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The Effects from Physical Exercise on the Blood Glucose Levels, HbA1c and Quality of Life of Type 2 Diabetes Mellitus Patients: A Systematic Review

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ABSTRACT

Introduction: Physical inactivity affects the physical and mental health status of T2DM patients. Physical training is recommended in several studies and guidelines for the control of T2DM. The present study aimed to analyze the effects of aerobic exercise, resistance and a combination of both on blood glucose levels, HbA1c and quality of life for patients with T2DM.

Methods: This systematic review used PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis). Scopus, Science Direct and PubMed online databases were extensively searched, focusing on the last five years. The search utilized the phrases "diabetes," "physical exercise," "glucose" and "quality of life." The inclusion criteria in the study regarding the literature was that it had to be an original article, that the source was a journal, that the article was in English and that it was available in full text.

Results: We identified 1017 articles where 17 were considered to be relevant for this systematic review. The combination of resistance and aerobic physical exercise seems to have a greater impact on glucose, HbA1c and quality of life. Aerobic exercise, resistance exercise and a combination of both have benefits when it comes to reducing blood glucose levels and HbA1c, as well as improving the quality of life of patients with T2DM.

Conclusion: The type and intensity of the exercise chosen for the management of T2DM must be adjusted to the clinical condition and the patient's individual physical fitness. Further research is needed to assess the combined effects of aerobic exercise and resistance on glucose, HbA1c and the quality of life of T2DM adjusted for different age categories.

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INTRODUCTION

Type 2 diabetes mellitus (T2DM) includes individuals who have insulin resistance (IR) and usually a relative (not absolute) level of insulin deficiency (American Diabetes Association (ADA), 2016). Diabetes and complications are related to long-term complications and the failure of various organ systems (Chawla, Chawla, & Jaggi, 2016). T2DM has become an observable global public health problem. The World Health Organization reports that the number of people with diabetes has increased from 108 million

in 1980 to 422 million in 2014. According to this increase, diabetes will be the seventh leading cause of death by 2030 (WHO). It has been predicted that by 2025, the world burden of diabetes will be 5.4% of the adult population (Rasekaba et al., 2012).

Current research shows that insulin resistance and β cell dysfunction are major factors in the pathogenesis of T2DM (Kahn, Cooper, & Prato, 2014). However, the disease process is heterogeneous including genetic and environmental determinants such as a lack of physical activity and poor nutrition (Hu, 2011)(Adamska et al., 2012). Physical inactivity

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has a negative impact on the quality of life of diabetic patients (Çolak et al., 2016). Psychological problems are relatively common among individuals suffering from T2DM (Van Der Heijden, Van Dooren, Pop, & Pouwer, 2013). The rate of mental illness among people with diabetes is almost twice that of people without diabetes. Individuals with type 2 diabetes have a worse quality of life so managing their emotional health is no less important than keeping their blood sugar under control. This condition requires constant attention which can trigger feelings of stress and anxiety (Bril & Perkins, 2013). Among the treatment strategies, exercise has been considered to be a 'gold standard' in treatment and it has a very important role in controlling diabetes (Rydén et al., 2013). Regular exercise effectively improves blood glucose control, increases insulin sensitivity, reduces the cardiovascular risk factors, improves psychological well-being and decreases diabetes-related mortality (Naci & Ioannidis, 2015) (Gillett et al., 2012). In addition, exercise also uses the extra calories to release endorphins. These are agents that create a sense of well-being for both the individual and their social life (Gilani & Feizabad, 2019).

