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REVIEW ARTICLE

Resisted Exercises and its effects on Glycemic control in type II Diabetes Mellitus- An Update

Divya Goyal[1], Kamran Ali[1], Neelima Mishra[2], Sahil Sachdeva[3], Manvi Sharma[3], Anand Kumar Singh[1], Manish Kumar[1], Vishwajeet Trivedi[1*]
[1]Department of Physiotherapy, School of Healthcare & Allied Sciences, GD Goenka University, Gurugram 122103
[2]Associate Director Internal Medicine, Max Super Specialty Hospital, Gurgram 122102
[3]Undergraduate Student, Department of Physiotherapy, School of Healthcare & Allied Sciences, GD Goenka University, Gurugram 122103
***Corresponding Author:** Vishwajeet Trivedi
Email: physiovishu87@gmail.com
ORCID: 0000-0003-2193-4665

ABSTRACT
The systematic review of eight selected articles provides robust evidence endorsing resistance exercise as an effective intervention for enhancing blood glucose control and reducing HbA1C levels in patients with type 2 diabetes mellitus. The review involved a thorough search of reputable databases, including Sage, ProQuest, Science Direct, Springer link, and Ebsco Host, and covered articles published between 2008 and 2022. The findings of the analysed studies demonstrate that resistance exercise has a positive effect on glycemic control in patients with type 2 diabetes. The intervention showed improvements in blood glucose levels and HbA1C, which are essential indicators of diabetes management. The American Diabetes Association (ADA) advocates for incorporating resistance training as a crucial component of a holistic strategy for managing blood glucose levels in individuals with type 2 diabetes. It complements other standard interventions such as medication, diet, and lifestyle modifications. Given the global health threat posed by the rising incidence of diabetes, especially in developing countries like India, the promotion of evidence-based interventions such as resistance exercise is essential. This approach offers a practical and accessible method for enhancing glycemic control and mitigating the burden of diabetes-related complications. The systematic review underscores the critical role of resistance exercise in the management strategies for patients with type 2 diabetes mellitus. It offers valuable insights for healthcare providers to develop personalized exercise regimens that address the unique needs and capabilities of each patient. In conclusion, based on the systematic review of the selected articles, resistance exercise is recommended as an effective and safe intervention to improve blood glucose and HbA1C in patients with type 2 diabetes mellitus. Implementing resistance exercise programs, in conjunction with other diabetes management strategies, can contribute to better glycemic control and overall health outcomes for individuals living with type 2 diabetes.
***Keywords**: Intervention, Resisted exercise, PRT, Type 2 Diabetes mellitus, HbA1c, Blood glucose level.*

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INTRODUCTION

Diabetes mellitus (DM) is a non-communicable disease that is on the rise globally, becoming a significant health threat, especially in developing countries like India. The number of DM cases is expected to increase substantially in the coming years, leading to a higher burden of the disease. Complications of DM can be severe, involving both microvascular (retinopathy, nephropathy, neuropathy) and macrovascular complications, which can even lead to death. One of the complications related to diabetic foot is Peripheral Artery Disease (PAD), which results from damage to the peripheral blood vessels due to high glucose levels [1,2]. Physical exercise, specifically resistance exercise, has been recommended for individuals with type 2 diabetes by the ADA [2,3]. Resistance exercise involves muscle group exercises against resistance, which activates multiple muscles. Active muscle movement increases the demand for glucose without a significant increase in insulin levels. This increased muscle movement also leads to improved blood flow, resulting in the opening of the capillary network. As a result, there are more insulin receptors available and increased receptor activity, which aids in glucose uptake by the muscles [4,5]. By engaging in resistance exercise, individuals with diabetes can improve their glycemic control and potentially reduce the risk of diabetic foot and other complications [6]. It provides an effective means to manage blood glucose levels and is particularly beneficial for those with type 2 diabetes [7,8]. However, diabetics need to work with health professionals to design safe and suitable resistance exercise programs tailored to their individual needs, capabilities, and health status. Regular physical activity, when integrated with other diabetes management approaches, can notably enhance the holistic health and quality of life for individuals managing diabetes. [9,10].

MATERIAL AND METHODS

The following methodology was engaged to review the articles:

The researchers performed comprehensive searches across prominent databases such as Proquest, SCIENCE DIRECT, Springer link, Sagepub, and EBSCO Host. They utilized specific search terms related to the intervention (resistance exercise or training), blood glucose levels, HbA1C, fasting blood glucose, glycemic control, and type 2 diabetes mellitus. The search was limited to articles published within the last 27 years starting from 1997 to 2024.

Inclusion Criteria: The researchers selected articles based on specific inclusion criteria. The criteria included studies that involved resistance exercise interventions, regardless of the duration of exercise, exercise repetitions, or age of the patients with high blood glucose. Articles that included combined exercise interventions affecting both blood glucose and HbA1C levels were also incorporated. All selected articles were required to be in the English language.

Exclusion Criteria: Systematic reviews were excluded from the selection process to maintain focus on original research articles.

Number of Articles Selected: Out of the initial 209 research articles identified through the literature search, 27 articles were deemed suitable based on the inclusion criteria and chosen for further analysis in the systematic review.

Types of Research Designs: As research on this intervention was limited, the systematic review included all types of research designs and not just randomized controlled trials. This allowed for a comprehensive evaluation of the available evidence.

Focus of the Systematic Review: The selected journal articles measured various variables related to resistance exercise and its impact on type 2 diabetes. However, the focus of this systematic review was specifically on the effect of resistance exercise on HbA1C and blood glucose levels (GDA and GDP).

