy individual.

Objectives

The purposes of this study were to investigate immediate effects of Buerger’s exercise on vascular diameter, blood flow velocity and blood volume in patients with type 2 diabetes compared with sedentary healthy individuals

Research Methodology

This study was an experimental study conducted to determine the effects of one session of Buerger's exercise. The study was approved by the Mahidol University Ethical committee (MU-CIRB 2018/188.0110).

Participants

Eighteen participants in each group were calculated from previous study (Bauer, Reusch, Levi, & Regensteiner, 2007). Healthy and diabetes subjects aged between 40 to 70 years old were recruited from Nakhon Pathom or nearby areas. Characteristics of participants were defined as following.

1. Healthy subjects were defined as taking no medication, blood pressure at rest <140/90 mmHg and fasting plasma glucose <126 mg/dL.

2. Type 2 diabetes subjects were diagnosed by physician based on American Diabetes Association or receiving glucose-lowering drugs. Diabetes subjects with coronary heart disease, chronic kidney disease, liver disease, vasculitis, hypothyroidism and diabetes complications such as neuropathy were excluded from the study.

Participants who were smoker, obese, having the history of cardiovascular disease, or active lifestyle (defined as participating more than three 20 minutes sessions of moderate intensity exercise/week for two or more years (Frank, Tong, Lobelo, Carrera, & Duperly, 2008) were excluded from the study.

Exercise protocols

Buerger's exercise was modified from standard procedures which consisted of 3 steps as followed 1) lie in supine position with leg elevated at 45° to 60° for 3 minutes, 2) sit on the edge of the bed with feet in relaxed position. Performed active exercises include ankle dorsiflexion, ankle plantarflexion, ankle inversion, ankle eversion, toe flexion, and toe extension for 3 minutes, and 3) lie on the bed in supine position for 3 minutes.

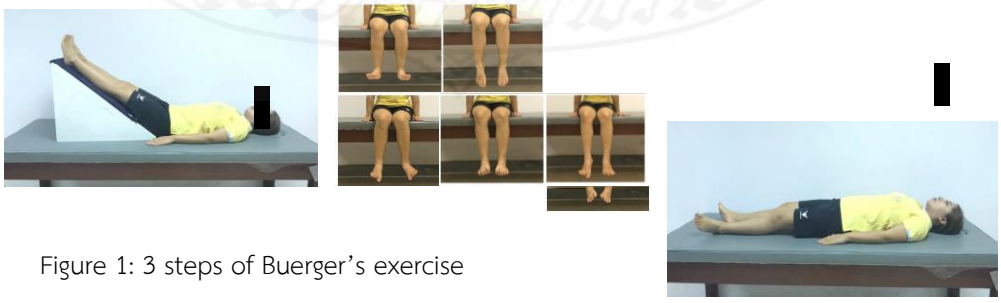

Figure 1: 3 steps of Buerger's exercise

For cycle 3rd to 5th, all participants were performed ankle active exercise with resistance band (Theraband®) in step 1 and step 2. Claudication leg pain (pain or cramping on lower extremities due to

inadequate blood supply to the muscles), fatigue or other abnormal symptoms were determined during exercise. If participants rated a claudication pain score for 3/4 or 4/4, the investigator was asked to stop the exercise. The entire cycle was repeated 5 times. The exercise duration was about 45 minutes for one session.

Outcome measurements

Doppler ultrasound machine equipped (CX-50, Philips Healthcare; Everett Hwy, Bothell, USA) was used to measure vascular diameter (cm), time average mean velocity or TAMV (m/s) and blood volume (l/min) at popliteal and posterior tibial arteries on the right leg. The transducer (linear L12-3) was placed on popliteal fossa for popliteal artery and medial malleolus for posterior tibial artery. Vascular diameter was automatically measured from interface marking of inner linear vessel wall. Mean blood flow velocity was automatically measured by longitudinal image of artery with isonation angle <60° and blood volume was calculated from mean blood velocity multiply by circular area and divided by 6×10^4. All of variables were measured at baseline and after one-session of Buerger's exercise.