The American Diabetes Association considers the important role of planned efforts as a form of prevention and treatment for diabetes, especially type 2 diabetes mellitus (American College of Sports Medicine, Pescatello, Arena, Riebe, & D., 2014). This is especially so for the individuals who are at a high risk of complications so as to minimize the occurrence of complications. Over the last few years, more research has used a continuous glucose monitoring system and provided self-management education. This provides unprecedented access to controlling the blood glucose levels and the psychological conditions of patients. However, there is still a lack of research that shows what type of exercise should be recommended

for T2DM. Scientific organizations (the International Diabetes Federation, the European Association for Diabetes Studies, the American College of Sports Medicine, the American Diabetes Association, the American Heart Association (Mancini et al., 2015), the Canadian Diabetes Association (Bril & Perkins, 2013), Sports and Sports Science Australia, the Francophone Diabetes Society and the Sweden National Institute of Public Health (American College of Sports Medicine et al., 2014)) recommend physical exercise as a pillar of diabetes treatment, namely aerobic activity, resistance training and a combination of aerobic training and resistance (Mendes et al., 2016). Therefore the type of exercise and the volume of exercise (frequency, intensity, and duration of exercise) must be carefully analyzed and adjusted based on the patient's medical history and medical profile which may be the main determinants of the appropriate blood glucose levels. The aim of our study was to review the effects of aerobic exercise, resistance and a combination of both on blood glucose level, HbA1c and the quality of life of patients with T2DM.

MATERIALS AND METHODS

Strategy used for searching for the studies

The articles published in English were searched for on Scopus, Science Direct and PubMed. The relevant literature was searched from September 5 to December 28, 2019. The publication time was limited to between 2015 and 2019. The search terms were "diabetes", "physical exercise", "glucose" and "quality of life."

Studies selection and extraction

The selection process of the papers was made using four steps: identification, selection, eligibility and included.

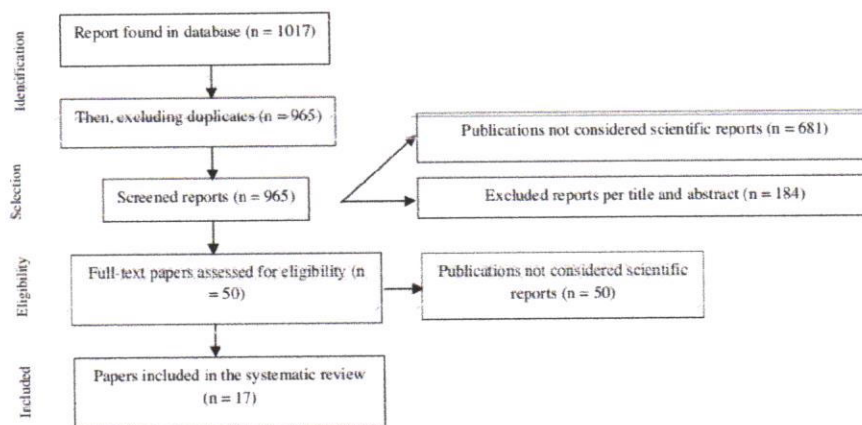


Figure 1 - Article selection process. Adaptation from Fisiko et al., 2020 (Fisiko et al., 2020)

inclusion. In total, 1017 articles were found. Of these, 52 duplicates and 681 were excluded because they were book chapters, conference summaries or other types of publication that are not considered to be articles, or because they were systematic review articles. There were 184 articles analyzed using their title and abstract; 50 were excluded due to the fact that they did not use physical exercise as an intervention, that did not indicate blood glucose level, HbA1c and quality of life as a marker or because did not have humans as samples. Of the 50 papers remaining for full-text evaluation, 33 did not meet the inclusion criteria because they didn't use randomized control trials, quasi-experiments, or observational studies, and because they didn't have one main marker.

The inclusion criteria were as follows: Type 2 diabetes mellitus as the searched disease, an intervention in the form of exercise/aerobic activity, resistance training, a combination of both (aerobic and resistance), all durations of exercise, repetition training, quality of life, the age of patients with type 2 diabetes mellitus as well as a combination of both exercises that affect the blood glucose levels, HbA1c, quality of life, randomized and controlled trials with humans, the document type being an original article, journal articles, articles in English and the article being available in terms of its full text. The article was excluded if the article was a systematic review and if the subjects in the study included T2DM patients accompanied by the complications of other diseases. The researcher set the inclusion and exclusion criteria. The researcher consulted with experts in the field of nursing study and their supervisors to determine the final results of the articles that were obtained for the final analysis. Finally, 17 articles were found following diabetes mellitus, thus they were included in the final analysis. The specific flow diagram has been shown in Fig 1 following the identification, selection, eligibility and included details. The table analysis can be seen in Table 2.

