REVIEW ARTICLE

Effect of Physical Activity on Blood Glucose Level and HbA1c in People with Diabetes Mellitus: A Review

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ABSTRACT

Among people with diabetes mellitus (DM), the two common strategies for evaluate DM management to reduce diabetic complication are to manage blood glucose and HbA1c level in the normal range. However, the reduction of this two element resulting from various forms and durations of exercise remains a subject of debate. Therefore, this study reviewed the blood glucose and HbA1c reduction based on various physical activity (PA) and its duration. The articles were sourced from three main scientific databases resulting 38 for full-text analysis. The endurance exercise is most widely used as part of PA with average duration range between 30-60 minutes. The most decrease in HbA1c levels is in the range of 0-0.9% whereas reduction in blood glucose levels was 72-126 mg/dl. The clinicians might recommend people with DM to cycling or walking as part of endurance exercise for their PA at least 30-60 minutes to minimize the DM complication.
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INTRODUCTION

In 2021, the International Diabetes Federation reported that over 500 million people worldwide were living with diabetes mellitus (DM) (1). The global prevalence of DM is estimated to reach almost 800 million people in 2045 (1). In 2021, Southeast Asia ranks 3rd in the world after the Middle East and North America reached 90.2 million people which is expected to rise to over 150 million people in 2045 (1). The rising prevalence of DM may be attributed to lifestyle changes, including unhealthy diets and a lack of physical activity (2).

DM is a metabolic disease characterized by hyperglycaemia due to pancreas disturbance and/or insulin secretion and function disorder (2). Physical activity is one of aspect that can influence DM management (3). Physical activity plays a crucial role in DM prevention (4). The American Diabetes Association (ADA) (5) advises that people with DM should achieve sufficient physical activity to lessen the high levels of HbA1c (6) or excess BMI (7). Physical activity showed its importance in improving glycaemic management (6), supporting a healthy body weight (7), and reducing the risk of cardiovascular diseases (8). The ADA recommends people with DM engage in moderate-intensity aerobic exercise for at least 150 min per week or perform vigorous aerobic exercise for at least 75 min per week (9). Additionally, regular physical activity is advised to enhance overall health.

Exercise activates the sympathetic nervous system to maintain homeostasis during increased cardiovascular, respiratory, and metabolic demands, elevates plasma levels of cortisol, epinephrine, norepinephrine, and dopamine which return to basal levels post-exercise, and enhances insulin sensitivity over time, potentially affecting HbA1c levels through various mechanisms (10). A randomized clinical trial revealed that short-term exercise in people with type 2 DM at moderate intensity can reduce their blood glucose levels (11). A review by Haris et al., declared that physical activity such as walking in people with DM have slower speed

and higher blood glucose level than non-DM people (12). However, a study found that 12 weeks of resistance exercise training had no significant effect on blood glucose levels in people with DM type 2 (13). Moreover, a study exposed similar result that exercise does not have effect in blood glucose levels reduction in people with DM type 2 (14).

Appropriate physical activity is more advantageous in DM people for their blood glucose and HbA1c level management. Yet, different results were found and to the best our knowledge, there has not been much research regarding the type and duration of physical activity in reducing blood glucose levels and HbA1c. Therefore, this study analyses previous studies to find the types and duration of physical activity that reduce blood glucose levels and HbA1c in people with DM.

METHODOLOGY

In April 2023, we conducted a search for published articles across three databases: Taylor & Francis, PubMed, and Wiley. The search protocols were based on the Population, Intervention, Comparison, and Outcome (PICO) model, utilizing search terms such as "exercise OR physical activity AND diabetes NOT gestational NOT type 1 AND blood glucose." We applied specific inclusion and exclusion criteria to address the research objectives.

The data were processed using SPSS version 25. Cohen's Kappa statistics were calculated to assess the level of agreement between the two reviewers on the selected papers (15). The inclusion criteria for this study were as follows: (1) participants aged 18 years or older with type 2 DM; (2) studies written in English; (3) types of studies: experimental and non-experimental; (4) types of exposure: had physical activity as people with DM exercises; (5) types of outcomes: at least one of blood glucose level, HbA1c, blood glucose or HbA1c reduction, and physical activity. The study's exclusion criteria pertained to the types of studies: abstract-only publications (such as proceeding books, symposiums, and conferences), review papers, systematic reviews, literature reviews, meta-analyses, and protocols were excluded.