RESULTS

Eriksson et al. [19] demonstrated that circuit resistance training in elderly, sedentary individuals with non-insulin-dependent diabetes mellitus (NIDDM) significantly improved HbA1c levels and increased muscle endurance and size, indicating the feasibility of incorporating such programs into diabetes management. Studies such as Honkola *et al.* [22] and Ishii et al. [25] reported that resistance training improved insulin sensitivity and lipid profiles, with reductions in total cholesterol, LDL, and triglycerides. RT was also effective in increasing muscle strength without altering body composition significantly in non-obese diabetic individuals. Honkola *et al.* [22] investigated the effects of circuit-type resistance training on blood pressure, lipids, and long-term glycemic control (HbA1c) in type 2 diabetic subjects. Eighteen type 2 diabetic subjects participated in two sessions of resistance training per week for 5 months, performing 8-10 exercises focused on both upper and lower body. The exercise consisted of two sets of 16-20 repetitions at moderate intensity, with relaxation periods under 60 seconds. The results showed substantial improvements in total cholesterol (6.0 ± 0.3 vs 5.3 ± 0.3 mmol/L, $P < 0.01$), LDL-cholesterol (3.90 ± 0.22 vs 3.35 ± 0.21 mmol/L, $P < 0.01$), and triglycerides (1.91 ± 0.25 vs 1.53 ± 0.22 mmol/L, $P < 0.01$). Moreover, the exercise group showed a statistically significant reduction in HbA1c levels (0.5%, $P < 0.01$). These findings suggest that circuit-type resistance training is a viable and effective addition to exercise programs for moderately obese, sedentary type 2 diabetic individuals, yielding significant improvements in lipid profiles and glycemic control. Pan et al. [32] aimed to determine whether diet and exercise interventions in individuals with impaired glucose tolerance (IGT) could delay the development of non-insulin-dependent diabetes mellitus (NIDDM). Follow-up evaluations were conducted at 2-year intervals over a 6-year period. Physical activity was classified into different levels: mild (e.g., slow walking, traveling by bus, housecleaning), moderate (e.g., faster walking, cycling, heavy laundry, ballroom dancing), strenuous (e.g., slow running, climbing stairs, playing volleyball), and very strenuous (e.g., jumping rope, playing basketball, swimming for varying durations). Participants were divided into four groups: a diet group, an exercise group, a diet + exercise group, and a control group. The diet group was encouraged to increase vegetable intake, reduce alcohol consumption, and cut back on simple sugars. The exercise group was instructed to engage in at least 1 or 2 units of physical activity per day. The diet + exercise group followed both dietary recommendations and the same physical activity guidelines. The control group received general information about diabetes and IGT. At baseline, fasting plasma glucose levels were similar across all groups, with the control group at 5.52 ± 0.82 mmol/L, the diet group at 5.56 ± 0.81 mmol/L, the exercise group at 5.56 ± 0.83 mmol/L, and the diet + exercise group at 5.67 ± 0.80 mmol/L. Similarly, baseline 2-hour post-glucose challenge levels were also comparable across groups, ranging from 8.83 ± 0.79 mmol/L in the exercise group to 9.11 ± 0.93 mmol/L in the diet + exercise group. After 6 years, fasting plasma glucose levels had decreased in all intervention groups compared to the control group, with the control group showing a rise to 7.59 ± 2.59 mmol/L. The diet group had a mean of 6.94 ± 4.49 mmol/L, the exercise group had 6.83 ± 2.24 mmol/L, and the diet + exercise group had 7.15 ± 2.72 mmol/L. Similarly, the 2-hour post-glucose challenge levels were lower in the intervention groups, with the control group showing an increase to 12.99 ± 4.19 mmol/L. The diet group showed a decrease to 10.51 ± 4.89 mmol/L, the exercise group had 10.51 ± 3.93 mmol/L, and the diet + exercise group had 10.76 ± 4.37 mmol/L. These results suggest that diet and exercise interventions may help improve glucose control in individuals with IGT, although the combined diet and exercise intervention did not show significant additional benefit over either intervention alone and Ishii et al. [25] reported that resistance training improved insulin sensitivity and lipid profiles, with reductions in total cholesterol, LDL, and triglycerides. RT was also effective in increasing muscle strength without altering body composition significantly in non-obese diabetic individuals. Ishii [25] investigated the effect of resistance training on insulin sensitivity in non-overweight patients with non-insulin-dependent diabetes mellitus (NIDDM). Seventeen sedentary patients were divided into an experimental group (9) and a control group (8). The experimental group underwent resistance training five times a week for 4-6 weeks, performing nine exercises (four lower body, five upper body) in sets with rest intervals of less than one minute, and repetitions at 40-50% of one-repetition maximum. Results showed a significant 48% increase in glucose disposal rate during hyper insulinemic-euglycemic clamp in the resistance training group (6.85 ± 1.86 to 10.12 ± 3.15 mg/kg lean body mass/min; $P < 0.05$), while the control group remained unchanged. Quadriceps strength increased by 16% in the training group (191.1 ± 45.8 to 216.9 ± 42.8 Nm; $P < 0.05$), but body composition and VO2 max remained unchanged. These findings suggest that mild-intensity, high-volume resistance training improves insulin sensitivity in non-obese NIDDM patients without affecting cardiovascular fitness. Dunstan et al. [17] investigated the effects of short-term circuit weight training (CWT) on glycemic control in non-insulin-dependent diabetes mellitus (NIDDM) patients. Fifteen NIDDM patients underwent CWT, while 12 served as controls. The 8-week CWT program consisted of 3 sessions per week, featuring 10 exercises (3 lower body, 7 upper body) with 3 sets, 30-second rest periods, and active recovery on a cycle ergometer. Participants performed 10-15 repetitions at 50-55% of 1-repetition maximum. Outcomes showed significant improvements in strength across all exercises. Additionally, oral glucose tolerance tests revealed significant reductions in glucose (-213 mmol/L per 120 min, $P<0.05$) and insulin (-6130 pmol/L per 120 min, $P<0.05$) area under the curve. These findings suggest that short-term CWT can effectively improve glycemic control in NIDDM patients, providing a practical exercise option for lifestyle management. Maiorana et al. [29] and Misra et al. [30] emphasized the benefits of resistance and circuit training in improving not only glycemic control but also body composition, muscular strength, and cardiorespiratory fitness. Maiorana's study showed a decrease in body fat percentage and waist-to-hip ratio, while Mishra et al. observed reductions in total cholesterol and serum triglycerides. The reviewed studies consistently highlight the benefits of both resistance and combined training modalities in managing T2DM. Circuit and resistance training can significantly reduce HbA1c levels, improve insulin sensitivity, and enhance cardiovascular health. Moreover, the inclusion of resistance training as part of a comprehensive exercise regimen seems particularly beneficial for increasing muscle mass and strength, which may counteract the muscle-wasting often observed in diabetic patients. The addition of aerobic exercises to resistance training further enhances fat loss, particularly abdominal fat, which is a critical factor in reducing cardiovascular risk in T2DM. While both aerobic and resistance training have proven benefits, combined training appears to provide superior outcomes in terms of glycemic control, body composition, and cardiovascular health. These findings are in line with current recommendations that advocate for a mixed modality approach to exercise in diabetes management. In a study by Dunstan et al. [16] high-intensity progressive resistance training (PRT) over 26 weeks significantly improved glycemic control, reduced HbA1c by 1.2%, and increased lean body mass