Ethical issues when preparing the manuscript of the systematic reviews were as follows: 1) avoiding plagiarism, 2) avoiding redundant or duplicates among the publication, 3) the transparency when screening the articles, the process analysis and the evaluation and 4) ensuring accuracy (Wager & Wifien, 2011).

RESULTS

General factors and types of studies

Several factors and types of articles have been analyzed in Table 1. Seventeen studies (100%) all refer to type 2 diabetes mellitus research. The most common type of research designs was a Randomized Controlled Trial, totaling 9 studies (52.94%). The details of the intervention programs in the studies have been given in Table 2.

Table 1. General characteristics of the selected studies (n=17)

Category	n	%
Year of publication		
2015	1	5,88
2016	1	5,88
2017	11	64,7
2018	1	5,88
2019	3	17,64
Type of DM		
T2DM	17	100
Type of Study		
RCT	9	52,94
Quasi-experiment	7	41,17
Retrospective observational study	1	5,88

Aerobic Exercise

The results obtained by the researchers from the 17 articles that have been analyzed all show that the articles indicate the final results of the decrease in blood glucose level, Hb A1c, and the improvement in the quality of life of patients with T2DM. Improved glycemic control and quality of life is not only demonstrated in adolescents or adults. It is also found among the older people with T2DM. The analysis also found that patients who routinely carry out aerobic exercise a minimum of 3 times a week with an average duration of 30-40 minutes per session, conducted for a minimum of 4 weeks (Benkar & Kanase, 2017) and a maximum of 25 weeks where the average study used a 12-week training protocol and an intensity of 50% -70% maximum heart rate, have a good quality of life, increased glycemic control and decreased HbA1c. The quality of life of T2DM patients can improve significantly, especially in terms of self-esteem, mental health, better perceived physical condition, decreased anxiety and insomnia (Ghani & Feizabad, 2019)(Lin et al., 2017).

Decreased blood glucose levels include fasting blood glucose (Benkar & Kanase, 2017; Lin et al., 2017; Rahbar et al., 2017; Shakil-ur-Rehman, Karimi, & Gillani, 2017), oral glucose tolerance levels (Lin et al., 2017) and post-prandial blood glucose (Nygaard, Rønnestad, Hammarström, Holmboe-Ottesen, & Høstmark, 2017)(Benkar & Kanase, 2017). In addition, the level of HbA1c decreased significantly ($p < 0.05$) after carrying out aerobic exercise (Rahbar et al., 2017)(Jhingan & Jhingan, 2017). The results of the study reported that aerobic exercise for 12 weeks (3 days / week) with the duration of each session being 30 minutes at 60% VO2 max can significantly improve the patient's respiratory cardiorespiratory fitness (Lin et al., 2017). The study results report that after 24 sessions (8 weeks) of aerobic exercise on a treadmill for 3 days per week for 30 minutes per session at an intensity of 50% -70% maximum heart rate, there was a reduction in glycosylation hemoglobin (HbA1c) to a significant level in the exercise group ($p < 0.05$) (Rahbar et al., 2017). The long-term exercise training program results from the study (Najafipour et al., 2017) can significantly reduce the HbA1c levels ($F = 11.08$, $P < 0.05$) in the

intervention group compared to the control group (Jhingan & Jhingan, 2017).

