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Effects of moderate exercise versus light exercise on fasting blood glucose in obese patients with type 2 diabetes mellitus

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Abstract

Introduction. Diabetes is an important cause of mortality throughout the world. Type 2 diabetes mellitus (T2DM) is characterised by hyperglycaemia and obesity, which are aggravated by a sedentary lifestyle. The consequences of long-term hyperglycaemia include neurological or vascular complications and can lead to amputation, retinopathy, kidney failure, or other severe complications and a consequently poor quality of life. This study was conducted to report the effect of moderate exercise versus light exercise on fasting blood glucose in obese patients with T2DM.

Methods. For three months, 60 patients with sedentary lifestyles aged 35 to 60 years were randomly assigned to one of two groups in this two-arm cluster randomised controlled trial. Group 1 received 30 minutes of treadmill walking at 40–60% of maximum heart rate. Group 2 was given 30 minutes of treadmill walking per day, divided into 5 minutes every 2 hours.

Results. At baseline, no significant difference was found between both groups in BMI, waist-to-hip ratio, 6-minute walk, fasting blood glucose and SF-36. After three months of treatment, there was no significant difference in BMI ($p = 0.111$), waist-to-hip ratio ($p = 0.271$), 6-minute walk ($p = 0.614$), blood glucose ($p = 0.105$), or SF-36 ($p = 0.106$) between the two groups, despite the fact that among each group, significant differences for all analysed parameters were observed.

Conclusions. Repeated short walking has a similar effect on blood glucose, obesity, and quality of life as continuous long walking. Walking for 5 minutes every 2 hours may be a useful alternative for patients with T2DM.

Key words: diabetes mellitus, moderate exercises, light exercises, obesity, sedentary behaviour

Introduction

Diabetes mellitus type two (T2DM) is a major threat to public health, manifested by high blood glucose levels due to a lack of insulin or the ineffective use of insulin by the human body. Patients with T2DM account for 90% of patients with diabetes, and they are frequently affected by overweight or obesity, so they spend the majority of their time sedentary. Physical inactivity and obesity are important contributors to the incidence of T2DM [1]. The time spent sitting increases the risk of diabetes, increases harmful blood lipids such as triglycerides, low-density lipoproteins and very-low-density lipoproteins, increases blood pressure, accelerates decline in functional status, and decreases the strength of the muscles. The net result is poorer long-term mortality outcomes, and this is not related to the quality of physical activity [2, 3]. Sedentary behaviour is defined as any waking behaviour characterised by an energy expenditure of 1.5 metabolic equivalents (METs) while recumbent or sitting, as well as a decrease or absence of physical activity. Sedentary behaviour and physical activity are negatively correlated in bivariate analysis [4]. In sedentary behaviour, the use of skeletal muscles is diminished, which leads to a rapid decline in the strength of muscles and functional status. Sustained sedentary behaviour, especially after a meal, diminishes glucose uptake from the bloodstream and, with the secretion of more insulin by the pancreas, increases the risk of cell dysfunction [5]. Within the same age group, elderly diabetic patients have lower muscle mass and muscle strength compared to non-diabetics. Muscles play an important role in glucose transportation and uptake, so a decrease in muscle mass and strength results in longer exposure to high circulating insulin and decreased insulin-mediated glucose uptake by skeletal muscle. This hyperinsulinemia increases adiposity and worsens insulin resistance, which results from the promotion of lipogenesis and uptake of fatty acids into adipose tissue [6].

Åsvold et al. [7] stated that diabetes risk is increased after sitting for 8 hours a day among subjects with little leisure-time physical activity, even after adjustment for BMI. In the presence of regular moderate-to-vigorous intensity physical activity, sitting 5 hours daily was still associated with about 30% of diabetes incidence due to long periods of sedentary behaviour, increased fasting blood glucose levels, and insulin resistance. Intermittent light-intensity activity such as gentle walking is sufficient to reduce sedentary behaviour and ameliorate this effect. Current public health guidelines state that physical activity with moderate intensity and progress to vigorous physical activity is indicated to decrease chronic diseases such as T2DM, increased blood lipids, high blood pressure, and the risk of all-cause mortality [8].