The selection process, based on the titles and abstracts of the identified studies, was independently conducted by two researchers (F.H. and F.S.) in accordance with the inclusion and exclusion criteria. They also independently analysed the selected studies. The agreement between the two reviewers for screening titles and abstracts was measured (Kappa = 0.754), as well as for full-text screening (Kappa = 0.721). Cohen suggested the Kappa values 0.61–0.80 as substantial (15). A third researcher (Y.P.) was consulted to resolve any disagreements between the two primary researchers, and they provided the final decision. However, there were no disagreements regarding the articles selected for this review.

A matrix table was developed to extract the data from the selected studies. The leading information to be collected was related to: (1) blood glucose and HbA1c reduction, (2) physical activity, and (3) duration of physical activity.

RESULTS

A total of 8992 papers were found. A total of 8,986 studies remained after eliminating duplicates (n=6). Following the review of titles and abstracts, 8,936 articles were removed, leaving 50 papers for full-text analysis. After carefully full-text analysis, 12 studies were excluded due to irrelevance, resulting in 38 articles included in the final analysis. Figure 1 illustrates the flow diagram of the study selection process for this review. Table I shows the selected 38 paper used in this review

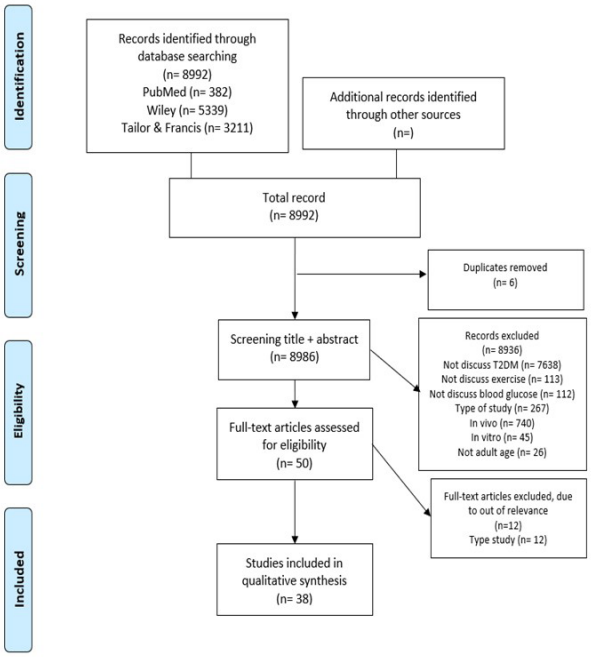

Figure 1: PRISMA diagram

Type of Physical Activity

Researchers grouped types of exercise into four, namely endurance exercise discussed in 33 journals (86.8%), strength exercise discussed in 13 journals (34.2%), flexibility exercise discussed in 5 journals (13.1%) and balance exercise discussed in 4 journals (10, 5%). The types of endurance exercise that are most often done are cycling and walking. The type of strength exercise that is most often done is resistance exercise training with upper and lower body exercises. The most widely used type of flexibility exercise is stretching. The most widely used type of balance exercise is yoga.