Resistance exercise

The results of this study revealed that there was a significant reduction in postprandial sugar levels ($P < 0,000$) (Gurudut & Rajan, 2017). Russel et al's (2017) research shows that resistance training improves glycemic control (fasting blood glucose, HbA1c, and glucose areas below the curve) (Russell et al., 2017). There were significant differences between the resistance training group and the control group when it came to reducing glucose levels ($P < 0,05$) (Aminilari et al., 2017). In addition, Benkar & Kanase's study (2017) resulted in a decrease in fasting blood glucose levels $p \leq 0,0001$ (Benkar & Kanase, 2017). The results of Russel et al's (2017) research report showed that while undergoing an oral glucose challenge (OGC), blood glucose levels during OGC were significantly lower at each point in time after resistance training, i.e. fasting blood glucose decreased by $0,95 \text{ mmol / L}$ ($P = 0,003$). As a result, the area under the glucose-time curve was also lower after resistance training ($P, 0,005$) (Russell et al., 2017). Resistance training for 12 weeks can improve glucose homeostasis by increasing insulin sensitivity, i.e. the oral glucose tolerance test (OGTT) result increases after 15, 30, 45 and 90 minutes compared to resting at baseline after 12 weeks of training ($P < 0,05$). HbA1c, in the post hoc tests, showed the same result before and after reductions in both groups (short: 213%; $p = 0,01$; length: 218%; $p = 0,001$) (Park et al., 2016). Russel et al's (2017) research shows that resistance training decreases HbA1c by $0,16\%$ ($1,76 \text{ mmol / mol}$) ($P = 0,025$) (Russell et al., 2017). Resistance training with a Thera-Band could enhance muscular strength and improve the quality of life of the elderly (Pourtaghi, Moghadam, Ramazani, Vashani, & Mohajer, 2017).

Combined aerobic and resistance exercise

Kang et al's (2016) study confirms that an aerobic training program and a 12-week combination of resistance reduces the fasting blood glucose concentration significantly (Liu et al., 2015). In addition, 3 weekly sessions for 60 minutes for 12 weeks is effective at improving glucose control (18% in HbA1) (Carus et al., 2015). In addition, the HbA1c level was reduced by $0,67\%$ to an average sample value below $7,0\%$ after 12 weeks of UTT (Conners, Caputo, Coons, Fuller, & Morgan, 2019). The results of the study of Carus et al in 2015 showed a significant increase in HRQoL. This was accompanied by much larger relative improvements in the HRQoL scores of physical function (53%), vitality (21%) and overall mental health (40%) (Carus et al., 2015).

DISCUSSION

This review has systematically assessed the effectiveness of aerobic exercise, resistance training

and joint training on blood glucose levels, HbA1c and the quality of life of patients with type 2 diabetes mellitus. The most widely used intervention in at least one group was aerobic training 3 times a week for 12 weeks. Aerobic exercise is a form of physical exercise that uses the aerobic energy-producing systems that involve large muscle groups. This can increase the capacity and efficiency of this system and it is effective at increasing cardiorespiratory endurance (Colberg et al., 2016) (Knapen, Vancampfort, Moriën, & Marchal, 2015). Types of aerobic exercise include running, walking, cycling, swimming and rowing (Thent, Das, & Henry, 2013). The American Diabetes Association recommends that adults with regular T2DM engage in aerobic activity that lasts for at least 10 minutes with a goal of 30 minutes / day or more almost every day of the week (Colberg et al., 2016). The International Diabetes Societies recommends 150 minutes of aerobic exercise spread over a minimum of 3 days per week at a moderate intensity (40% -59% of the heart rate reserves, 64% -76% of the maximum heart rate) with no more than 2 consecutive days without sports (Mendes et al., 2016). Moderate exercise training increases glucose utilization and tolerance, cardiorespiratory fitness, blood pressure and the quality of life and depression status of patients with T2DM over a 12 week exercise training program (Lin et al., 2017). Exercise training can stimulate the metabolism and blood glucose utilization of T2DM patients. The results of Gilani et al. in 2019 show that regular aerobic exercise is an effective strategy and it plays an important role in improving self-esteem and mental health as well as improving the quality of life of patients with type 2 diabetes mellitus (Gilani & Feizabad, 2019). Regular aerobic exercise training is an effective strategy to improve personal health and self-esteem. This improves the quality of life of diabetic patients and is highly recommended (Gilani & Feizabad, 2019). Aerobic exercise increases the action of insulin and it is effective at managing blood glucose, blood lipids, blood pressure, the risk of cardiovascular death, and general quality of life. In addition to physical and psychological benefits, physical exercise and sports have other benefits including mental, emotional, and social benefits [30][38].