(LBM) in older adults with T2DM. Similarly, Castaneda et al. [10] showed that PRT reduced plasma glycosylated hemoglobin and the dose of diabetes medications in older adults. Study [10] investigated the efficacy of high-intensity progressive resistance training (PRT) on glycemic control in older Latino adults with type 2 diabetes. Sixty participants were randomly assigned to supervised PRT or a control group. The 16-week PRT program consisted of three sessions per week, involving five exercises (three lower body, two upper body) with three sets of 8-10 repetitions, progressing to 75% of 1-repetition maximum, and 2-3 minutes of rest between sets. Results showed significant improvements in the PRT group, including decreased plasma glycosylated hemoglobin levels (8.7 ± 0.3% to 7.6 ± 0.2%), increased muscle glycogen stores (60.3 ± 3.9 to 79.1 ± 5.0 mmol glucose/kg muscle), and decreased medication dosage in 72% of exercisers ($P = 0.004$-0.05). Moreover, PRT participants gained lean mass (+1.2 ± 0.2 kg), decreased systolic blood pressure (-9.7 ± 1.6 mmHg), and decreased trunk fat mass (-0.7 ± 0.1 kg), while control participants showed opposite trends ($P = 0.01$-0.05). These findings demonstrate that PRT, as an adjunct to traditional care, is feasible and effective in improving glycemic control and addressing metabolic syndrome abnormalities in high-risk older adults with type 2 diabetes. Cuff et al. [13] compared the effects of aerobic exercise, resistance training, and combined aerobic and resistance training on glycemic control in obese postmenopausal women with type 2 diabetes. Twenty-eight participants were randomly divided into 3 groups: control (no exercise), aerobic only, and combined aerobic and resistance training. The 16-week program consisted of three sessions per week. The combined group's 75-minute sessions included a warm-up, aerobic exercise (60-75% heart rate reserve), resistance training (upper body, 3 lower body exercises, 2 sets, 12 repetitions), and a cool-down. Results showed significant improvements in glucose infusion rates ($P < 0.05$) in the combined aerobic and resistance training group. Both exercise groups showed decreased abdominal subcutaneous and visceral adipose tissue and increased muscle density. Significantly, the combined group exhibited greater muscle density increases than the aerobic-only group. Improved glucose disposal was associated with changes in subcutaneous and visceral adipose tissue and muscle density. After controlling for abdominal adipose tissue, muscle density retained a significant relationship with glucose disposal. These findings suggest that adding resistance training to aerobic exercise enhances glucose disposal in postmenopausal women with type 2 diabetes, likely due to a loss of abdominal adipose tissue and increased muscle density. Baldi et al. [5] investigated the effect of mild-intensity resistance training (RT) on glycemic control in obese men with type 2 diabetes. Eighteen participants were randomly assigned to RT or control groups. The ten-week RT program consisted of 3 sessions per week, involving 10 exercises for the upper and lower limbs with progressive intensity (10 RM upper body, 15 RM lower body) and 60-second rest periods. Results showed significant decreases in fasting glucose and insulin ($p < 0.05$) in the RT group, with near-significant reductions in glycosylated hemoglobin (HbA1c) ($p = 0.057$). Fat-free mass increased by 3.5% in the RT group, while fat mass increased by 6.9% in controls. Muscular strength and endurance improved by 25-52% in the RT group. Changes in fasting glucose and HbA1c correlated inversely with changes in fat-free mass. These findings suggest that resistance training effectively improves glycemic control and decreases fasting insulin levels in overweight type 2 diabetic men. A study conducted by Fennichi et al. [20] examined the effects of acute and continual resistance training on glucose and insulin responses to a glucose load in women with type 2 diabetes. Seven women with type 2 diabetes and eight age-matched controls participated in a six-week program, working out three times per week. This program consisted of eight exercises (chest press, shoulder press, lat pull-down, leg curl, leg extension, leg press, and triceps extension) performed in 3 sets of 8-12 repetitions at 80% of one-repetition maximum weight. Results showed significant improvements in glucose control after a single exercise session (acute bout), such as decreased integrated glucose response (3,355.0 ± 324.6 to 2,868.0 ± 324.0 mmol/L·min, $P < 0.01$) and peak glucose level (20.2 ± 1.4 to 17.2 ± 1.7 mmol/L). However, these improvements were not sustained after six weeks of chronic training. These findings suggest that resistance training can provide immediate benefits for glucose control in diabetic patients, complementing aerobic exercise. Misra et al. [30] used a prospective study design to examine the effects of Progressive Weight training intervention on fasting blood glucose and HbA1C levels in 30 respondents with type 2 diabetes mellitus. The respondents were selected from hospitals & clinics based on the inclusion criteria. Before the intervention, participants underwent a pretest using the short insulin tolerance test (SITT) following the inclusion criteria. The last post-test was conducted 72-96 hours after the exercise intervention, at the end of the 12-week (3 months) duration. Additionally, biochemical examinations were done by checking the fasting blood glucose levels before the intervention. The intervention consisted of Progressive Resistance Training and was carried out three times a week for 12 weeks. The results of the study showed significant improvements in both fasting blood glucose and HbA1C levels. Fasting blood glucose levels observed a decrease in the values, while HbA1C levels decrease to 7.3 ± 0.2 ($p < 0.001$). The results indicate that engaging in average-intensity Progressive Resistance Training for three months led to notable enhancements in HbA1C and fasting blood glucose levels among individuals diagnosed with type 2 diabetes. This suggests that resistance training could serve as an effective method for regulating blood sugar control among type-2 diabetic individuals. It's important to note that this study's strengths lie in its prospective design, which allows for tracking changes over time, and the significant improvements observed in blood glucose and HbA1C levels. Bweir *et al.* [9] employed a controlled trial study design with a parallel group design, matching subjects, to assess the impact of two interventions on blood glucose concentration and HbA1C measurements in 20 diabetics. Participants were divided into two groups: one received treadmill intervention while the other received resistance exercise intervention. Before initiating the treatment, researchers monitored participants' glycemic control and any treatment modifications for 12 weeks, which included measuring HbA1C levels. Blood glucose levels were measured pre- and post-training sessions, with the interventions administered 3 times/week over a span of 10 weeks. The study's findings revealed a major reduction in plasma glucose levels in both intervention groups, with statistical significance ($p < 0.05$) observed at weeks 1, 6, and 10. Notably, by the end of the 10 weeks, 80% of participants in the resistance exercise group achieved a normal range of blood glucose concentration levels of 140 mg/dl, whereas only 20% of participants in the treadmill intervention group attained normal glucose values. Additionally, there was a significant rise in average HbA1C levels before and after exercise in both cohorts ($p < 0.001$). However, the resistance exercise group exhibited a more substantial reduction in HbA1C levels compared to the treadmill exercise group ($p<0.006$). These findings suggest that the resistance exercise intervention yielded superior results in reducing HbA1C levels compared to the treadmill intervention. While both interventions effectively lowered glucose concentration levels and HbA1C levels, the weight exercise intervention demonstrated a more pronounced decrease in HbA1C levels. This underscores the potential of resistance exercise as a particularly beneficial approach for managing glycemic control in diabetics. Ng et al. [31] employed a randomized trial design to explore the effects of progressive resistance exercise intervention on glycosylated hemoglobin levels in 60 type 2 diabetics. Participants exhibited high HbA1c levels over the past month. HbA1c measurements were obtained using 10 ml of fasting blood from each participant, collected after a minimum fasting period of 10 hours from the previous night. These blood samples were analyzed in the General Hospital Laboratory by a laboratory assistant who was blinded to the study's objectives. High-performance liquid chromatography was utilized to measure HbA1c levels. The intervention involved progressive resistance exercise, with participants engaging in 2-3 practice sessions per week, each lasting approximately 50 minutes and preceded by a 10-minute warm-up. Over 8 weeks, each group completed a total of 18 sessions. The findings indicated that the PRT group experienced a reduction in HbA1c levels by 0.4% following the 8-week intervention. Additionally, the group showed a greater decrease in waist circumference. The data table indicates that the HbA1c value of the intervention group decreased from 8.9 at the beginning to 8.4 after 8 weeks of intervention. Similarly, the glucose level decreased from 10.4 at the beginning to 10.1 after 8 weeks of intervention. These findings suggest that progressive resistance exercise intervention led to a reduction in HbA1c levels and waist circumference in type 2 diabetics. The decrease in HbA1c is indicative of improved glycemic control, which is essential in