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PREVENTION & REHABILITATION: Randomized Clinical trial

The effects of passive stretching on the blood glucose levels of patients with type 2 diabetes

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ABSTRACT

Background: Type 2 diabetes is characterized by poor glycemic control due to decreased insulin sensitivity. Physical activity plays an important role in the management of diabetes and reduces blood glucose level. The aim of this study was to evaluate the effectiveness of passive stretching (PS) on the blood glucose level (BGL) of diabetic patients.
Materials and methods: In this randomized clinical trial, fifty patients with type 2 diabetes and mean age of 50.7 ± 4.8 years were randomly and equally allocated into control and intervention groups. Patients in the intervention and control groups underwent 20 min of passive stretching (PS) and passive movement (PM), respectively. BGL was measured before and immediately after, 20 min after and 1 h after PS/PM in the two study groups. BGL at the mentioned times was compared between and within the groups.
Results: The findings showed that when compared with before the PS (195.7 ± 30.1), BGL significantly reduced ($p < 0.001$) immediately after (178.9 ± 29.7), 20 min after (183.2 ± 29.1), and 1 h after (187.8 ± 29.6) the PS. However, BGL after PM (immediately, 20 min and 1 h after PM) did not significantly change ($p > 0.05$).
Conclusion: The findings of this study indicated that PS has a significant effect on the reduction of the immediate BGL in type 2 diabetic patients. The trend reduced even though the effect remained for 1 h after PS. It is therefore suggested that the effectiveness of these types of activities should be evaluated over a longer duration of study.

1. Background

Type 2 diabetes is one of the common chronic metabolic disorders with a high rate of fatal chronic condition, morbidity and mortality. It is characterized by a poor glycemic control caused by decreased insulin sensitivity (Rao Kondapally Seshasai et al., 2011, Wu et al., 2014). According to the report of International Diabetes Federation in 2015, 415 million people suffer from the disease worldwide and the rate will increase to 642 million cases in 2040 (Guariguata et al., 2014).

Prolonged hyperglycemia in diabetic patients results in different micro- and macro-vascular complications, which consequently affect their life qualities. Furthermore, diabetic patients are susceptible to various musculoskeletal disorders resulting from glycation and shortening of peri-articular tissues (Venkataraman et al., 2013; Wyatt and Ferrance, 2006).

The increasing global trend of type 2 diabetes has been well established. The main reasons for the projected rate reported are epidemiologic and nutritional transitions, including unhealthy dietary habits combined with lower levels of physical activity (Mattei et al., 2015; Drewnowski and Popkin, 1997).

As a part of lifestyle modification, physical activity plays an important role in the prevention and better management of the disease, as well as its related co-morbidities. It is well established that diabetic patients substantially benefit from different types of physical activities. They are recommended to have at least 150 min of moderate to vigorous aerobic exercise per week for better management of the disease (Van Dijk et al., 2012; Armstrong and Sigal, 2015). Muscle contraction during physical activity reduces the periods of daily hyperglycemia by triggering cellular glucose

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uptake (Manders et al., 2010; Hawley and Lessard, 2008).

However, evidence shows that many diabetic patients cannot achieve the recommended levels of physical activity due to the occurrence of different diabetes complications identified. In addition, most of the patients are elderly people with different disabilities that prevent them from performing the exercises (Zarowitz et al., 2006).

Recently, the usefulness of other types of physical activities, such as passive stretching (PS) was reported in this regard. Accordingly, these types of training could result in a better glycemic control, improvement of muscle function and joint mobility, and consequently amelioration of life quality (Nelson et al., 2011; Park, 2015; Solomen et al., 2015).

2. Objectives

Considering the increasing trend of type 2 diabetes and its related complications, as well as the roles of different methods of lifestyle modification in the prevention of the disease and reduction of its consequences, it is suggested that PS as a form of physical activity, be mainly practiced by the disabled or elderly patients. In this study, the effectiveness of PS alone on the blood glucose level (BGL) of diabetic patients was accurately and double blindly evaluated using a real and specific control group involved in passive movement (PM).

3. Materials and methodes

3.1. Participants

In this randomized trial, 50 patients with type 2 diabetes (40 male and 10 female) were recruited according to the inclusion and exclusion criteria. Diabetic patients aged 40–65 years with a body mass index (BMI) between 22 and 25 kg/m^2, a history of more than 6 months of diabetes and fasting blood glucose of ≥ 126 mg/dl were included in this study (Sigal et al., 2006). Those with a high blood pressure (>=160/95 mmHg), a history of limb surgery or fracture, instability in the joints, and acute muscular pain or soft tissue contracture, as well as those who had a regular physical activity twice a week or more were excluded from the study (Kisner and Colby, 2012).