Resistance training is a type of anaerobic exercise that is used to increase muscle strength, overall strength, and endurance by varying the intensity range of resistance between 50% -75% of the maximum 1-repetition [36][39]. According to the Position Statement from the American Diabetes Association, resistance training at any intensity is recommended for adults with diabetes. They should do resistance training at a frequency of 2-3 sessions / week on non-consecutive days (Colberg et al., 2016) (Colberg, 2017). In addition, resistance exercise can reduce the restrictions on motor function in the elderly. This is a positive impact that can encourage older people to continue with sports and training, especially when the sports are interesting such as training using the elastic band Thera-Band. Therefore

a cycle is established which can have many positive effects on muscle strength as well as the physical and mental health of this age group (Burrows, 2002). It should be noted that increased muscular strength is considered to be the basis for improved physical and motor functioning. Physical activity can also decrease the disabilities among the elderly and improve their independence and quality of life (Leinonen et al., 2007). However, the combination of the two types of exercise seems to have a greater impact on blood glucose level, HbA1c and the quality of life of patients compared to only one of the two types of exercise. A combination of aerobic and resistance training may be more effective for blood glucose management than either type of exercise alone. Exercise simulates the GLUT4 protein translocation in the muscle cells leading to an improved intake of glucose in the muscle (Sano, Peck, Kettenbach, Gerber, & Lienhard, 2011). The progressive and continued stimuli of this mechanism may lead to a relatively stable metabolic adaptation (Carus et al., 2015). This common complication of diabetes usually leads to muscle weakness and atrophy in the legs and feet. Accordingly, motor disturbances such as the inability to walk on the heels are outcomes that are often present. These can be used to identify highly-affected diabetic patients. Similarly, muscle fatigue is a common characteristic among diabetic patients. Despite the molecular mechanisms remaining unidentified, evidence suggests that several metabolic pathways may be involved such as reduced mitochondrial function or the inability to mobilize glycogen and phosphocreatine at the start of exercise (Halvatsiotis, Short, Bigelow, & Sreekumaran Nair, 2002).

Interestingly, a combination of aerobic and resistance exercise also results in significant improvements in mental health and related interventions. This has important implications for several aspects of a patient's daily life (Carus et al., 2015). This study by Carus et al (2015) showed that combined aerobic-resistance exercise therapy was very effective at reducing muscle fatigue and improving muscle strength, glycemic control and the physical and mental aspects of HRQoL in moderately-affected T2DM patients (Carus et al., 2015). The psychological mechanisms of the beneficial effects of exercise on quality of life including increased self-esteem, increased self-satisfaction, increased self-confidence and increased disorder and physiological mechanisms including increased central norepinephrine, changes in the adrenocortical system of the hypothalamus and changes in the synthesis and metabolism of serotonin and endorphins. Thus the patients' perception of their own health seems to be improved by exercising. Physical exercise is an extraordinary opportunity in the care of patients who have physical and mental health problems (Knapen et al., 2015). Physical activity can reduce geriatric pain if it is based on humor and laughter. Because pain is considered an important component of quality of life in the elderly (Behrouz et al., 2017), it can be

concluded that pleasant physical activity along with laughter has a positive effect on the quality of life among this population.