Weight management and physical training are the cornerstones of controlling blood glucose, in addition to medications for T2DM. Physical training consists of aerobic exercises such as cycling, jogging, walking, and resistance exercises, or a combination of these, involving the use of large muscle groups [9].

Walking is an aerobic exercise that is accessible to most people, does not require any equipment, and has lower costs when compared to clinic attendance. It can also help with blood glucose control.

Walking involves the use of large muscles, such as the quadriceps. Repeated muscle contraction stimulates glucose uptake and transportation in muscles mediated by both the insulin and contraction-mediated (insulin-independent) glucose uptake pathways and increases energy expenditure.

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Regularly replacing long periods of sitting time with short periods of light activity, such as standing or walking, can improve glycemic control in healthy subjects and those with T2DM [10].

This study was conducted to measure the effects of 30 minutes of walking at 40–60% of maximum heart rate, 3 times/week against repeated short work for 5 minutes at 40–60% of maximum heart rate, every 2 hours for 12 hours daily on quality of life, obesity, and blood glucose in patients with T2DM.

Subjects and methods

Inclusion criteria:

1 – T2DM (according to the diagnosis of the referred physician).

2 – Age between 35 and 60.

3 – BMI ≥ 30.

4 – Sedentary lifestyle (did not participate in any type of physical activity in the last 6 months).

Exclusion criteria:

1 – Renal failure with a GFR of less than 60 mL/min/1.73m^2.

2 – Cardiac or pulmonary disease, which were contraindications to physical activity in the opinion of the doctor caring for the patient.

3 – Any lower limb diseases or fractures that could affect the results of the study.

This three-month randomised controlled trial used two arms to divide the subjects into two groups, with an odd hospital admission number designated as group 1 and an even hospital admission number designated as group 2. Group 1 received 30-minute sessions of treadmill walking at 40–60% of the maximum heart rate 3 times weekly. Group 2 was treated by treadmill walking for 30 minutes daily at 40–60% of maximum heart rate, divided into 5 minutes every 2 hours for 12 hours. All patients were on an adjusted low-carbohydrate diet.

The study procedures were performed in the physical therapy unit in the department of internal medicine at Cairo University hospitals and were carried out in compliance with the Declaration of Helsinki and the ethical committee of the faculty of physical therapy REC/012/002607. All patients who agreed to participate in the study signed an informed consent form. The study was registered at www.clinicaltrials.gov, NCT 04622371.

Randomisation

This three-month randomised controlled trial used two arms to divide the subjects into two groups, with an odd hospital admission number designated as group 1 and an even hospital admission number designated as group 2. All the procedures were explained to the patients, and all patients signed an informed consent form, except 5 patients who refused to sign the informed consent and were excluded from the study. This left thirty-three patients in group 1 and 32 patients in group 2. Three patients dropped out of group 1 and were excluded from the study. Two patients did not continue the programmed treatment in group 2, and their data was removed. Thirty patients in each group completed the treatment program. See Figure 1.

Intervention

Three times per week, group 1 received 30-minute sessions of treadmill walking at 40–60% of the maximum heart rate. Group 2 was treated by treadmill walking at 40–60% of the maximum heart rate for 30 minutes daily, divided into 5 minutes every 2 hours for 12 hours. The original Borg Scale assessed the perception of exercise intensity.