managing diabetes and preventing complications. It's important to acknowledge that the study's strengths include its randomized trial design, which helps establish cause-effect relationships, and the significant improvements observed in HbA1c levels. Church et al. [11] implemented a clinical trial involving around 265 participants aged 31-75 years type 2 diabetics, with HbA1C levels ranging from 6.5% to 11%. Selection criteria were applied to recruit participants, ensuring adherence to specific inclusion and exclusion criteria. The study comprised four distinct groups: an aerobic group, a resistance group, a combination group (involving both aerobic and resistance exercises), and a control group, which engaged in stretching and relaxation exercises. During the intervention, participants in the resistance training group engaged in a 9-month training program, exercising three days per week. Each session encompassed a structured routine, comprising two sets of four upper body exercises (including bench press, seated row, shoulder press, and pull down), three sets of three leg exercises (such as leg press, extension, and flexion), and two sets of abdominal crunches and back extensions. The study's findings revealed that the absolute mean change in HbA1c within the combination exercise group was -0.34%, indicating a statistically significant decrease. However, the mean changes in HbA1c were not statistically significant in the aerobic group when compared to the control group. Additionally, the combined exercise group exhibited an increase in maximum oxygen consumption compared with the control group. Moreover, all exercise groups demonstrated reductions in waist circumference ranging from 2.0 to 2.8 cm compared with the control group. Regarding weight loss, the training group displayed an average loss of -1.3 kg, while the combined training group demonstrated an average loss of -1.8 kg relative to the control group. Based on these findings, the researchers concluded that among type 2 diabetics, the combination of endurance/aerobic and load exercise proved to be more effective in reducing HbA1c levels compared to any one type of training alone. Moreover, the exercise group that combined different exercises showed improvements in maximal oxygen consumption, along with reductions in waist circumference and fat mass compared to the control group. The study by Timothy et al. [36] aimed to examine the effects of aerobic training, resistance training, and a combination of both on hemoglobin A1c (HbA1c) levels in individuals with type 2 diabetes over a 9-month period. Participants in the resistance training group performed two sets of four upper body exercises, three sets of three leg exercises, and two sets each of abdominal crunches and back extensions. The combination group completed two resistance training sessions per week, consisting of one set of each of the nine exercises mentioned. The aerobic group performed exercise at an intensity of 50-80% of maximum oxygen consumption, with a weekly energy expenditure of 12 kcal/kg, while the combination group aimed for 10 kcal/kg per week. After 9 months, the baseline HbA1c level was 7.7%. The results indicated significant reductions in HbA1c for all exercise groups. The combination exercise group experienced the greatest decrease in HbA1c, with a reduction of -0.34%. The aerobic group had a decrease of -0.24%, while the resistance training group showed a smaller reduction of -0.16%. These changes were statistically significant, with the confidence intervals supporting the findings. In contrast, the control group, which did not engage in structured exercise but was offered weekly stretching and relaxation classes, showed no significant changes in HbA1c levels. This suggests that both aerobic and resistance training can be effective in improving glycemic control in individuals with type 2 diabetes, with the combination of both providing the greatest benefit. Baaci et al. [4] utilized an RCT design to examine the effects of aerobic and resistance exercise on type 2 diabetics. The intervention was administered 3 times/week for 4 months, with each session lasting 1 hour. Notably, blood sugar levels were continuously monitored using a CGMS (Continuous Glucose Monitoring System) over 2 days, commencing from the training sessions. To evaluate the effects of the exercise modalities, CGMS detectors were installed on each subject after they had consistently achieved and maintained the prescribed exercise volumes for at least two months. The participants were then divided into two groups: an aerobic intervention group consisting of 13 participants, and a resistance exercise group consisting of 12 participants. The aerobic group engaged in exercises such as treadmill running, cycling on a stationary bike (cycle), and using an elliptical machine, three times a week. Initially, the duration of training sessions ranged from 30 to 40 minutes, gradually increasing to 1 hour per session over the course of 5 weeks. The intensity of the exercises reached up to 65% of the maximum heart rate, with the use of a heart rate monitor to standardize intensity levels. In contrast, the resistance exercise group performed nine distinct exercises during each 3-week session, utilizing advanced load machinery and weights. During the starting learning stage up to 2 weeks, participants in both groups performed 3 sets of minimum 10-12 repetitions at 30-50% of their one-repetition maximum (1RM). Over time, the resistance progressively heightened, reaching the desired training program intensity of 71-85% of 1RM by the 6 weeks. All training sessions were closely supervised by an exercise specialist to ensure proper execution and safety. After the four-month intervention period, the researchers evaluated the changes in HbA1c levels in both groups. The results indicated that HbA1c levels in the aerobic group improved by an average of 0.48% (SD 0.14), while the resistance exercise group demonstrated an average improvement of 0.39% (SD 0.16). However, this disparity was insignificant, as evidenced by the p-value of 0.70. A 2012 study by Yavari et al. [39] compared the effects of aerobic exercise, resistance training, and combined training on glycemic control, cardiovascular risk factors, and body composition in 80 patients with type 2 diabetes. Participants exercised three times per week for 52 weeks. The aerobic group used treadmills, ellipticals, or bicycles for 20-60 minutes. The resistance training group performed 10 exercises (bench press, seated row, shoulder press, etc.) with three sets of 8-10 repetitions, starting at 60% one-repetition maximum (1RM) and progressing to 75-80% 1RM. The combined group did 20-30 minutes of aerobic exercise plus two sets of 8 exercises. Results showed significant HbA1c reductions in all training groups. Additionally, postprandial glucose, blood pressure, VO2 max, and muscle mass improved in all groups. Plasma triglycerides reduced significantly in the aerobic and combined groups, while body fat percentage decreased in the resistance and combined groups. Notably, combined training led to greater improvements in HbA1c and triglycerides compared to aerobic or resistance training alone. These findings suggest that both aerobic and resistance training effectively manage type 2 diabetes complications, but combined training yields greater benefits. The effects of exercise order on acute glycemic responses in people with type 1 diabetes performing both aerobic and resistance exercise was investigated by Yardley et al. [38]. They took twelve physically active participants with type 1 diabetes completed two experimental sessions, separated by at least five days. Each session consisted of 45 minutes of aerobic exercise (60% VO2 max) followed by 45 minutes of resistance training (three sets of eight exercises), or vice versa. Results showed significant declines in blood glucose levels during aerobic exercise preceded by resistance training (AR), but not when resistance training followed aerobic exercise (RA). After 45 minutes, glucose levels were higher in RA (9.2 ± 1.2 mmol/L) compared to AR (5.5 ± 0.7 mmol/L, P=0.006). However, glucose levels converged by the end of exercise (AR: 7.5 ± 0.8, RA: 6.9 ± 1.0 mmol/L, P=0.436). These findings suggest that performing resistance exercise before aerobic exercise improves glycemic control and decreases the risk and severity of post-exercise hypoglycemia in people with type 1 diabetes. Abebe and Balcha [1] undertook a study with 22 diabetic individuals to evaluate how a supervised Progressive Resistance Training (PRT) protocol affects weight loss, body composition, glycemic control, and the reduction of cardiovascular disease risk markers aimed at preventing and managing complications associated with Type 2 diabetes. The intervention consisted of three sessions per week for a duration of 12 weeks. Each supervised session began with a 10-minute warm-up routine that included brisk walking around the exercise facility, stretching exercises, and warming up on a treadmill and stationary bicycle. Following the initial activity, a 30-minute Progressive Resistance Training (PRT) session ensued, comprising exercises such as bench press, weightlifting, pull-downs, leg presses, dumbbell seated shoulder presses, knee extensions, and sit-ups. The session concluded with a 5-minute cool-down period, incorporating walking around the exercise facility and flexibility and stretching exercises. The training load was incrementally raised as participants achieved the ability to perform 3 sets of 15 or more repetitions at a specified load. Initially, exercise intensity began at 50-60% of one repetition maximum (1RM) in the first week and increased by 10% weekly, culminating in 80% of 1RM over 30 to 50 minutes in subsequent weeks. The study revealed significant improvements in various health