There are several limitations to our study that have been included. First, only one study assessed the effects of a combination of aerobic exercise and resistance and how it relates to quality of life (Carus et al., 2015). Because of the small number of studies conducted, the effect of a combination of exercises requires more evidence. Second, some of the studies did not include supervised exercise. We could not determine whether the participants completed the training program or whether they achieved the moving targets, which might affect the quality of life outcomes. In addition, in some of the studies without a follow-up, we could not observe the long-term effects. Physical exercise must be categorized by age (young adult, adults, elderly) because age affects the body's metabolism and degenerative processes, thus preventing biased results.

CONCLUSION

Aerobic exercise, resistance training and combination training have benefits when it comes to reducing the blood glucose level and HbA1c, in addition to improving the quality of life of patients with type 2 diabetes mellitus. The type and intensity of the exercise chosen for the management of T2DM must be adjusted to the clinical condition and to the patient's physical fitness. Further research is needed to assess the combined effect of aerobic exercise and resistance to glucose, HbA1c and quality of life adjusted for the different age categories. The implications for nursing are that it can be used as a form of therapeutic modality in the promotion and prevention of the complications of type 2 diabetes mellitus. This is tailored to the clinical profile of the patient.

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APPENDIX

Table 2. Detailed Intervention Programs in the Studies

Author	Modality	Local/Year	Method	Duration, Frequency	Protocol	Measuring Instruments and Result
Park <i>et al.</i> (Park <i>et al.</i> , 2016)	Elastic Band Resistance Training	Korea/2016	Design: Quasi-experimental Sample: 26 Age: 46 - 65 years	The frequency (5 day/week) over 12 weeks involved training twice a day (morning and afternoon) over 15-20 repetitions maximum maximum (RM).	Patients used the lowest resistance available (i.e, yellow band) and they were instructed on the proper exercise technique under the supervision of a clinical exercise physiologist.	Patients with a long history of diabetes responded positively to resistance training and in a manner comparable to their recently diagnosed counterparts.
Pourtaghi <i>et al.</i> (Pourtaghi <i>et al.</i> , 2017)	Resistance Training using Thera-Band	Iran/2017	Design: RCT Sample: 70 Age: ≥ 65 years	The intervention was implemented through 2 30-minute sessions a week, lasting for 6 weeks.	Prior to each session, the elderly individuals performed stretching exercises for 10 mins to warm up and then they went jogging for 10 mins to cool down. The resistance training used a Thera-Band to perform 9 movements.	Resistance training with Thera-Band could enhance muscular strength and improve the quality of life of the elderly.
Rahbar <i>et al.</i> (Rahbar <i>et al.</i> , 2017)	Aerobic exercise	Iran/2017	Design: RCT Sample: 30 Age: 40-60 years	24 sessions (3 days per week) for 30 minutes over an 8 week duration.	Aerobic exercise on a treadmill (Motorized treadmill®, Omegag, Usa) with no slope. Max heart rate estimated from the Bruce protocol test. The training protocol was 50% to 70% of the max heart rate.	A safe exercise regimen is advised in order to maintain a healthy cardiovascular function and to reduce the complications in patients with diabetes.
Jhingan & Jhingan (Jhingan & Jhingan, 2017)	Cycling	India/2017	Design: Retrospective observational study Sample: 20 Age: 18 to <40 years	Distance of 25 km per day for at least 5 days a week.	The study was conducted in accordance with ethical principles of the Declaration of Helsinki and it was approved by the Institutional Ethics Committee.	Regular aerobic exercise in the form of cycling results in a significant reduction in HbA1c, BP and weight.
Chiang <i>et al.</i> (Chiang <i>et al.</i> , 2019)	Treadmill	Taiwan/2019	Design: Prospective longitudinal Sample: 66 Age: 40-60 years	3 sessions/week, 3x/days, 30 minutes/session for 12 weeks (total of 36 sessions).	The training protocol followed the "FITT" principle according to ACSM's Guidelines including Frequency, Intensity, Time and Type. 12 week duration. 70% heart rate over 150 minutes of moderate-intensity aerobic activity per week for 30 minutes.	12-week moderate intensity exercise training appears to be safe for patients with T2DM.
Lin <i>et al.</i> (Lin <i>et al.</i> , 2017)	Treadmill	Taiwan/2017	Design: Quasi-experiment Sample: 17 Age: 20 - 60 years	3x/week. 12 weeks. 30 minutes	Moderate exercise. The intensity of the exercise training was set at 60% VO2max (72% HRmax) obtained from the participant's GXT.	Moderate exercise training improves glucose utilization, glucose tolerance, cardiorespiratory fitness, blood pressure, and QOL as well as the depression status of patients with T2DM.
Zhang & Kim (Zhang & Kim, 2018)	Aerobic exercise (Taiji, Dance & jogging)	Korea/2018	Design: Experimental study Sample: 37 Age: 37 - 68 years	Single aerobic exercise lasting for about 60 minutes, 3 times a week	Aerobic exercises like Taiji and square dance can be adopted by elderly patients. Aerobics and jogging can be adopted by younger patients. The heart rate was controlled at about 60%.	The aerobic exercise intervention can improve the blood fat and blood glucose indicators of the patients with type 2 diabetes and reduce their body fat and weight. It can improve their treatment effect and life quality.