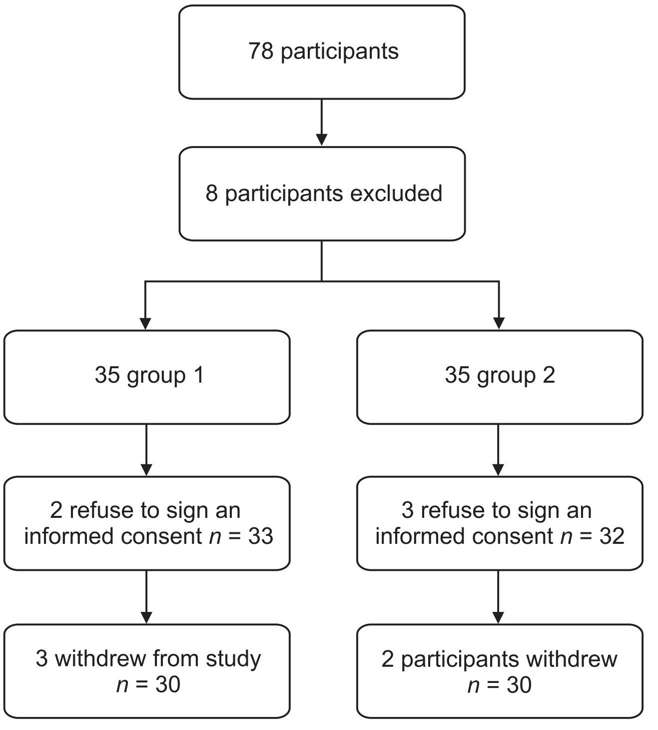


Figure 1. Consort flow chart

Measurements

The following parameters were measured pre- and post-treatment after 3 months:

1 – BMI.

2 – Waist-to-hip ratio (WHR).

3 – Six-minute walk test (6MWT).

4 – Fasting blood glucose (BG) is measured before each exercise session in the morning.

5 – 36-Item Short-Form (SF-36) Health Survey, submitted by the National Center for Interprofessional Practice and Education on Oct 21, 2016, is used to evaluate a patient's quality of life using the items: physical functioning, role-physical functions, bodily pain, overall health, vitality, social functioning, role-emotional functions, and mental health. The items' results were classified and summed up. A value between 0 and 100 represents the entire score.

Statistical analysis

The collected data was statistically described in terms of mean ± *SD*; the collected data was fed into a computer for statistical analysis and the statistical significance was at a confidence level of 95%. All statistical calculations were carried out using Microsoft Excel 2010 (Microsoft Corporation, New York, USA) and Minitab version 19.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, followed the tenets of the Declaration of Helsinki, and has been approved by the ethical committee of Faculty of Physical Therapy Cairo University Hospitals, Giza, Egypt REC/012/002607. It was also registered in www.clinicaltrials.gov, NCT 04622371.

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

Seventy-eight patients from the department of internal medicine chose to participate in the study, but eight were excluded, leaving 70 participants (41 females and 29 males) with a BMI of over 25. The age range was 35–60, which represents the most common age of the individuals hospitalised in our department. Three of the original 78 patients had chronic renal failure, three had cardiopulmonary diseases, and two had severe osteoarthritis of the knees, so these eight patients were excluded.

At the beginning of the study, analysis of demographic data showed that the differences were not significant between groups in age, $p = 0.243$, sex, $p = 0.326$, and height, $p = 0.765$, as shown in Table 1. The difference between both groups in waist circumference pretreatment ($p = 0.795$) was non-significant, but after treatment there was a significant difference in waist circumference among each group (group 1, $p = 0.000$, and group 2, $p = 0.000$). A non-significant difference in waist circumference was found between groups after treatment, $p = 0.205$ (Table 1). No significant difference was found between both groups in weight pretreatment, $p = 0.643$, but after treatment there was a significant difference between group 1, $p = 0.035$ and group 2, $p = 0.000$. There was a post-treatment, non-significant difference between groups, $p = 0.280$ (Table 1). Pretreatment, the results indicate a non-significant difference between groups in BMI, waist-to-hip ratio, 6-minute walk test, blood glucose and SF-36 (Figure 2, 3).

After treatment, there were significant differences in BMI, waist-to-hip ratio, 6-minute walk test, blood glucose and SF-36 in-group 1, as shown in Figure 2 and 3. In group 2, after treatment, there were significant differences in BMI, waist-to-hip ratio, 6-minute walk test, blood glucose and SF-36. Non-significant differences in BMI, waist-to-hip ratio, 6-minute walk test, blood glucose and SF-36 were found between both groups post treatment (Table 2).