Figure 2: Doppler ultrasound machine

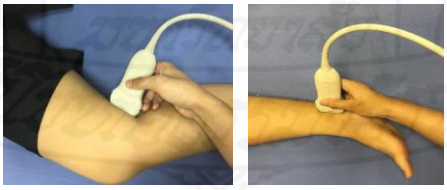

Figure3: Positions of transducer at popliteal and posterior tibial arteries

Both groups were received the same exercise protocols. Before testing, all participants must avoid from alcohol, caffeine, and heavy exercise at least 24 hours. Room temperature was controlled at 24±2 ºC. All participants were rest in supine position on the bed for 15 minutes before testing and exercise. All data were analyzed by SPSS version 23 and significant value (p-value) was less than 0.05. Kolmogorov-Smirnov goodness of fit test was used for data distribution testing. The data of participants

were showed in mean and standard deviation (SD). Paired-t test was used to compare before and after intervention and independent t-test was used to compare between groups.

Results

Thirty six participants were participated in the study. Table 1 showed selected subject characteristics. Diabetes group aged 57.33±6.95 years, consisted of 5 males and 13 females. The mean weight was 69.80±10.09 kg, body mass index was 27.38±2.56 kg/m^2, waist circumference was 89±6.79 cm and fasting blood glucose was 147.65±26.57 mg/dl. For healthy group, the mean age was 59.06±6.47 years. All of participants were female which the mean weight was 59.10±9.36 kg, body mass index was 23.89±3.05 kg/m^2, waist circumference was 79.22±9.86 cm and fasting blood glucose was 84.86±9.29 mg/dl. Diabetes subjects showed higher level of blood glucose significantly (p< 0.001). The diabetes group had significant higher level of weight (p= 0.002), BMI (p= 0.001), waist circumference (p= 0.001) and heart rate (p= 0.001) than the healthy group.

Table 1: Selected subject characteristic (mean±SD)

Demographic data	Healthy	Diabetes
Age (years)	59.06±6.47	57.33±6.95
Gender (male/ female; n)	0/18	5/13
Weight (kg)	59.10±9.36	69.80±10.09*
Height (cm)	157.06±7.26	159.44±8.14
BMI (kg/m^2)	23.89±3.05	27.38±2.56*
Waist circumference (cm)	79.22±9.86	89.00±6.79*
Heart rate (bpm)	63±7	74±11*
Brachial blood pressure (mmHg)	125±15/72±8	129±12/76±9
Ankle blood pressure (mmHg)	144±17/75±8	152±16/80±9
Blood chemistry		
Fasting blood glucose (mg/dl)	84.86±9.29	147.65±26.57#
High-density lipid cholesterol; HDL (mg/dl)	58±8.83	49.20±9.70*
Low-density lipid cholesterol; LDL (mg/dl)	149.57±28.47	99.06±29.48#
Cholesterol (mg/dl)	223.21±30.78	174.87±36.93*
Triglyceride (mg/dl)	78.21±26.10	165.94±84.56*

* p-value <0.05 versus healthy

\# p-value <0.001 versus healthy

Table 2 showed leg blood flow data. At baseline, popliteal blood flow velocity (6.24±2.73 m/s VS 9.06±3.79 m/s, p= 0.015) and popliteal blood volume (0.07±0.03 l/min VS 0.11±0.06 l/min, p= 0.019) in diabetes subjects were higher than healthy. Posterior tibial artery showed the same results as popliteal artery, the results showed significant difference between group in vascular diameter (p= 0.022), blood flow velocity (p= 0.015) and blood volume (p= 0.009).

After one session of Buerger's exercise, healthy subjects showed significant differences between baseline and post-exercise of popliteal vascular diameter (p= 0.004). Blood flow velocity at posterior tibial artery in healthy decreased after Buerger's exercise (p= 0.029).

There were no significant differences between baseline and post-exercise in diameter, blood flow velocity and blood volume of popliteal artery in diabetes patients. Blood flow velocity (p= 0.046) and blood volume (p= 0.031) of posterior tibial artery showed significantly decreased after Buerger's exercise.

After the one-session of Buerger's exercise, there were significant differences between group of popliteal and posterior tibial diameter (p= 0.023, p= 0.032). The study showed increasing trend of popliteal blood flow velocity and blood volume in both groups while posterior tibial diameter, blood flow velocity and volume of posterior tibial artery were decreased.