The study protocol was approved by the Institutional Review Board of Physiotherapy Department and Regional Ethics Committee of Isfahan University of Medical Sciences. A written informed consent was obtained from each participant after explaining the study and its methods to them.

3.2. Sampling method

The participants were selected from patients referred to the Diabetes Clinic of Ardekan City, Isfahan University of Medical Sciences from April to August of 2015, through convenience sampling method. The selected patients were randomly divided into the PS and PM groups by simple randomization using random-number table (see Fig. 1).

3.3. Data collection

The baseline characteristics of all the studied patients were recorded from their medical files in the diabetes clinic. All of them were clinically examined by an expert physician (endocrinologist) and results were recorded for each. All the selected patients were under a similar treatment of the standard protocol of type 2 diabetes management while they were asked to follow the recommended diet 48 h before the study and continue their current treatment regimen for diabetes.

The selected patients were randomly divided into the two groups: PS and PM groups. Patients in the two studied groups were advised to follow the diet recommended by endocrinologist. Accordingly, 48 h before the study, the patients were advised to take similar diet. In addition, the recommended time for dinner and medication was similar. All of them were asked to avoid any intake after dinner before the intervention.

Patients in the PS group underwent a 20-min intervention with PS. The intervention consisted of 4 and 6 upper and lower body PS, respectively. During each stretch, the muscle was held in a stretched position for 30 s for 4 times. A 15-s relaxation interval was considered for the repetition of each stretch. A 30-s interval was considered between two different stretches (Nelson et al., 2011). The details of the stretches used in the intervention are described in Table 1 (see Table 1). Patients in the PM group followed the same movements with the same relaxation and movement times for their upper and lower extremities but without any sensation of muscle stretching. PS was administered by a physical therapist in such a way that all periarticular structures and muscles could stretch through the end range of motion and the participant could have a strong but tolerable feeling of muscular stretching. PM was administered by the physical therapist through the range of motion but the participant had no feeling of muscular stretching in the end range of motion. Both PS and PM were performed by a physical therapist.

Both participants and those who performed the sampling and biochemical measurements were blinded to the grouping.

Blood glucose level (BGL) was measured before the stretches and immediately, 20 min and 1 h after the stretches. It was also measured at the mentioned times in the control group, that is, before, immediately, 20 min and 1 h after the movements.

The BGL was measured from the drops of blood taken from a finger prick using a calibrated glucometer, the Accu-Chek Performa (Roche Diagnostics, Penzberg, Germany). The fingertips of patients were cleaned with alcohol before blood sampling. Accuracy of the device was checked before the measurements and the strips were utilized according to the manufacturer's instructions.

3.4. Statistical analysis

The data were analyzed using SPSS, version 20 (SPSS Inc. Chicago, IL, U.S.A). The normal distribution of the studied variables was evaluated using Shapiro-Wilk test. The studied variables in the two groups and at different times were compared using *t*-test, repeated measures analysis of variance (ANOVA) and analysis of covariance (ANCOVA). The level of significance was set at $p < 0.05$.

4. Results

In this study, 50 diabetic patients (40 males and 10 females) were randomly allocated into the control (25 subjects) and intervention (25 subjects) groups with the mean values of the following variables: age, 50.7 ± 4.8 years; weight, 70.05 ± 7.4 kg; height, 171.45 ± 5.2 cm; BMI, 23.8 ± 1.95. No significant difference was observed in age, weight, height and BMI between the two studied groups ($p > 0.05$ in all instances) (see Table 2).

At baseline, BGL was not significantly different between the groups ($p = 0.84$). The BGLs immediately, 20 min and 1 h after the interventions were significantly low in the PS as compared to the PM (control) group ($p < 0.001$ in all instances) (see Table 3).

Comparisons in the control group indicated that the BGL did not change significantly during the measurements ($p = 0.11$), while it showed a sudden significant decrease immediately after the stretch. BGL started to increase after that, but after 1 h, it was still significantly lower than baseline level (see Fig. 2).