Table 2. (Continued)

Author	Modality	Local/Year	Methods	Duration, Frequency	Protocol	Measuring Instruments and Result
Gilani & Feizabad, (Gilani & Feizabad, 2019)	Aerobic Exercise	Iran/2019	Design: Clinical trial study Sample: 60 Age: 45-55 years	Exercised in 3 45 to 60-minute sessions a week for 12 weeks	The intensity of the training, obtained by measuring pulses on the left wrist radial within one minute, was considered equal to be to 60% of the maximum consumed oxygen. Maximum oxygen consumption was controlled using the heart reserve rate (HRR).	Regular aerobic exercise training as an effective strategy plays an important role in improving self-esteem and mental health while also promoting better life quality among diabetic patients.
Najafipour et al., (Najafipour et al., 2017)	Aerobic Regular exercise training	Iran/2017	Design: Quasi-experimental trial Sample: 65 Age: 33-69 years	3 sessions per week with a duration of 15-40 min.	The activities of the sessions included warm-up movements and aerobic exercise at a moderate intensity. 50% -80% VO2max.	Long-term regular physical activity training was found to be helpful for improving glycemic control, body composition and cardiovascular fitness among the patients with T2DM.
Shakil-ur-Rehman, Karimi, & Gillani (Shakil-ur-Rehman et al., 2017)	Supervised structure aerobic exercise training (SSAET). Medicaly-graded treadmill	Pakistan/2017	Design: Randomized controlled trial Sample: 102 Age: 40-70 years	25 week SSAET program divided into 5 phases of 5 weeks each.	In phase 1, the duration of a single session was 10 minutes and the total duration per week was 30 minutes. A thirty minute increase per week was followed in the subsequent 4 phases.	SSAET program along with routine medical management is a more effective treatment in the management of fasting blood glucose level, glycemic control, plasma insulin level and insulin resistance compared to the routine medical management and dietary plan in the management of T2DM.
Benkar & Kanase (Benkar & Kanase, 2017)	Aerobic exercise, Resistance Training	India/2017	Design: Comparative study Sample: 30 Age: 30 - 65 years	5 days/week for 4 weeks.	Aerobic exercise on a static bicycle. Resistance training using dumbbells and weight cuffs.	Aerobic exercises and resistance training is proven to be beneficial at controlling the blood glucose levels of T2DM subjects.
AminiLari et al., (AminiLari et al., 2017)	Aerobic, Resistance, and Combined Exercises	Iran/2017	Design: Randomized controlled trial Sample: 60 Age: 45-60 years	3 times per week sessions for a total of 12 weeks AE: 50% - 55% Heart max RE: intensity : 50% to 55% of one-repetition maximum (RM) or 1 RM.	AE, RE, CE: 3 sessions per week in 3 phases: warm-up, the main section and cooling-down. The warm-up involved 20 minutes of stretching exercises and jogging on the spot. The cooling-down phase involved running, exercising & stretching. AE: The main phase consisted of 25 minutes of exercise. RE: The main phase consisted of 3 sets x 8 repetitions of weight training including leg extensions, prone leg curls, abdominal crunches, biceps, triceps, and seated calf movements. CE: The main phase consisted of aerobic training integrated with RE.	Compared to aerobic and resistance exercises, 12 weeks of combined exercise was more efficient at improving HOMA-IR and increasing serum omentin-1 among women with T2DM.
Nygaard, Rønneestad, Hammarström, Holmboe-Ottesen, & Høstmar (Nygaard et al., 2017)	Moderate exercise	European/2017	Design: Randomized cross-over design Sample: 8 Age: -	30 minutes/day. 60 min of treadmill walking	3 test days in a randomized cross-over design encompassing one test day without exercise, one test day with 60 min of treadmill walking prior to breakfast and one test day with an identical bout of exercise 30 min after the start of breakfast. Moderate exercise in the postprandial state	Performing moderate exercise was done in the postprandial state but not fasted state. This decreased the glucose excursions during a subsequent 22 hours period in hyperglycemic individuals not using antidiabetic medications.