parameters before and after the Progressive Resistance Training (PRT) intervention. Specifically, there were reductions in fasting blood glucose (FBG) by 28.1%, total cholesterol by 12.9%, triglycerides by 33.1%, resting pulse rate by 9.9%, resting maximum arterial blood pressure by 11.4%, resting minimum arterial blood pressure by 6.9%, weight by 1.9%, BMI by 2.5%, and body fat percentage by 9.7%. Furthermore, there was a 1.5% enhancement in muscle and bone density. Although the reductions in LDL (4%) and visceral fat percentage (3.9%) did not demonstrate statistical significance (P>0.05), they exhibited favourable tendencies. The conclusion drawn from the study was that supervised PRT over 12 weeks led to significant enhancements in blood glucose control, blood pressure regulation, dyslipidaemia, and body composition among Type 2 diabetics. A 2012 study by Balducci *et al*. [6] compared the effects of high-intensity (HI) versus low-intensity (LI) exercise on modifiable cardiovascular risk factors in 22 sedentary patients with type 2 diabetes. Participants exercised twice a week for 12 months, performing both cardiovascular training (treadmill, step, elliptical, arm, or cycle ergometer) and resistance training (four exercises targeting push movement, squat movement, trunk flexion, and abdominals). The LI group exercised at 55% VO2 max (aerobic) and 60% 1-RM (resistance), while the HI group exercised at 70% VO2 max and 60% 1-RM. Results showed that HI training yielded marginally better improvements in HbA1c (-0.17%, P=0.03), triglycerides (-0.12 mmol/l, P=0.02), and total cholesterol (-0.24 mmol/l, P=0.04) compared to LI training. However, no significant differences were observed in other risk factors or 10-year heart disease risk scores. These findings suggest that for low-fitness individuals, such as sedentary patients with type 2 diabetes, increasing exercise intensity does not offer significant additional benefits on cardiovascular risk factors. Bachi et al. [4] compared the acute blood glucose changes after aerobic (AER) and resistance (RES) exercise in 25 type 2 diabetes patients. Participants exercised three times per week for 4 months, divided into AER and RES groups. The AER group used treadmills, cyclettes, and ellipticals, starting at 30-40 minutes, 40-60% heart rate reserve, and progressing to 60 minutes, 60-65% heart rate reserve. The RES group performed 9 exercises with weight machines and free weights, starting at three sets of 10-12 repetitions, 30-50% 1RM, and progressing to 70-80% 1RM. Outcomes showed similar HbA1c reductions in both groups. However, glucose levels decreased during AER exercise (time-by-group interaction, p=0.04) but not RES exercise. Nocturnal glucose levels also differed (time-by-group interaction, p=0.02), with an improved nocturnal low blood glucose index (LBGI) in the AER group (p=0.012) but not the RES group (p=0.62). These findings suggest that while AER and RES exercise have similar long-term metabolic effects, their acute effects on glucose levels differ, with a potential increased risk of late-onset hypoglycemia after AER exercise. A 2012 study by Dijk et al. compared the effects of endurance and resistance exercise on 24-hour blood glucose homeostasis in individuals with impaired glucose tolerance (IGT) and type 2 diabetes. Fifteen individuals from each group (IGT, insulin-treated type 2 diabetes, and orally medicated type 2 diabetes) underwent three intervention periods. The endurance exercise session consisted of 45 minutes of moderate-intensity cycling (50% Wmax). The resistance exercise session included upper-body and leg exercises with progressive intensity (40-75% 1RM). Results showed significant reductions in average 24-hour blood glucose concentrations after both exercise types (p < 0.001). Specifically, blood glucose decreased from 7.4 ± 0.2 to 6.9 ± 0.2 mmol/L (resistance) and 6.8 ± 0.2 mmol/L (endurance) in IGT participants, and from 9.6 ± 0.5 to 8.6 ± 0.4 mmol/L (resistance) and 8.6 ± 0.5 mmol/L (endurance) in orally medicated type 2 diabetes participants. Hyperglycemia (>10 mmol/L) occurrence decreased by 35 ± 7% (resistance) and 33 ± 11% (endurance) over 24 hours ($p < 0.001$). These findings suggest that both resistance and endurance exercise improve glycemic control and can be integrated into exercise intervention programs for individuals with impaired glucose tolerance and type 2 diabetes. Barzegari and Mahdirejei [7] investigated the effects of resistance training on plasma vaspin and lipid profile levels in 30 patients with type 2 diabetes. Participants underwent eight weeks of circuit resistance exercise, three times per week, including 10 exercises (bench press, knee extension, etc.) with 8-15 repetitions at 50-80% of one-repetition maximum. Results showed significant reductions in vaspin levels (330.50 ± 82.51 to 251.62 ± 107.28 ng/ml, p=0.03) and total cholesterol (TC) levels (185.21 ± 47.51 to 171.10 ± 37.91 mg/dl, p=0.02) in the resistance training group. Additionally, HDL-C levels increased (38.20 ± 20.65 to 43.80 ± 7.87 mg/dl, p=0.01). In comparison, the control group experienced increased vaspin levels (344 ± 78.64 to 436 ± 70.47 ng/ml, p=0.03). Significant differences in plasma vaspin levels were found between the two groups. These findings suggest that resistance training decreases vaspin levels and improves lipid profiles, particularly TC and HDL-C, in patients with type 2 diabetes. Ghalavand et al. [21] investigated the effects of resistance training on blood glucose, blood pressure, and resting heart rate in 20 men with type 2 diabetes. Participants underwent 8 weeks of resistance training, 3 sessions per week, consisting of exercises focused on chest, deltoid, lower back, biceps, triceps, thighs, legs, and trunk muscles. This program started with 15-20 repetitions at 30-40% of one-repetition maximum (1RM) and progressed to 60-70% 1RM.Outcomes showed significant decreases in fasting blood sugar (P=0.002), glycosylated hemoglobin (HbA1c) (P=0.005), and systolic blood pressure (P=0.022) within the resistance training group. In comparison to the control group, significant differences were found in blood sugar (P=0.003) and HbA1c (P=0.031). These findings confirm that resistance training positively affects blood glucose and blood pressure control in men with type 2 diabetes, highlighting its potential as an effective adjunct therapy. Jin, Park, and So [26] employed a randomized controlled trial design to examine the impact of elastic band resistance exercise intervention on blood glucose levels in 16 participants who met the specified accepted criteria. The participants were divided into experimental groups and a control group. To mitigate the influence of diet, subjects were instructed to fast for a minimum of 12 hours before blood collection. Pre-test blood samples were obtained 2 days before the exercise intervention, while post-test samples were collected 2 hours after the conclusion of the 12-week intervention. Blood collection was conducted as per the approved protocol, with each sample totalling 10 ml. The samples were subsequently preserved in evacuated tubes containing EDTA solution for the analysis of sugar levels. Once the blood was transferred into plain vacutainers, serum was isolated centrifugally. Regarding the intervention, each session lasted 60 minutes and comprised a warm-up session, followed by an exercise session, and concluded with a cooling down period of 10, 40, and 10 minutes respectively. This exercise regimen was conducted 3 times/week for 12 weeks. The results demonstrated significant alterations in blood sugar levels pre & post-intervention. Specifically, in the experiment group, blood sugar levels decreased from 122 ± 2.5 before the intervention to 103.12 ± 4.56 after the intervention. This reduction in blood sugar levels was deemed statistically significant ($p < 0.021$), underscoring the favorable impact of the elastic band resistance exercise on blood sugar levels. It's worth emphasizing the strength of this study, which lies in its trial design, enabling more robust conclusions regarding the intervention's influence on blood sugar levels. Luh Inca and Agustini [28] employed a one-group pretest-post-test design to explore the impact of a rubber band resistance exercise intervention on the blood sugar levels of 15 participants with pre-hypertension. The intervention was applied to participants who met the inclusion criteria, and data were collected in March 2017 through questionnaires and observations of blood sugar levels. The researchers employed precise tools and materials, including needles, adjustable lancing devices, 70% alcohol, cotton, blood glucose tests, and Gluco Strips as reagents. Peripheral blood samples were taken from the fingertips for subsequent analysis. The intervention involved performing rubber band resistance exercises for 30 minutes every day for one week, totalling 210 minutes of exercise over the week. The study findings demonstrated a notable and statistically significant reduction in blood sugar levels among participants before exercise, with a mean blood sugar level of 176.47 (standard deviation = 88.19). The statistical analysis revealed a significant t-value of 2.02, with a p-value less than 0.05 (two-tailed), indicating that the decrease in blood sugar was not due to chance. Furthermore, the effect size, indicated by eta squared statistics, was 0.28, which is considered a large effect size. This implies that the rubber band resistance exercise intervention had a substantial impact on lowering blood sugar levels in the respondents. The study outcomes indicate that engaging in rubber band resistance exercises for one week led to a notable reduction in blood glucose levels, highlighting the potential benefits of this type of exercise in managing blood glucose in individuals with pre-hypertension.