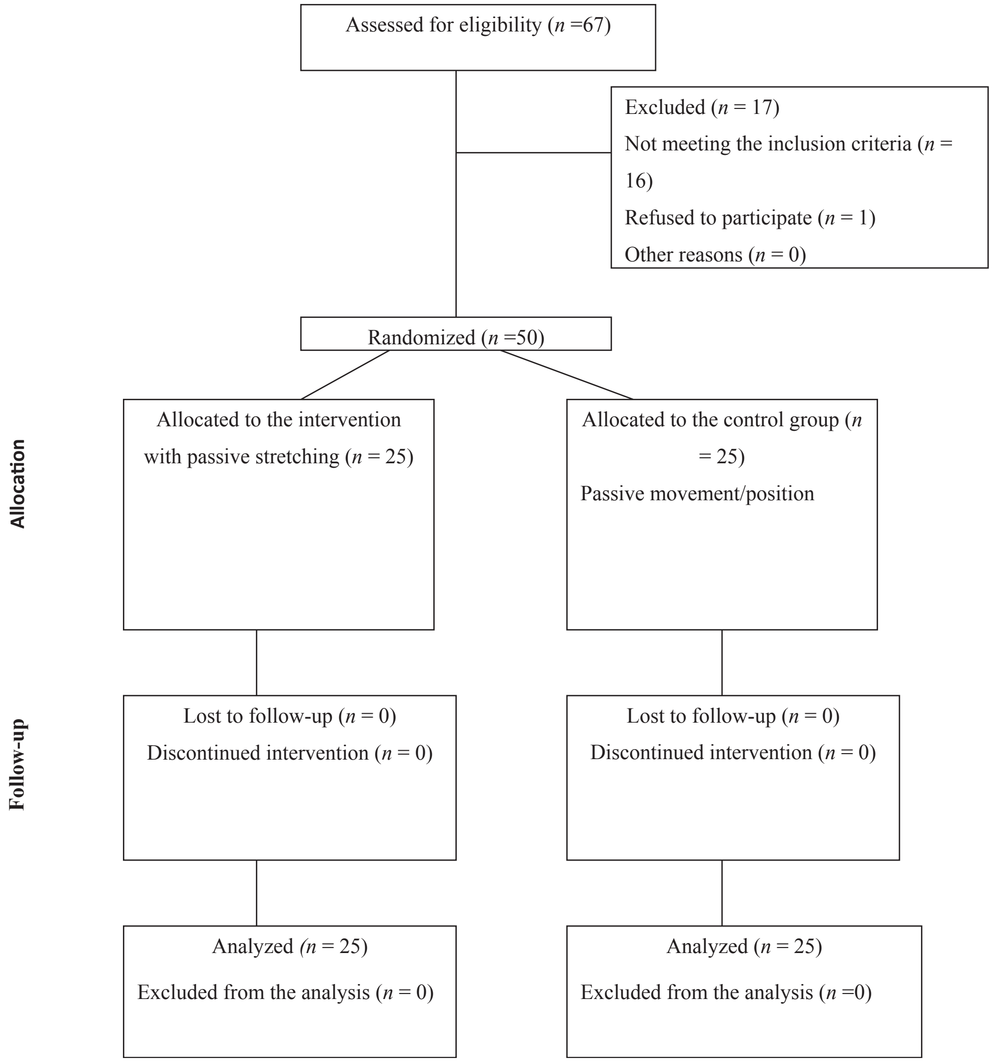

Fig. 1. A consort diagram of the clinical trial.

Table 1
Description of the stretches used during the intervention for type 2 diabetic patients.