Physical Activity Duration

Exercise duration was categorized into 3 areas, 30-60

Table I. List of Articles in Systematic Review Research

Type of Physical Activity	Duration of Physical Activity	Frequency of Physical Activity	Study Population	Participants	Duration Of Study	Results	References
Tai Chi	60 Minutes	2x/week	DM Type 2 (39)	Tai Chi Diabetes vs Control Group	12 Weeks	12 weeks of Tai Chi Diabetes (TCD) program effectively reduced blood glucose and HbA1c levels in patients with DM Type 2.	(43)
Light ADL, continous cycling exercise	15 Minutes (ADL), 45 Minutes (exercise)	3x after meals (ADL) and 1x/day (exercise)	DM Type (20)	Control vs ADL vs Exercise	3 Days	45 Minutes of exercise is more effective in reducing the prevalence of hyperglycemia and ADL improves postprandial glycemic control although not significant in Type 2 DM patients.	(21)
AER (Treadmill, elliptical,cyclette) & RES (Weight Machine dan Free Machine)	40-60 Minutes	3x /weeks	DM Type 2 (25)	Aerobic Group vs Resistance Group	4 Months	Aerobic exercise is more significant in lowering blood sugar levels in Type 2 DM patients.	(35)
-Endurance Training: Cycling -Strength Training: angkat beban, sit up, bench press, chest cross), shoulder press, pull down, bicep curl leg press, calf raise dan leg extension..	15 Minutes	3x /weeks	DM Type 2 (15)	ET (Endurance Training) vs ST (Strength Training)	4 Months	ST had a significant effect on reducing blood sugar and ET had no significant effect and there was no significant decrease in HbA1c in both..	(16)
-Endurance training: cycling on bicycle ergometer. - Strength training: chest presses, seated rows, abdominal crunches, back extension, dan leg presses.	30-60 Minutes (30 Minutes cycling)	3x /weeks	DM Type 2 (30)	F (Training in the overnight-fasted state) vs C (Training in the fed state)	8 Weeks	There is no significant effect of lowering blood sugar on physical activity after 2 hours of eating and 12 hours after fasting in Type 2 DM patients.	(45)
Continous cycling on cycle ergometer	45-60 Minutes	1x/day	DM Type 2 (60)	Exercise vs Control	3 Days	The exercise group with moderate intensity training had a significantly greater reduction than the control group.	(19)
Cycling constant workload dan anaerobic threshold	Non-daily: 60 Minutes Daily: 30 Minutes	1x/Day	DM Type 2 (30)	Daily vs Non-daily vs Control	4 Days	30-Minutes regular exercise is as effective as 60-Minutes interval exercise in reducing blood glucose and glycemic control in patients with Type 2 diabetes.	(33)
-Walking meditation -Traditional Walking	50 Minutes (10 Minutes warm up, 30 Minutes walking, 10 Minutes cool down)	3x/week	DM Type 2 (23)	TW (Traditional Walking) vs WM (Buddhist Walking Meditation)	4 Months	Walking meditation that combines walking on a treadmill and mentioning BUD and DHA is more effective in lowering blood sugar levels in patients with Type 2 DM.	(24)
Cycling aerobic (upright bicycle ergometer)	60 Minutes	1x/week	DM Type 2 (9)	A (No exercise after oral consumption of 1.75 mg gliben clamide) vs B (exercise after placebo administration) vs C (Exercise after taking 1.75 mg) vs D (Exercise after taking 3.5 mg)	4 Days	The average decrease in blood glucose levels is effective in the combination of exercise and glibenclamide at the right dose in Type 2 DM patients.	(25)
Walking (aerobic walking)	60 Minutes	1x/day	DM Type 2 (11)	**IW1**(1 Minutes slow& 1 Minutes fast walking) vs **IW3** (3 Minutes slow& 3 Minutes fast walking) vs **CON** (without intervention)	2 Days	Interval walking of 3 Minutes (IW3) is recommended to improve post prandial glycemic control in Type 2 DM patients.	(27)
Aerobic exercise: lunge, step up and down, squat, calf raises, left right pivot, shoulder abduction with abduction bands and without bands while squatting, arm swinging with elastic bandage	30-60 Minutes	3x/ week	DM Type 2 (39)	Control vs Intervention group	12 Weeks	12 weeks of WBV-based intervention is easy, safe and effective to reduce HbA1c and blood glucose levels in Type 2 DM patients.	(46)
Elliptical trainer exercise	30 Minutes	3x /week	DM Type 2 (16)	Intervention group (High Intensity Interval Training on elliptical)	12 Weeks	There was no significant effect on reducing HbA1c post intervention but had a significant effect on fasting blood sugar levels in Type 2 DM patients.	(23)
-Yoga -Standard exercise (SE)	Yoga: 60 Minutes SE: 60 Minutes	2x /week	DM Type 2 (47)	Yoga vs Walking (SE)	12 Weeks	Yoga has a better long-term effect than standard exercise in controlling blood glucose.	(44)
WBE: Deep-water walking/ running with life vest. LBE: Walking/running on an athletic track.	45 Minutes	3x/Week	DM Type 2 (25)	WBE (Water-Based Exercise) Vs LBE (Land Based Exercise)	9 Weeks	Between the two Types, WBE and LBE have an acute response effect on glycemic control in Type 2 DM patients.	(47)