Table 2 Leg blood flow responses after one session of Buerger's exercise

Variables	Healthy		Diabetes	
	Baseline	Post-exercise	Baseline	Post-exercise
Popliteal artery				
Vascular diameter (cm)	0.47±0.05	0.51±0.06*‡	0.49±0.10	0.49±0.09
Blood flow velocity (m/s)	6.24±2.73	6.56±2.35	9.06±3.79†	9.98±4.44
Blood volume (l/min)	0.07±0.03	0.08±0.03	0.11±0.06†	0.12±0.06
Posterior tibial artery				
Vascular diameter (cm)	0.18±0.04	0.19±0.05‡	0.22±0.06†	0.20±0.04
Blood flow velocity (m/s)	5.17±2.01	4.12±1.37*	7.61±3.50†	5.58±2.55*
Blood volume (l/min)	0.01±0.01	0.01±0.00	0.02±0.02†	0.01±0.01*

* Significant from baseline

† Significant between group at baseline

‡ Significant between group after Buerger's exercise

Discussion

Normally, diabetes patients have a reduction of blood flow and vessel size when compared with healthy individuals in both macro- and micro-vascular. Moreover, endothelial function of diabetes patients was impared by high blood sugar for a long time. However, the results showed diameter, blood flow velocity and volume of diabetes were greater than the healthy at baseline. In this study, diabetes participants consisted of 5 males and 13 females whereas 18 healthy subjects were female. Previous study reported that vascular diameter and blood flow in men were greater than women significantly (Joannides et al., 2002). So, there was a possibility that blood flow in diabetes was more than the healthy in the study.

At baseline, it was interesting that cholesterol and LDL in diabetes group less than the healthy. Previous study showed that LDL cholesteral was not elevated in type 2 DM. However diabetes patients was at high risk of high triglyceride and low HDL (Basa & Garber, 2001; "Dyslipidemia Management in Adults With Diabetes," 2004). Moreover, diabetes participants were routinely received cholesteral lowering drug.

The present study significantly showed immediate effects of Buerger's exercise in healthy individuals by improvement of popliteal diameter. In addition, position changes and gravitational effects of one session of Buerger's exercise showed the trend of improvement in blood flow velocity, blood volume and posterior tibial diameter. The possible mechanism of blood flow improvement by position changes may modulated by baroreceptor reflex (Crisafulli, Marongiu, & Ogoh, 2015). Moreover, popliteal blood flow and volume in diabetes trend to increase. According to previous study, the 8 weeks of Buerger's exercise in diabetes with neuropathy increased skin blood flow by measuring red blood cell concentration via near-infrared spectroscopy (Lin et al., 2018).

However, the study found that diameter, blood flow velocity and volume at posterior tibial artery were not responsed to one session of Buerger's exercise in diabetes. Based on the previous unpublished study, the immediate effects of these exercise may not improve diameter, blood flow velocity and volume at posterior tibial artery. However, there were significant increased of posterior tibial blood flow after 8 weeks of the exercise program. So, only one session of Buerger's exercise that consisted of gravitational effects and different positions may not enough for improve blood flow in diabetes.

In addition, popliteal and posterior tibial diameter in healthy subjects were better than the diabetes after exercise. These findings represented that the endothelial function of healthy was intact whereas that of diabetes was dysfunction. Endothelial dysfunction in diabetes may occurred by impaired

bioavailability and bioactivity of nitric oxide (Tessari et al., 2010). So, the response of blood flow to Buerger's exercise in diabetes were lower than healthy.

Suggestion

The present study showed the benefits of Buerger's exercise on leg blood flow. This study found that the diabetes participants was responsed to Buerger's exercise less than the healthy. However, one session of Buerger's exercise may not enough for increasing blood flow to lower extremities in diabetes patients. So, further study is needed to investigate short-term and long-term effects of Buerger's exercise to confirm the findings. In addition, some factors may effect to the results of this study such as gender and onset of diabetes. Furthermore, Buerger's exercise is alternative exercise for diabetes patients and suggested by therapist due to increasing of blood supply to the legs.

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