Muscle	Description
Knee flexor (bilateral)	Each person sat on the floor with the legs extended and arms above the head. From this position, each person lowered their head towards the knees, while the experimenter pushed down on their back.
Knee flexor – hip adductor (bilateral)	The participants sat on the floor in the “lotus position”. From this position, each person lowered their head towards the floor, while the experimenter pushed down on their back.
Shoulder lateral flexor (bilateral)	The participants sat on a chair with fingers interlocked and placed behind the head. Keeping the arms in this position, the experimenter stood behind the person and pulled the elbows back towards the body's midline
Supine hip flexor-knee extensor (unilateral)	The participants laid on their backs with their leg hanging over the edge of the table and the knee flexed at approximately 90°. The hip was then hyperextended by the experimenter pushing down on the thigh.
Hip external rotators, extensors (unilateral)	Each person sat on the floor with one leg extended. The opposite leg was flexed at the knee, and the foot placed flat against the extended leg's inner thigh. The participants then lowered their head towards the extended knee, while the experimenter pushed down on their back.
Shoulder extensors, adductors, retractors (unilateral)	While seated on a chair, each person extended one arm and placed it horizontally across the front of the chest. The experimenter stood behind the person, took hold of the wrist and pulled the arm against the chest as much as possible while keeping the arm parallel to the floor.
Supine knee flexor-plantar flexor (unilateral)	Participants laid on their back with the legs extended. The experimenter then raised one leg, and simultaneously flexed the hip and dorsiflexed the ankle.
Prone hip flexor (unilateral)	Participants laid on their stomach and flexed one knee at approximately 60°. Keeping the knee at the flexed position, the experimenter lifted the thigh to hyperextend the hip.
Shoulder flexors, depressors (bilateral)	Each subject sat on the floor with the legs extended. The experimenter then grabbed the wrists and, while keeping the back and elbows straight, hyperextended the shoulder by raising the arms behind the back and up towards the head.
Shoulder and elbow flexors (unilateral)	Each subject sat on the floor with the legs extended, with one elbow flexed and brought up near the ear. From this position, the shoulder was hyperflexed by the experimenter pushing the upper arm down towards the floor.

Table 2
Sample characteristics[a,b].

Variables	Passive stretch	Passive movement	P. value
Number of subjects	25	25	
Gender (male/female)	20/5	20/5	
Age (year)	50.4(4.8)	50.9(4.8)	0.68
Weight (kg)	70.8(7.9)	69.3(6.9)	0.49
Height (cm)	171.3(5.2)	171.6(5.2)	0.87
BMI (kg/m^2)	24.1(2.01)	23.5(1.9)	0.35

[a] Values are presented as mean (SD).
[b] Abbreviations: kg: kilogram; cm: centimeter; BMI: body mass index; m: meter.

Table 3
BGL in the passive stretching vs. passive movement groups at different times[a,b].

Time interval	Passive stretch	Passive movement	P. Value
Baseline	195.7(30.1)	197.7(38.8)	0.84
Immediately	178.9(29.7)	196.5(38.3)	< **0.001***
After 20 min	183.2(29.1)	197.4(37.9)	< **0.001***
After 1 h	187.8(29.6)	197.8(38.01)	< **0.001***

*Statistically significant.
[a] Values are presented as mean (SD).
[b] Abbreviations: BGL: blood glucose level; min: minute; h: hour.

5. Discussion

In this trial, the effects of PS in comparison with PM on the BGLs of type 2 diabetic patients were evaluated. The findings indicated that PS as a subgroup of physical activity could reduce BGL in this group of patients and its immediate effect was more significant than its long-term effect.

Although, several studies have confirmed the usefulness of physical activity in the proper glycemic (Park, 2015) and metabolic control of diabetic patients (Geidl and Pfeifer, 2011), there are few studies on the effectiveness of PS in the glycemic control of these patients.

The first study in this field was conducted by Nelson et al. in the USA. They investigated the effectiveness of 20-min PS on the BGL among 22 adult diabetic patients or those who were at a higher risk of diabetes. Their results showed that the static stretching of skeletal muscles in this high-risk population could reduce BGL. They concluded that passive static stretching could be used by diabetic patients for the appropriate control of blood glucose, as an alternative to routine exercises (Nelson et al., 2011).

In another study carried out in Korea, Park studied the consequences of passive static stretching on the BGLs of 15 patients with type 2 diabetes. They evaluated the effectiveness of PS by measuring both blood glucose and glycated hemoglobin before and 8 weeks after the intervention, and also investigated the long-term effects of the intervention with a longer period of intervention. They concluded that PS could be used to achieve an appropriate glycemic control as compared to other active exercises (Park, 2015).

In a pilot study conducted in India recently, Solomen et al. evaluated the impacts of 40 min of both active and passive stretching on the immediate BGL among 20 patients with type 2 diabetes. Their findings indicated that both groups had a significant reduction in their immediate BGLs. The effectiveness of passive stretching in reducing BGL immediately after stretching was more significant than that of active stretching (Solomen et al., 2015).

Given that genetic factors or ethnic variations could possibly affect the effectiveness of some therapeutic or interventional methods, this study was conducted among Iranian population. The results are similar to those reported in the mentioned studies. PS resulted in a significant reduction in the immediate BGLs of diabetic patients. Similar to the results reported by Nelson et al. (2011), the most significant effect was seen immediately after the intervention though the reduction rate persisted for 20 and 60 min after the intervention.