Discussion

Both aerobic and resistance exercises have a significant effect on the treatment of diabetes mellitus; they lower blood glucose, improve physical performance, and lower the de-

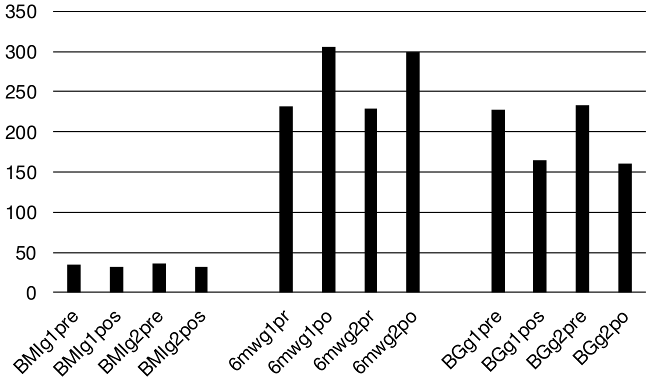
Table 1. Demographic data of both groups

Item	Group 1 pre	Group 2 pre	*p*-value	Group 1 post	Group 2 post	*p*-value
Age (years)	43.47 ± 9.25	45.70 ± 7.25	0.243			
Sex	1.33 ± 0.47	1.36 ± 0.49	0.326			
Waist circumference (cm)	118.10 ± 19.55	117.77 ± 18.9	0.759	108.33 ± 19.93	110.07 ± 19.49	0.205
Weight (kg)	97.9 ± 14.19	98.13 ± 14.14	0.643	90.53 ± 20.63	94.33 ± 14.06	0.280
Height (cm)	160.37 ± 8.21	160.70 ± 11.16	0.765			

Table 2. Difference between parameters before and after the intervention period for both groups

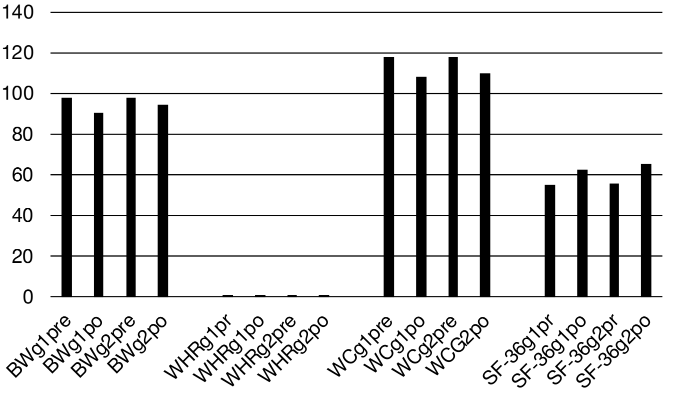
Item	Group 1 pre	Group 1 post	*p*-value	Group 2 pre	Group 2 post	*p*-value	Difference between groups pre	Difference between groups post
BMI	34.8 ± 5.8	31.7 ± 1.4	0.000	35.8 ± 1.5	32.3 ± 0.9	0.000	0.310	0.111
WHR	1.39 ± 0.14	1.16 ± 0.12	0.000	1.37 ± 0.12	1.12 ± 0.11	0.000	0.478	0.271
6MWT	231.26 ± 39.26	306.03 ± 51	0.000	228.5 ± 32.3	298.8 ± 68.2	0.000	0.745	0.614
BG	228.26 ± 12.3	164.46 ± 13.94	0.000	232.49 ± 9.2	159.97 ± 1.43	0.000	0.890	0.105
SF-36	55.54 ± 3.26	62.71 ± 10.04	0.000	55.6 ± 1.97	65.3 ± 1.9	0.000	0.928	0.106