Table I. List of Articles in Systematic Review Research (continue)

Type of Physical Activity	Duration of Physical Activity	Frequency of Physical Activity	Study Population	Participants	Duration Of Study	Results	References
Walking program	2 jam setelah makan	2x/week	DM Type 2 (100)	DE (Diet exercise) vs D (Diet) vs C (Control)	8 Weeks	8 weeks intervention program for changing lifestyle diet and diet exercise has an impact on better glycemic control in Type 2 DM patients.	(50)
4 upper and 6 lower body exercise: -Passive Stretch -Passive Movement	20 Minutes	1x/Days	DM Type 2 (50)	PS (Passive Stretch) vs PM (Passive Movement)	1 Day	Passive stretching has a significant effect in acutely lowering blood glucose levels in type 2 DM.	(22)
Aerobic exercise: walking in treadmill	20 Minutes	1x / 2 Days	DM Type 2 (29)	MIE (Moderate Intensity Exercise) vs CON (Non Exercise Day)	7 Days	Short duration of moderate intensity exercise after eating can reduce blood sugar levels in type 2 DM patients.	(11)
Gym-based training program (cycling, walking, jogging, stepping, rowing) dan Home-based (walking, jogging, swimming)	Gym-based: 60 Minutes Home-based: 30 Minutes	150 Minutes/ week minimal	DM Type 2 (132)	ET (Exercise training) vs control	4 Weeks	There were no significant results or effects on insulin sensitivity in type 2 DM patients.	(26)
'circuit' training (CT)	60 Minutes	3x/week	DM Type 2 (16)	Trained Group vs Untrained Group	8 Weeks	The results show that combined exercise significantly reduces blood glucose levels in type 2 DM patients.	(36)
Treadmill walking and stationary cycling	60 Minutes	1x/ Days	DM Type 2 (13)	7D-EX	6 Days	There were no significant results between respondents who carried out daily activities and aerobic exercise within 7 days.	(42)
Cycling (cycle ergometer) and resistance exercise training	25 Minutes	4-5x /week	DM Type 2 (24)	Control vs Nil-Whey vs Whey-control	10 Weeks	There was no significant increase in blood sugar control during cycling & resistance exercise training for 10 weeks.	(17)
Walking on treadmill (moderate intensity training)	30 Minutes	3x/week	DM Type 2 (20)	Morning vs afternoon vs evening	12 Weeks	12 weeks moderate intensity training is safe and improves metabolic control in type 2 DM patients. Exercise in the morning has a greater impact on blood sugar control than exercise in the afternoon or evening.	(84)
Walking	10 Minutes	3x/Days	DM Type 2 (41)	Post meal walks vs 30 Minutes walks	2 Weeks	30 minutes of walking every day is significantly more effective in reducing blood glucose levels in Type 2 DM patients.	(20)
Walking on treadmill and cycling (cycle ergometer)	Week 1-4: 30 Minutes Week 5-8 :45 Minutes Week 9-12: 60 Minutes	5x/week	DM Type 2 (15)	HI-IE (High Intensity Interval Exercise) vs MI-CE (Moderate Intensity Interval Exercise)	12 Weeks	High Intensity Interval Exercise (HI-IE) is more influential in reducing CApBG	(32)
-Moderate exercise: brisk walking -Aerobic Exercise: cycling with cycle ergometer -Resistance training	Aerobic dan resistance training → 60 Minutes Moderate exercise → minimal 30 Minutes	3x/week	DM Type 2 (29)	PD (Paleolithic Diet) vs PD-EX (Paleolithic Diet and Exercise)	12 Weeks	12 weeks of paleolithic diet and exercise are effective in reducing HbA1c levels in Type 2 DM patients.	(39)
Walking/ running on treadmill (ETT)	10 Minutes	2 after meals/ Days	DM Type 2 (14)	Diabetes (D) vs control (C)	12 Weeks	Short-term submaximal exercise can reduce the frequency of hyperglycemia in type 2 DM patients during the recovery period	(85)
Cycling with cycle ergometer. Water break and three static stretches, seated low row, horizontal leg press, seated chest press and hamstring curls, and abdominal crunches.	60 Minutes	3x/ week	DM Type 2 (22)	MICT (moderate-intensity continuous training) vs HIIT (high- intensity interval training)	12 Weeks	HIIT is effective in significantly reducing blood sugar levels with an exercise duration of 60 minutes per session.	(41)
Kaimai-style Qigong	30 Minutes	3x/week	DM Type 2 (55)	Intervention vs Control Group	12 Weeks	Low intensity exercise has a significant effect on reducing HbA1c and fasting blood sugar when compared with the control group.	(49)
-Sham yoga -Yoga	75 Minutes	3-6x /week	DM Type 2 (40)	Yoga vs Sham Yoga	12 Weeks	There was no significant reduction between the results of the yoga and sham yoga interventions, however, yoga had a better reduction compared to sham yoga.	(48)
Jumping jacks	2 Minutes	After meal or minimal 3x/Days after meals	DM Type 2 (36)	**FL**(fruit last) vs FF (fruit first) vs **FL+PE** (fruit last +post exercise) vs **FF+PE** (fruit first+post exercise)	1 Week	post prandial exercise does not have an acute effect on blood glucose regulation in Type 2 DM patients. Post prandial exercise has a delayed effect on the patient's FBG.	(18)
Indoor cycling exercise virtual reality	50 Minutes	3x /week	DM Type 2 (41)	VRT (Virtual Reality Therapy Group) vs IBE (Indoor Bicycle Exercise Group) vs CG (Control)	2 Weeks	2 weeks of application of the Virtual Reality Exercise (VRT) program was able to reduce the average blood glucose in type 2 DM patients	(28)
- Cycling indoor - resistance exercise training	60 Minutes	2x /week	DM Type 2 (33)	Exercise plus liraglitude vs Exercise plus placebo	16 Weeks	Exercise plus liraglitude GLP-1RA for 16 weeks improves glycemic control and reduces blood glucose levels in Type 2 DM patients.	(37)