DISCUSSION

Eriksson *et al*. [19] demonstrated that a 13-week circuit resistance training program significantly improved glycemic control in individuals with non-insulin-dependent diabetes mellitus (NIDDM), reducing HbA1c levels from 8.8% to 8.2%. The program, featuring moderate- to high-intensity upper and lower body exercises, also increased muscle endurance and enhanced the vastus lateralis cross-sectional area by 21%, promoting muscle hypertrophy and improved insulin sensitivity. This low-intensity, accessible approach is particularly suitable for sedentary, moderately obese elderly individuals with NIDDM. The study highlights the value of integrating resistance training into comprehensive diabetes management programs to improve metabolic health and clinical outcomes. Honkola *et al.* [22] demonstrate that circuit-type resistance training significantly improves health parameters in individuals with type 2 diabetes. The study reports notable reductions in total cholesterol (6.0±0.3 to 5.3±0.3 mM), LDL cholesterol (3.90±0.22 to 3.35±0.21 mM), and triglycerides (1.91±0.25 to 1.53±0.22 mM), all of which lower cardiovascular disease risks. Additionally, a 0.5% improvement in HbA1c highlights better long-term glycemic control. These findings suggest that circuit-type resistance training is both feasible and effective for sedentary, moderately obese individuals with type 2 diabetes, offering significant benefits in lipid profiles and glycemic management while reducing cardiovascular risks. Pan *et al*. [32] demonstrate that diet and exercise interventions significantly delay the progression from impaired glucose tolerance (IGT) to non-insulin-dependent diabetes mellitus (NIDDM) over six years. Intervention groups (diet, exercise, and their combination) showed smaller increases in fasting plasma glucose and 2-hour glucose levels compared to the control group, which experienced substantial rises (e.g., fasting glucose from 5.52±0.82 to 7.59±2.59 mmol/l). The combined diet and exercise group yielded slightly superior outcomes, suggesting a synergistic effect. These findings underscore the importance of lifestyle modifications, including diet and physical activity, in diabetes prevention. Ishii et al. [25] highlight resistance training's benefits in improving insulin sensitivity (48% increase in glucose disposal rate) and muscle strength (16% increase in quadriceps strength) among non-overweight individuals with NIDDM. Despite no changes in body composition, the training enhanced metabolic health and mobility. These results emphasize resistance training as a valuable diabetes management tool, offering significant benefits independent of weight loss. The data from Dunstan et al.'s 1998 [17] study reveals important trends regarding the impact of short-term circuit weight training (CWT) on glycemic control and strength in patients with non-insulin-dependent diabetes mellitus (NIDDM). One key finding is the significant improvement in glycemic control observed in the CWT group. Oral glucose tolerance testing showed a marked reduction in glucose levels, with a decrease of 213 mmol/L over 120 minutes ($P<0.05$), as well as a substantial reduction in insulin levels, with a decrease of 6130 pmol/L over 120 minutes ($P<0.05$). These changes in glucose and insulin levels indicate that CWT can enhance the body's efficiency in handling glucose, a critical outcome for managing blood sugar levels in individuals with NIDDM. By comparison, the control group did not experience such changes, highlighting the effectiveness of the CWT intervention in improving metabolic parameters associated with diabetes. Strength improvements were another notable result of the CWT program, with significant gains observed across all exercises. This strength increase, achieved within an 8-week period with only three sessions per week, underscores the program's efficiency and potential accessibility. Building muscle strength is especially valuable for individuals with diabetes, as improved muscular fitness supports daily function, enhances insulin sensitivity, and may aid in better overall metabolic health. Together, these findings suggest that short-term CWT provides a dual benefit for NIDDM patients: it not only aids in glycemic control but also enhances muscular strength, both of which are important for managing diabetes. Given its relatively short duration and manageable frequency, this exercise regimen offers a practical and effective option for lifestyle intervention in diabetes care, potentially helping patients achieve better blood sugar control and improved physical strength without intensive time commitments. The data presented in Maiorana et al.'s 2002 study [29] illustrates the comprehensive impact of an eight-week circuit training (CT) program that combines aerobic and resistance exercise on several health parameters in individuals with type 2 diabetes. The study highlights improvements across multiple domains, including glycemic control, cardiorespiratory fitness, muscular strength, and body composition. The most significant outcomes are observed in cardiorespiratory fitness, with the ventilatory threshold increasing from 11.8±0.7 to 13.8±0.6 $ml \cdot kg^{-1} \cdot min^{-1}$ ($P<0.001$) and peak oxygen uptake also improving significantly ($P<0.05$). These results suggest that the CT program effectively enhances cardiovascular and respiratory efficiency, an essential factor in improving endurance and exercise capacity for individuals with type 2 diabetes, who often experience limitations in these areas. Muscular strength also improved markedly, with total strength increasing from 403±30 to 456±31 kg ($P<0.001$). This gain in strength, achieved over a relatively short period, demonstrates that combining aerobic and resistance training yields benefits in muscle conditioning. Improved strength is beneficial for functional activities, supporting greater independence in daily tasks and potentially reducing the risk of injury. Body composition improvements were another key outcome, with reductions in skinfold measurements (148.7±11.5 to 141.1±10.7 mm, P<0.05), percentage body fat (29.5±1.0% to 28.7±1.1%, P<0.05), and waist-to-hip ratio (99.2±1.5% to 97.9±1.4%, P<0.05). These changes indicate a shift toward a healthier body composition, which can have positive effects on metabolic health and further support glycemic control in individuals with diabetes. Glycemic control also improved, evidenced by decreases in glycated hemoglobin and fasting blood glucose levels (both P<0.05). These reductions indicate better long-term blood sugar management and suggest that circuit training may help mitigate the progression of diabetes-related complications. Improved glycemic control is critical in managing type 2 diabetes, as it helps reduce the risk of cardiovascular issues and other related health problems. Overall, the findings underscore the effectiveness of circuit training as a multifaceted intervention. The program's success in improving cardiorespiratory fitness, strength, body composition, and glycemic control highlights its value as a lifestyle intervention for individuals with type 2 diabetes. The diverse benefits of this CT program make it a valuable approach not only for managing diabetes but also for enhancing general health and functional capacity, thereby improving quality of life for patients. The data from Dunstan et al.'s 2002 study provides valuable insights into the effects of combining high-intensity progressive resistance training (RT) with moderate weight loss (WL) on glycemic control and body composition in sedentary, obese patients with type 2 diabetes. One of the study's key findings is the significant improvement in glycemic control in the RT & WL group, as indicated by a greater reduction in HbA1c levels at both three and six months. At three months, HbA1c levels decreased by 0.6 ± 0.7% in the RT & WL group compared to only 0.07 ± 0.8% in the WL-only group (P < 0.05). By six months, this reduction was even more pronounced, with a decrease of 1.2 ± 1.0% in the RT & WL group versus 0.4 ± 0.8% in the WL-only group (P < 0.05). This indicates that incorporating resistance training into a weight loss regimen offers added benefits for glycemic control, beyond what weight loss alone can achieve. Improved glycemic control is particularly important for patients with type 2 diabetes, as it reduces the risk of diabetes-related complications and improves long-term health outcomes. Both groups showed similar reductions in body weight and fat mass after six months, which suggests that weight loss was comparable across both interventions. However, a notable difference was observed in lean body mass. In the RT & WL group, lean body mass increased by 0.5 ± 1.1 kg, whereas it decreased by 0.4 ± 1.0 kg in the WL-only group (P < 0.05). This suggests that