BMI – body mass index, WHR – waist-to-hip ratio, 6MWT – 6-minute walk test, BG – blood glucose
SF-36 – 36-Item Short-Form Health Survey



g1 – group 1, g2 – group 2

Figure 2. Body mass index (BMI), 6-minute walk test (6MWT), blood glucose (BG) of both groups pre- and post-treatment



g1 – group 1, g2 – group 2

Figure 3. Body weight (BW), waist-to-hip ratio (WHR), waist circumference (WC), SF-36 of both groups before and after treatment in both groups

pression scale [11, 12]. However, despite the benefits of exercise [13], most people, particularly obese people, find it difficult to practice, so walking is a simple, easy, and inexpensive way to exercise. Walking for 30 minutes three times a week is regarded as moderate exercise and can be used to reduce T2DM and depression [14, 15].

The current study was conducted to measure and compare the effects of treadmill walking at 40–60% of maximum heart rate three times/week to repeated short treadmill walking for five minutes every two hours, six times daily at 40–60% of maximum heart rate on blood glucose in obese patients with T2DM. After three months, the results revealed a non-significant difference between both types of treatment in BMI ($p = 0.111$), WHR ($p = 0.270$), 6MWT ($p = 0.614$), blood glucose ($p = 0.105$), and SF-36, ($p = 0.106$).

It was noted that diabetic patients spend most of their time in a sedentary or inactive position due to their obesity. The more sedentary the person, the lower the insulin sensitivity, due to reduced peripheral blood flow in the lower limbs, which leads to abnormal glucose tolerance, especially in bedridden subjects. A study by Balkau et al. [16] on bedridden patients shows that daily bouts of exercise (1 hour/day) protect against continuous (> 23 hours/day) bed rest. Aerobic exercise, which uses groups of muscles such as the lower limb muscles, improves glucose transportation by increasing muscle stimulation to uptake glucose, as well as increasing energy expenditure, glucose tolerance, glucose control microvascular blood flow in the muscles, and muscle strength [17]. Repeated walking for five minutes every two hours may help increase blood flow, insulin sensitivity, and glucose control, which explains the 31% decrease in blood glucose found in group 2 using interrupted walking and the 28% decrease in group 1 using continuous walking ($p = 0.105$, non-significant difference).

Larsen et al. [18] compared prolonged sitting every day for 7 hours to 2-minute light-intensity walking breaks every 20 minutes for 7 hours daily for 3 days in either overweight or obese adults. They found that the walking breaks significantly reduced insulin and glucose compared to the prolonged sitting condition in the 7-day period, but walking breaks on subsequent days did not give further improvement in the glycemic response, with some effects persisting for up to 24 hours.

Way et al. [19] found that twenty to thirty minutes of moderate-intensity aerobic exercise, done three to four times weekly, is effective in providing regular stimulation, which activates blood glucose uptake and enhances insulin sensitivity. The effect of exercise therapy on insulin sensitivity lasts 72 hours after the last bout of exercise. In the present study, there was a 28% reduction in blood glucose in the continuous walking group after three months of exercise.

Wheeler et al. [20] stated that performing exercise in the morning does not fully compensate for the prolonged negative effects of sitting for the rest of the day. Similar insulin and glucose postprandial responses were found after light-to-moderate-intensity walking, which agrees with the current study's finding that repeated light walking exercises for short periods, even 5 minutes every 2 hours, could prevent the effect of sitting for long periods on blood glucose. The same results were observed in healthy, overweight, and obese adults who engaged in either light- or moderate-intensity walking as a method of breaking up sedentary behaviour [21].

Karstoft et al. [22] demonstrated that in individuals with T2DM, repeated cycles of three minutes of slow and fast walking at a one hour before meals decreased post-meal incremental blood glucose levels. This is due to increasing the energy expenditure through standing, walking, or cycling at a light-intensity (2 METs) done during the 8-hour workday, reducing the whole 24-hour and postprandial glucose levels.