Evidence from both animal (Roberts et al., 1997; Ho et al., 2004) and human (Nelson et al., 2011; Dohm, 2002) studies indicated the effectiveness of PS in the reduction of BGL. Accordingly, PS of skeletal muscles could reduce BGL by increasing glucose uptake in muscle cells through the following mechanisms: inducing skeletal muscle ischemia, increasing glucose transporter type 4 (GLUT-4) levels in the muscles, and enhancing nitric oxide levels and Mitogen-Activated Protein Kinase (MAPK) (Poole et al., 1997; Dohm, 2002; Roberts et al., 1997; Ho et al., 2004).

It is suggested that continued multiple daily implementation of

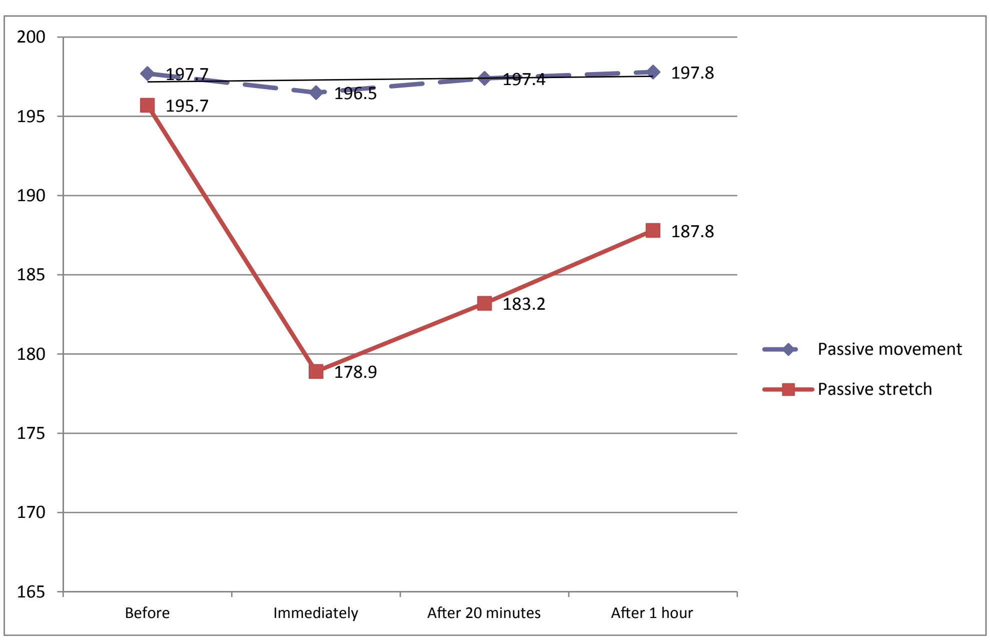

Fig. 2. The blood glucose level before, immediately, 20 min and 1 h after passive stretching/passive movement in type 2 diabetic patients.

PS can be more effective in the proper glycemic control and consequently metabolic control of diabetic patients, which may prevent the occurrence of diabetes-related micro- and macro-vascular complications. Furthermore, due to the fact that this type of exercise can be used by patients with different disabilities, it does not need any additional facility, equipment and cost, it seems it can be readily introduced to primary care physicians to recommend it to their patients during a routine diabetes management and follow-up process.

Limitations of the current study were the small sample size, especially that of the female patients, and short duration of the intervention. The sample size was larger than those reported in previous studies, yet, larger sample sizes are required to achieve more favorable results (Nelson et al., 2011; Park, 2015; Solomen et al., 2015). The difference and strength of the current study is that the control group underwent the same movements without stretching and in a completely similar way as the case group.

The findings of this study indicated that PS had a significant effect on reduction of the immediate BGL after training in type 2 diabetic patients. Though, the effect remained 1 h after training, it showed a decreasing trend and it is thus suggested that the effectiveness of these types of movements be evaluated in a long-term period with a longer duration of study.

However, for assessment of the effectiveness of PS in the glycemic control and consequent prevention of diabetes-related complications, a long-term intervention is needed. In addition, it would be more favorable to compare the effectiveness of different types of physical activities with varied types of PS. It is also suggested to study the long-term effect of PS on biochemical and metabolic factors such as lipids, HbA1c and inflammatory factors.

Conflicts of interest

None.

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