resistance training helped to preserve, or even increase, lean body mass while participants were losing weight. Preservation of lean body mass is crucial, especially for older adults, as it supports strength, functionality, and metabolic health, which can contribute to overall physical resilience and quality of life. Study suggests that high-intensity progressive resistance training combined with moderate weight loss is particularly beneficial for obese, sedentary patients with type 2 diabetes. Not only does this approach improve glycemic control more effectively than weight loss alone, but it also helps maintain lean body mass, which is essential for physical function and metabolic health. This combination provides a practical and comprehensive approach to diabetes management, highlighting the value of including resistance training in lifestyle interventions for this population. In analyzing the data presented in the 2002 study by Castaneda et al. [10] several key trends and implications emerge. The study highlights significant improvements in glycemic control among participants engaged in high-intensity progressive resistance training (PRT). The plasma glycosylated hemoglobin (HbA1c) levels decreased markedly from 8.7 ± 0.3% to 7.6 ± 0.2%, indicating better long-term glucose management. This reduction in HbA1c is crucial for individuals with type 2 diabetes, as it correlates with lower risks of diabetes-related complications. Additionally, muscle glycogen stores increased significantly from 60.3 ± 3.9 to 79.1 ± 5.0 mmol glucose/kg muscle. This enhancement suggests that PRT not only improves muscle strength but also enhances the muscles' ability to store glucose, which is essential for energy during physical activity and overall metabolic health. The study also found that 72% of participants in the PRT group reduced their prescribed diabetes medication dosage. This reduction implies that PRT can serve as an effective adjunct to pharmacological treatment, potentially leading to lower healthcare costs and diminished risks of medication-related side effects. Furthermore, changes in body composition were notable; PRT participants gained lean mass (+1.2 ± 0.2 kg), while control participants saw a slight decrease (-0.1 ± 0.1 kg). This increase in lean body mass is significant because it can enhance metabolic rate and overall physical function, which is particularly important for older adults. Participants also experienced improvements in cardiovascular health, with a reduction in systolic blood pressure of -9.7 ± 1.6 mmHg, while control subjects experienced an increase (+7.7 ± 1.9 mmHg). The reduction in blood pressure among PRT participants suggests an additional health benefit, helping to mitigate the risk of cardiovascular disease, which is often associated with diabetes and aging. Overall, these findings demonstrate that high-intensity progressive resistance training is a feasible and effective intervention for improving glycemic control and addressing various metabolic syndrome abnormalities in high-risk older adults with type 2 diabetes. The study supports the integration of resistance training into diabetes management programs, emphasizing its role not only in physical fitness but also in enhancing metabolic health and potentially reducing reliance on medication. In analyzing the data from the 2003 study by Cuff *et al*., [13] several important trends, comparisons, and implications can be drawn regarding the effects of different types of exercise on glycemic control among obese postmenopausal women with type 2 diabetes. The study indicates a significant improvement in glucose disposal rates in the combined aerobic and resistance training (Ae+RT) group, with statistical significance ($P < 0.05$). This improvement suggests that the combination of both types of exercise may synergistically enhance the body's ability to manage blood glucose levels effectively. Both the aerobic-only and Ae+RT groups showed reductions in abdominal subcutaneous and visceral adipose tissue (AT), which are critical factors in metabolic health and glycemic control. The reduction in visceral fat, in particular, is noteworthy since visceral fat is closely linked to insulin resistance and various metabolic diseases. When comparing the exercise groups, the Ae+RT group exhibited significantly greater increases in muscle density compared to the aerobic-only group. This suggests that the inclusion of resistance training not only improves muscle strength but also contributes to the structural adaptations of muscle tissue that are beneficial for metabolic health. Moreover, while both groups experienced reductions in adipose tissue, the Ae+RT group's superior gains in muscle density likely contributed to their enhanced glucose disposal rates. This indicates that simply performing aerobic exercise may not be sufficient to achieve the same level of metabolic improvements as a combined approach. The findings of this study have several implications for managing type 2 diabetes in postmenopausal women. First, incorporating resistance training into exercise regimens may provide greater benefits for glycemic control than aerobic exercise alone. The enhancement of muscle density could lead to better overall metabolic health, reduced risk of complications associated with diabetes, and potentially lower healthcare costs due to improved disease management. Furthermore, the relationship between muscle density and glucose disposal, even after controlling for abdominal fat, suggests that maintaining or increasing muscle mass is critical for improving insulin sensitivity. This highlights the importance of resistance training in any comprehensive diabetes management program, particularly for older adults who may experience age-related muscle loss. They [13] emphasize the value of a mixed exercise approach, combining aerobic and resistance training, for improving glycemic control and overall metabolic health in obese postmenopausal women with type 2 diabetes. The data support the need for personalized exercise prescriptions that include resistance training as a key component to enhance the effectiveness of diabetes management strategies. The 2003 study by Baldi et al. [5] provides valuable insights into the role of low-intensity resistance training (RT) in managing glycemic control among overweight men with type 2 diabetes. In this study, a total of 18 participants were randomly assigned to either a RT group or a control group, allowing for a robust comparison between the two interventions. The RT program spanned 10 weeks and comprised three sessions per week, each featuring 10 exercises targeting both upper and lower limbs. The program employed a progressive intensity approach, with initial resistance set at 10 repetitions maximum (10RM) for the upper body and 15 repetitions maximum (15RM) for the lower body, gradually increasing by 5% to ensure continued adaptation. The results of this investigation revealed significant reductions in fasting glucose and insulin levels within the RT group, with a statistical significance of $P < 0.05$. Furthermore, a borderline significant decrease in glycosylated hemoglobin (HbA1c) was observed ($P = 0.057$), suggesting a trend toward improved long-term glycemic control. These findings are particularly noteworthy, as they underscore the potential of resistance training as an effective intervention for managing diabetes-related metabolic parameters. In addition to the improvements in glycemic control, the study noted that fat-free mass in the RT group increased by 3.5%, while the control group experienced a 6.9% increase in fat mass. This discrepancy highlights the beneficial effects of RT on body composition, contributing to the overall metabolic health of participants. Moreover, muscular strength and endurance demonstrated marked improvements, with enhancements ranging from 25% to 52% in the RT group. Such significant gains in physical fitness not only aid in daily functioning but may also play a critical role in managing diabetes. Interestingly, the analysis revealed that changes in fasting glucose and HbA1c were inversely related to changes in fat-free mass. This relationship suggests that as fat-free mass increases, there may be a corresponding improvement in glycemic control, indicating the importance of muscle preservation in the metabolic management of type 2 diabetes. Overall, the findings from Baldi et al. emphasize that resistance training is an effective form of exercise for modestly improving glycemic control and reducing fasting insulin levels in overweight men with type 2 diabetes. These results support the incorporation of resistance training into diabetes management programs, highlighting its potential to improve both metabolic outcomes and overall health in this population. In analyzing the data from the 2004 study by