Table I. List of Articles in Systematic Review Research (continue)

Type of Physical Activity	Duration of Physical Activity	Frequency of Physical Activity	Study Population	Participants	Duration Of Study	Results	References
Exercising in Treadmill, Leg extension, knee flexion, leg curl and lat machines.	Fase: 1 (1-2 week): 30 Minutes 2 (3-6 week): 30 Minutes 3 (7-12 week): 40 Minutes	3x /week	DM Type 2(23)	Sedentary Control (SED) vs Interval Exercise Training (INT) vs Continous Exercise Training (CON)	12 Weeks	Interval Exercise Training (INT) has a significant reduction in HbA1c, between Interval Exercise Training (INT) and Continuous Exercise Training (CON) there is a significant reduction in fasting blood glucose. So INT is more effective in controlling blood sugar levels in Type 2 DM patients.	(38)
- Gym based training: Cycling & walking. -Aerobic training	60 Minutes	Minimal 150 Minutes/ week	DM Type 2 (34)	Short-term exercise	4 Weeks	Exercise for 4 weeks can reduce blood sugar levels acutely and increase the acute response to blood glucose in type 2 DM patients.	(34)
Cycling exercise on cycle ergometer	45-60 Minutes	1x/Days	DM Type 2 (9)	LI (Low Intensity) vs HI (High Intensity) vs NE (Non-Exercise)	2 Days	Low intensity cycling exercise is more consistent in reducing blood sugar levels and the prevalence of hyperglycemia in type 2 DM patients.	(29
Treadmill walking	40 Minutes: 5 Minutes warming up, 20 Minutes core movement, dan 5 Minutes cooling	1x /week	DM Type 2 (15)	HIIT (High Intensity Interval Training) vs MICT (Moderate Intensity Continous Training) vs Control	3 Weeks	Treadmill walking in HIIT has a greater impact in reducing blood sugar without side effects compared to MICT.	(30)
Cycling on a bicycle ergometer. - Resistance upper and lower body exercise	60 Minutes	1x /Day	DM Type 2 (11)	Day 1 (pre-intervensi) vs Day 2 (post-intervensi)	5 Days	Acute exercise substantially reduces the prevalence of hyperglycemia in the long term but does not significantly reduce blood sugar levels in type 2 DM patients.	(40)
Light walk (5 Minutes), treadmill, and Anaerobic threshold	Continous→35 Minutes Interval→ 45 Minutes	2x /week	DM Type 2 (14)	Continous vs Interval Group	8 Weeks	Reducing blood sugar levels in both the continuous and interval groups had a significant reduction in Type 2 DM patients.	(31