Gillen et al. [23] discovered that a single high-intensity interval exercise session reduced hyperglycaemia in T2DM individuals for 24 hours, but they did not compare it to a non-interval exercise session. When compared to a low-intensity, non-interval exercise session, a single high-intensity, non-interval exercise session has been demonstrated to result in worse improvements in glycemic control [24].

It was found that blood glucose in T2DM decreased more after postprandial walking than after pre-dinner exercise, and this resulted from increased glucose uptake due to localised increases in contractile-mediated (insulin-independent) glucose transport and this provides evidence that brief activity can reduce glucose levels. Light walking every 2 hours involves walking after meals and leads to a decrease in blood glucose and increased energy expenditure. This decreased BMI ($p = 0.000$) and WHR ($p = 0.000$), and at the end of three months, it increased the 6-minute walking distance ($p = 0.000$) and quality of life as measured by SF-36 ($p = 0.000$). In addition, long walks need to be done before meals, as it is difficult for those with T2DM to walk after meals. This gives priority to repeated short walking, and 30 minutes of walking three times per week is difficult for obese patients.

Several studies, however, such as Bailey et al. [25], have investigated the effect of brief bouts of exercise on blood glucose levels. Dunstan et al. [26] have demonstrated that standing for 2–3 min or performing small bouts of physical activity at light-intensity to prevent long sitting every 30 minutes is coupled with an improved blood glucose and metabolic profile.

The same results were found by Dempsey et al. [27], who found that 2-min walking bouts every 20 min lowered postprandial glucose by 24% and insulin concentrations by 30% in 19 subjects with BMI above 25 and at risk for T2DM, irrespective of whether the bouts were of light- or moderate-intensity, when compared with prolonged sitting. Another study done by Chastin et al. [28] revealed that 5-min bouts of light standing or walking changed the long period of sitting and reduced postprandial glucose by 20% and insulin responses by 24% in postmenopausal women, and had high liability for T2DM.

Furthermore, Chen et al. [29] discovered that regular short bouts of walking without regard to mealtime reduced postprandial glycemic 48% and insulin 42%, and all these studies agree with the findings of the current study, which revealed that repeated short walking decreases blood glucose 31% and continuous walking decreases blood glucose 28%. The results showed that light repeated walking has a greater effect on decreasing blood glucose than moderate continuous walking.

Benatti et al. [30] discovered that doing light-intensity physical activity for a period of 1 min and 40 seconds to regularly break up prolonged sitting is more beneficial than one continuous 30-min session of moderate-to-vigorous intensity exercise in decreasing postprandial glucose and insulin concentration in normal adults with healthy weight, and this may be explained by the fact that breaking up sitting by walking requires additional energy, which is gained from carbohydrate oxidation. This oxidation of carbohydrates may be partly responsible for the relatively lower blood glucose observed in that trial, and also resulted in a decrease in BMI and WHR in patients with T2DM. The same results were found in the present study.

From the previous studies, we can conclude that dividing the exercise into multiple short periods of exercise with a period between 1.5 to 5 minutes was more beneficial than the same amount of continuous exercise for decreasing the level of blood glucose over 8–12 h due to repeated muscle contractions that act as a stimulus for glucose uptake through insulin-independent cellular mechanisms that facilitate removal of glucose from the circulation, and it is sufficient to reduce the postprandial level of blood glucose in obese and overweight adults, those with hyperglycaemia and plasma triacylglycerol, and in those taking oral glucose-lowering medication for T2DM [21].

Limitations

The study needs to be done on a larger number of patients, and follow-up of the results is required to document if the results last after stopping the exercises.

A comparison between healthy, obese and patients with diabetes would also be beneficial.

Conclusions

Short walks done repeatedly for a short period of 5 minutes every 2 hours have the same effect on blood glucose, obesity, and quality of life as long walks. Patients with T2DM may find that walking for 5 minutes every 2 hours is a good is a good alternative to long walks to improve the metabolic parameters such as weight and glycemia as well as QoL.

Disclosure statement

The author does not have any financial interest and did not receive any financial benefit from this research.

Conflict of interest

The author states no conflict of interest.

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