Table 2. (Continued)

1 st Author	Modality	Local/Year	Methods	Duration, Frequency	Protocol	Measuring instruments and Result
Carus et al. (Carus et al., 2015)	Combined aerobic-resistance exercise	Portugal/2015	Design: Randomized controlled trial Sample: 43 Age: -	3 weekly sessions of 60 minutes for 12 weeks	1) 10 minutes of warming up with slow walks. 2) 25 minutes of aerobic exercises at 60-65% of the maximal heart rate. 3) 15 minutes of strength exercises targeting specific muscle groups.	12 weeks of combined aerobic-resistance exercise was highly effective at improving muscle strength and fatigue, glycemic control and several aspects of HRQoL in T2DM patients.
Benkar & Kanase (Benkar & Kanase, 2017)	Aerobic exercise. Resistance Training	India/2017	Design: Comparative study Sample: 30 Age: 30 - 65 years	5 days/week for 4 weeks.	Aerobic exercise on a static bicycle. Resistance training using dumbbells and weight cuffs	Aerobic exercises and resistance training are proven to be beneficial for controlling the blood glucose level of T2DM subjects.
Conners, Caputo, Coons, Fuller, & Morgan (Conners et al., 2019)	Underwater treadmill training (UTT)	Huntsville/2019	Design: Randomized treatment-control research Sample: 26 Age: Middle-aged adults	36 UTT sessions (12 weeks x 3 sessions per week)	The study participants completed 3 UTT sessions per week on alternate days for a total of 12 weeks. Each training session consisted of 3 walking sessions separated by at least 5 minutes of rest on a flotation device. The water temperature was kept in a neutral range (29-31°C).	UTT is a safe and effective multimodal training approach that can improve glycemic control, blood lipid profile, cardiovascular function, body composition, and leg strength in middle-aged adults with type 2 diabetes.
Russell et al. (Russell et al., 2017)	Resistance Training (RT)	Australia/2017	Design: Quasi-experiment Sample: 17 Age: 18-60 years	3 days/week. 6 weeks	All of the exercises were fully supervised by trained sports physiologists and the weights were adjusted according to the individual abilities. Minerals follow the training trail, length and development.	RT improves the OGC-stimulated muscle MBF and glycemic control concomitantly, suggesting that MBF plays a role in improved glycemic control due to RT.

*T2DM: Type 2 Diabetes mellitus; RCT: Randomized Controlled Trial; HRQoL: Health Related Quality of Life; AE: Aerobic exercise; RE: Resistance Exercise; CE: Combined Exercises; OGC: Oral Glucose Challenge; MBF: Microvascular Blood Flow

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