minutes discussed in 30 journals (78.9%), <30 minutes discussed in 9 journals (23.6%), and >60 minutes discussed in 1 journal (2.6%). From the <30 minutes category, results were obtained including strength and endurance exercise (16, 17), endurance exercise (11, 18-21), flexibility exercise (22). The type of exercise that is most widely used in the <30-minute category is endurance exercise. In the <30 minutes category, the decrease in HbA1c ranged from 0-0.9%, obtained from the journal (16). Post-intervention fasting blood glucose levels in the range of 72-126 mg/dl were found in the journals (16, 18, 19). Blood glucose levels 2 hours post prandial (≤156 mg/dl) post intervention are available in the journal (11).

In the 30-60 minute category, endurance exercise results were obtained (Chiang et al., 2019; del Pozo-Cruz et al., 2014; Delevatti et al., 2016(19, 23-33), strength training (34), strength and endurance exercise (35-41), flexibility exercise (42), balance exercise (43), flexibility and balance exercises (44), strength and balance exercises (45). The type of exercise that is most widely used in the 30–60-minute category is endurance exercise. In the 30-60 minute category, the decrease in HbA1c in the range of 0-0.9% was obtained from the journals (39, 43-47). The decrease in HbA1c in the range of 1-1.9% was obtained from the journal (39). The decrease in HbA1c in the range of 2-2.9% was obtained from the journal (37). Post-intervention fasting blood glucose levels in the range of 72-126 mg/dl were found in the journals (16, 24, 37, 38, 42-44). Category >60 minutes results were obtained (48) flexibility and endurance exercise. In the >60 minutes category, the decrease in HbA1c in the range of 0-0.9% was obtained from the journal (48).

Blood Glucose Reduction

The decrease in post-intervention blood glucose levels was divided into 2, namely the decrease in Fasting Blood Glucose (FBG) 72-126 mg/dl discussed in 11 journals (28.9%) and 2 hours post prandial ≤156 mg/dl discussed in 1 journal (2.6%). The decrease in post-intervention blood glucose levels in the Fasting Blood Glucose category 72-126 mg/dl was obtained from the journals (16, 18, 19, 23, 24, 37, 42-44). A decrease in blood glucose levels 2 hours post prandial ≤156 mg/dl was obtained in the journal (11).

HbA1c Reduction

The results of the decrease in HbA1c levels (%) were divided into 3, a decrease of 0-0.9% discussed in 9 journals (23.6%), a decrease of 1-1.9% discussed in 2 journals (5.2%), and a decrease of 2-2.9% discussed in 2 journals (5.2%).

A decrease in HbA1c (%) in the range of 0-0.9% was obtained in the journal (43) included in the balance exercise category with a duration of 60 minutes, (16) strength exercise category with a duration of 15 minutes, (45) strength and endurance exercise category with a duration of 30-60 minutes, (46) endurance exercise category with a duration of 30-60 minutes, (44) balance and endurance exercise category with a duration of 60 minutes, (39) endurance exercise category with a duration of 30-60 minutes and strength exercise with a duration of 60 minutes, (48) balance and flexibility exercise category with a duration of 75 minutes, (37) strength and endurance exercise category with a duration of 60 minutes. The average duration of exercise is 60 minutes.

A decrease in HbA1c in the range of 1-1.9% was found in the journal (39) endurance exercise category with a duration of 30-60 minutes and strength exercise with a duration of 60 minutes, (49) balance exercise category with a duration of 30 minutes. A decrease in HbA1c in the range of 2-2.9% was obtained in the journal (50) endurance exercise category but the specific duration is not explained, (37) strength and endurance exercise category with a duration of 60 minutes.

DISCUSSION

Type of Physical Activity that Reduce Blood Glucose and HbA1c Levels

The type of exercise most widely used in this research is endurance exercise. Endurance exercise has been proven to be widely used as exercise to reduce blood glucose levels. Endurance exercise is a type of aerobic exercise that aims to increase cardiovascular capacity which involves several muscle tissues with forms of exercise such as swimming, jogging or cycling and is recommended as the main choice over strength exercise (51).

The increase in mitochondria in skeletal muscle and the GLUT4 protein produced from exercise then has an effect on increased insulin sensitivity and body metabolism in type 2 DM patients (52). This is supported by the results of a systematic review by Sampath Kumar et al., (2019) which states that endurance exercise has the impact of improving glycaemic control and insulin sensitivity in DM patients (53). The American College of Sports Medicine (ACSM) and the American Diabetes Association (ADA) recommend endurance exercise as an effective intervention for physical activity in patients with Type 2 DM (9). On the other hand, research conducted by Ambelu & Teferi stated that the combination of endurance exercise and strength exercise had a greater impact in controlling blood glucose in type 2 DM patients. For further research, they can search for evidence of a combination of endurance and strength exercise to reduce blood glucose levels.

The types of endurance exercise that are most often used are cycling (50%) and walking (28.9%). In the cycling activity, the burning of fat, carbohydrates and a small portion of protein (±5%) stored in the body occurs to produce ATP (adenosine triphosphate) which causes blood glucose levels to decrease or become normal. Cycling carried out for 6 months can have a significant and consistent effect on HbA1c (54). A systematic review stated that cycling can cause blood glucose to decrease by an average of -2.7 mmol/L (55).

The next most widely used type of exercise, namely walking, has been done for more than 4 decades (12). Walking and brisk walking cause an increase in the sensitivity of insulin receptors in muscles when exercising to form energy so that it can reduce blood glucose levels (56). A significant decrease occurred when walking for 30 minutes ($p<0.010$) compared to the control group (57). Blood glucose can decrease bigger because walking can trigger the release of glucose in the liver caused by increased glucose use in muscles (58).

The results of this study showed that blood glucose levels could decrease from the range of 72-126 mg/dl. This may be caused by exercise which causes the Metabolic Clearance Rate (MCR) to increase, glucose homeostasis increases which results in an increase in glucose flux and the flux fraction decreases because it decreases during the oxidation process so that it can reduce blood glucose levels (59). During endurance exercise, MCR increases the use of blood glucose that is not previously metabolized by the body (60) due to an increase in the need for glucose in the muscles which results in a difference between insulin production and an increase in the body's demand for blood glucose, thereby stimulating acetyl-CoA for the process of gluconeogenesis and massive liver perfusion in converting glucose into energy so that blood glucose can decrease (59). This is in line with research that endurance exercise can reduce blood glucose levels in type 2 DM patients (61). Exercise 3 times a week for 2 months is effective in lowering blood glucose (62). Endurance exercise reduces fasting blood glucose levels by around 6.3 mg/dl for 4-5 days per week (63). It can be concluded that endurance exercise can reduce blood glucose levels due to the glucose metabolism process in the body's organs.

This study found that HbA1c levels fell from the range of 0-0.9%. This may be due to endurance physical activity releasing more glycogen from the liver (64). The decrease in HbA1c levels due to exercise causes the gluconeogenesis process to increase which is important in the process of glycaemic changes to regulate the reduction of glycogen in the muscles and liver (65). This is in accordance with research conducted by Turcotte et al., (1990) which stated that during endurance exercise, blood glucose concentrations and HbA1c decreased by 35% (66). Exercise in type 2 DM patients can consistently reduce HbA1c levels (-0.89%) (67). Exercise and physical activity can significantly reduce HbA1c levels (-0.14%) (68). It can be concluded that HbA1c levels have decreased significantly due to the process of glucose metabolism and the role of gluconeogenesis in regulating insulin levels in the body.

Physical Activity Duration that Reduces Blood Glucose and HbA1c Levels

From the results of the researcher's review, the most commonly used duration is 30-60 minutes and the most reduction in HbA1c is in the range of 0-0.9% and blood glucose is 72-126 mg/dl. This study is in line with the results of a systematic review conducted by Kurniawati et al., (2019) which states that endurance exercise for more than 30 minutes can provide a more optimal

reduction in blood glucose levels (62). Exercise for 12 weeks with a duration of 60 minutes per session done 3 times a week can improve glycaemic control effectively (69). From research that supports above 30-60 minutes endurance exercise is dominant in intervention because endurance exercise carried out for more than 30 minutes has the effect that glucose circulating in the blood can be used by skeletal muscles for metabolic processes which can reduce blood glucose levels and if done repeatedly will able to provide muscle and insulin adaptation in the glucose metabolism process which can control long-term glucose (70).

Adults who have DM should do moderate to vigorous intensity endurance exercise for a minimum of 150 minutes per week or 3 times a week and for a maximum of 2 consecutive days not doing sports activities can help regulate glycaemic control (71). DM patients do at least 150 minutes of moderate to vigorous endurance exercise, 3-5 times a week with 30 minutes per session without exercising for no more than 2 days (56). Endurance exercise has a long endurance in controlling blood glucose even though the activity has been stopped and one session of endurance exercise can enhance insulin sensitivity for 24-72 hours, but this is also influenced by the duration and intensity (70). So DM sufferers are advised to do endurance exercise at least once every 2 days to maintain stable blood glucose (70). It can be concluded that endurance exercise can be done 3-5 times a week to enhance control blood glucose levels.
DM patients should do 30-60 minutes of moderate to heavy endurance exercise while always adjusting the duration of the exercise (72). Type 2 DM patients are advised to do a minimum of 150-300 minutes of moderate intensity aerobic physical activity or a minimum of 75-150 minutes of vigorous intensity aerobics (73). High intensity aerobic exercise has the advantage of being shorter in duration compared to low or moderate intensity (74). There are needs to be monitoring that high intensity endurance exercise can cause hyperglycaemia due to the impact of increased catecholamine concentrations from the glucogenesis process (75). It can be concluded that 30-60 minutes of endurance exercise, either moderate or high intensity, has an influence on glycaemic control due to increased glucose use during exercise.

From this research, it was found that within 30-60 minutes blood glucose levels fell from the range of 72-126 mg/dl. This is as explained by researchers that the decrease in blood glucose levels may be caused by the regulation of glucose homeostasis in the liver. During physical exercise, muscles require increased energy from glucose, which subsequently signals the liver to release additional glucose into the bloodstream. This process helps to lower blood glucose levels (76). Endurance exercise done consistently for 30-45 minutes per session is effective in reducing blood glucose levels (14). Blood glucose levels experienced an average decrease of 21.06 mg/dl after doing endurance exercise for 6 months (77). It can be concluded that the decrease in blood glucose levels in patients with type 2 DM is attributable to the impact of exercise, which stimulates the release of additional glucose from the liver for distribution to muscle cells.

This research found that in results lasting 30-60 minutes when HbA1c levels fell from the range of 0-0.9%. This may be caused by exercise which results in increased insulin sensitivity. This statement is supported by research by Sanghani et al., (2013) which states that a reduction in HbA1c of 0.14% (p=0.12) can be achieved by increasing physical activity and structured exercise training which can reduce HbA1c levels by 0.59% (p =0.030) (78). Exercise causes nitric oxide production to increase through the process of restoring cGMP and blood nitrite levels and reducing circulating oxidative stress (79) so that glucose use and angiogenesis increase which causes insulin sensitivity to increase and HbA1c levels to decrease (80). After exercising for 12 weeks, type 2 DM patients experienced an average decrease in HbA1c of -0.22% (81). Therefore, physical exercise enhances insulin sensitivity and reduces HbA1c levels in patients with type 2 DM.

Several well-conducted studies have synthesized and discussed the effects of exercise and its duration on blood glucose and HbA1c reduction. However, a limitation of this study is that they do not address the potential side effects or risks associated with physical activity in individuals with DM. Specifically, the risk of hypoglycemia, particularly in those taking insulin or other DM medications, is not considered. Several studies have confirmed that prescibed walking could lead mild or severe hypoglycemia in people with DM (82, 83). Therefore, future research might investigate the effects and risks of exercise and its duration in people with DM.

CONCLUSION

This study is essential in better understanding the physical activity that improve blood glucose and HbA1c reduction in various duration in people with DM. We recognised that the appropriate physical activity for DM people is endurance exercise, especially cycling and walking. The appropriate physical activity is 30-60 minutes per session that accordance with WHO recommendation. The HbA1c reduction was in the range 0–0.9% with the maximum decrease 2.9%. The blood glucose reduction was found in the range 72–126 mg/dL. Therefore, the healthcare members may recommend people with DM to do endurance physical activity at least 30–60 minutes to minimize the blood glucose and HbA1c increment.

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