Fennichia *et al*., [20] several key trends and implications emerge regarding the effects of acute and chronic resistance training on glucose and insulin responses in women with type 2 diabetes. The study demonstrated significant improvements in glucose control following an acute session of resistance training. Specifically, the integrated glucose area under the curve was reduced from 3,355.0 ± 324.6 mmol/L·min to 2,868 ± 324.0 mmol/L·min ($P < 0.01$). This reduction indicates a more favorable glucose response to a glucose load, suggesting that acute resistance training can enhance the body's ability to manage blood sugar levels effectively. Additionally, peak glucose levels decreased from 20.2 ± 1.4 mmol/L to 17.2 ± 1.7 mmol/L after the acute exercise bout, further supporting the notion that resistance training can lead to immediate improvements in glucose metabolism. While the acute effects of resistance training were notable, the study also found that chronic training did not sustain these improvements, as glucose concentrations returned to pre-training levels after the six-week program. This contrast highlights an important distinction between the immediate benefits of exercise and the long-term effects of regular training. The inability of chronic resistance training to maintain lower glucose levels suggests that while resistance training is beneficial, it may need to be combined with other forms of exercise, such as aerobic training, to achieve lasting improvements in glycemic control. The findings from this study imply that resistance training can be an effective strategy for managing glucose levels in women with type 2 diabetes, particularly in the short term. The ability of resistance exercise to lower both the integrated glucose area under the curve and peak glucose levels highlights its potential as a valuable component of diabetes management strategies. However, the lack of sustained improvements in glucose control emphasizes the need for ongoing physical activity. Incorporating resistance training into diabetes management programs may provide patients with an alternative to traditional aerobic exercise, especially for those who may prefer strength training. This study suggests that a multi-faceted approach, including both resistance and aerobic exercises, may be necessary to achieve and maintain optimal glycemic control. Overall, while acute resistance training shows promise for improving immediate glucose responses, the findings underscore the importance of long-term exercise adherence and the potential necessity of combining different types of exercise to achieve sustained metabolic benefits for individuals with type 2 diabetes. The study by Misra *et al*. [30] focused on fasting blood glucose levels and investigated the effects of a prospective intervention using resistance exercise on 30 respondents with type 2 diabetes. The intervention was carried out three days a week for a duration of 12 weeks. The results showed a gradual decrease in fasting blood glucose levels over the course of the intervention. Before the intervention, fasting blood glucose levels were 10.07 ± 2.0 mmol/L, which decreased to 8.7 ± 1.3 mmol/L at one month, 8.2 ± 1.1 mmol/L at two months, and 7.4 ± 1.2 mmol/L at three months. The overall decrease in fasting blood glucose was 2.67 mmol/L, indicating an improvement in glycemic control with resistance exercise. Additionally, five articles discuss the influence of resistance exercise on HbA1C levels. The data from Bweir [9] study highlights key trends and comparisons between the effects of aerobic and resistance exercise on glycemic control in inactive patients with type 2 diabetes. Both exercise protocols—resistance and aerobic training—were effective in improving glycemic control, as evidenced by significant reductions in daily pre-exercise plasma glucose readings and HbA1c levels across both groups ($p < 0.001$). These reductions suggest that a consistent exercise regimen, whether aerobic or resistance-based, contributes to better glucose management in individuals with type 2 diabetes. However, the data reveal a more pronounced effect in the resistance exercise group. Although both groups saw improved HbA1c levels, the resistance training group experienced significantly larger reductions, resulting in notably lower HbA1c levels compared to the aerobic group by the end of the 10-week period ($p < 0.006$). This suggests that resistance training may have a unique advantage in enhancing glycemic control beyond the benefits achieved through aerobic exercise alone. The greater impact of resistance training on HbA1c reduction may be attributed to the nature of resistance exercises, which increase muscle mass and may improve glucose uptake and insulin sensitivity over time. This enhanced effect suggests that resistance training could be a particularly effective strategy for individuals with type 2 diabetes seeking improved glycemic control. In terms of clinical implications, this study supports the integration of resistance training into exercise recommendations for diabetes management, potentially offering better outcomes than aerobic exercise alone. Given the common association of type 2 diabetes with muscle mass decline and insulin resistance, resistance training could serve as an essential component in exercise regimens tailored for glycemic control in these patients. Indeed, the findings from Ng et al. [16] corroborate the effectiveness of resistance exercise in improving glycemic control among individuals with diabetes. The significant decrease in HbA1C levels observed in the intervention group following 8 weeks of resistance exercise, from 8.9 to 8.4, highlights the positive impact of this form of exercise on managing diabetes and reducing HbA1C levels. The study by Church et al. [11] included 262 participants and explored the effects of aerobic and resistance training on HbA1C levels. The intervention involved exercise sessions conducted three times a week over a period of nine months. However, the results indicated that the mean changes in HbA1C levels were not statistically significant in either the resistance training group or the aerobic training group compared to the control group. Interestingly, the combined exercise group, which engaged in both aerobic and resistance training, demonstrated a significant increase in maximum oxygen consumption compared to the control group. In summary, the studies suggest that both moderate-intensity Progressive Resistance Training (PRT) and combined aerobic and resistance exercise can lead to improvements in HbA1C levels in patients with type 2 diabetes. However, the results of the study by Bachi et al. [4] indicate that there may not be a significant difference between the effects of aerobic and resistance exercise on HbA1C levels. Timothy et al. [36] demonstrates the effectiveness of structured exercise programs in improving glycemic control in individuals with type 2 diabetes, as evidenced by reductions in hemoglobin A1c (HbA1c) levels over nine months. All exercise groups—resistance training, aerobic training, and the combination of both—resulted in decreased HbA1c levels compared to baseline, with the combined training group achieving the most significant reduction (-0.34%). This synergistic effect highlights the benefits of incorporating both aerobic and resistance exercises into a single program, which may optimize glycemic control by targeting different physiological pathways. Although the reductions in HbA1c for the aerobic (-0.24%) and resistance (-0.16%) groups were smaller, they still indicate meaningful improvements compared to the control group, which did not exhibit any structured exercise and only maintained current activity levels. These findings support the role of both aerobic and resistance exercises in managing type 2 diabetes, offering flexibility in tailoring interventions to patient preferences and capabilities. The study also underscores the importance of combining modalities for enhanced benefits, which could be particularly relevant for clinical recommendations aimed at maximizing outcomes in diabetes management. The study by Bachi et al. [4] highlights that both aerobic and resistance exercises are equally effective in improving glycemic control in individuals with type 2 diabetes. Over a 4-month period, participants in both exercise groups experienced similar reductions in HbA1c levels, with no significant differences between the two interventions ($p = 0.70$). These findings suggest that individuals with type 2 diabetes have flexibility in choosing between aerobic and resistance exercises based on personal preference, physical ability, or access to equipment, without compromising glycemic outcomes. This equivalence between the two exercise modalities underscores the importance of promoting regular physical activity in diabetes management, as both approaches are capable of achieving meaningful improvements in HbA1c. Additionally, the results provide clinicians with evidence to recommend diverse exercise options tailored to individual needs, thereby potentially improving adherence to physical activity regimens. The study supports the broader role of structured exercise programs as a cornerstone of diabetes care. In the 2012 study by Yavari et al., [39] the analysis of the data reveals several key trends and comparisons across the different exercise modalities for patients with type 2 diabetes. First, all training groups—those engaged in aerobic exercise, resistance training, and combined training—demonstrated significant reductions in HbA1c levels, indicating improved glycemic control. This highlights the efficacy of all three forms of exercise in managing blood sugar levels over the 52-week period. The study also noted improvements in other important health metrics, such as postprandial glucose levels, blood pressure, VO2max, and muscle mass across all groups. Specifically, the aerobic and combined training groups showed significant reductions in plasma triglycerides, suggesting that these forms of exercise may be particularly effective in improving lipid profiles. Conversely, the resistance training and combined groups experienced decreases in body fat percentage, which is crucial for overall metabolic health. Notably, the combined training group exhibited superior results in terms of HbA1c and triglycerides when compared to those participating in aerobic or resistance training alone. This suggests that integrating both aerobic and resistance training can provide synergistic benefits that enhance overall health outcomes for individuals with type 2 diabetes. The implications of these findings advocate for a holistic approach to exercise programming in this population, emphasizing that a combination of exercise types may yield the best results in managing diabetes-related complications. Yardley et al. [38] offers insights into how exercise order affects blood glucose levels in individuals with type 1 diabetes when performing both aerobic and resistance exercises in a single session. The study reveals a significant trend: when participants performed aerobic exercise followed by resistance training (AR), their blood glucose levels dropped substantially, reaching 5.5 ± 0.7 mmol/L after the first 45 minutes of aerobic exercise ($P = 0.006$). In contrast, when participants reversed the order—starting with resistance training followed by aerobic exercise (RA)—their blood glucose levels remained higher, at 9.2 ± 1.2 mmol/L, at the same point in the session. This initial difference in glucose responses indicates that beginning with aerobic exercise causes a sharper drop in blood glucose, potentially increasing the risk of hypoglycemia during the exercise. However, by the end of each session, glucose levels converged, with AR at 7.5 ± 0.8 mmol/L and RA at 6.9 ± 1.0 mmol/L ($P = 0.436$). This suggests that while exercise order influences the initial glycemic response, overall blood glucose levels stabilize by the end of the workout regardless of the sequence. The implications of these findings are significant for individuals with type 1 diabetes who are concerned about exercise-induced hypoglycemia. Starting with resistance exercise may help maintain a more stable blood glucose level throughout the workout, reducing the risk and duration of hypoglycemia. This order could be particularly useful for those looking to balance the benefits of aerobic and resistance training without significant drops in glucose levels. The study by Yardley et al. supports the idea that adjusting exercise sequence can improve glycemic stability and may be an effective strategy in managing exercise-related blood glucose responses in type 1 diabetes. The 2012 study by Abebe and Balcha [1] provides valuable insights into the impact of supervised progressive resistance training (PRT) on various health parameters in patients with type 2 diabetes. The data indicates significant positive changes in multiple health markers, underscoring the effectiveness of PRT as a therapeutic intervention for managing diabetes-related health issues. A key trend observed in the study is the substantial improvement in glycemic control, evidenced by a 28.1% reduction in fasting blood glucose levels. This reduction is particularly important as better glycemic control is associated with a lower risk of diabetes complications. The statistical significance ($p<0.05$) of this finding suggests that PRT can be a valuable addition to the management strategies for patients with type 2 diabetes. In terms of cardiovascular health, the study revealed notable improvements in both systolic and diastolic blood pressure, with reductions of 11.4% and 6.9%, respectively. The resting pulse rate also showed a significant decline of 9.9%. These changes indicate that PRT may enhance cardiovascular function and lower the risk of cardiovascular disease, which is a critical concern for individuals with diabetes. The lipid profile improvements are also noteworthy. The total cholesterol decreased by 12.9% and triglycerides by 33.1%, both of which contribute to a lower risk of heart disease. While the LDL cholesterol reduction was not statistically significant, the trend towards a 4% decrease alongside a 3.9% reduction in visceral fat percentage suggests positive changes in overall body composition. These findings highlight the potential for PRT to positively influence metabolic health beyond glycemic control. Muscle and bone density increases (1.5%) further emphasize the benefits of resistance training, as maintaining muscle mass and bone health is crucial for older adults and individuals with diabetes, who are at increased risk of musculoskeletal issues. Overall, the study by Abebe and Balcha [1] suggests that 12 weeks of supervised PRT can lead to significant improvements in glycemic control, cardiovascular health, and body composition in patients with type 2 diabetes. These findings imply that incorporating resistance training into diabetes management plans may enhance overall health outcomes and mitigate the risks associated with the condition, making it a valuable recommendation for both clinicians and patients. The 2012 study by Balducci et al. [6] provides important insights into the impact of exercise intensity on cardiovascular risk factors in sedentary patients with type 2 diabetes. The comparative analysis of high-intensity (HI) and low-to-moderate intensity (LI) training reveals several key trends and implications regarding the management of cardiovascular health in this population. One notable trend in the results is the slight advantage that HI training has over LI training in improving specific cardiovascular markers. The reductions in HbA1c, triglycerides, and total cholesterol observed in the HI group—of -0.17% ($P=0.03$), -0.12 mmol/L ($P=0.02$), and -0.24 mmol/L ($P=0.04$), respectively—indicate a statistically significant enhancement in glycemic control and lipid profiles. This suggests that even marginal increases in exercise intensity can yield beneficial effects on these critical health indicators. However, it is important to consider that the overall differences in cardiovascular risk factors between the two training intensities were relatively modest. The lack of significant differences in other cardiovascular risk factors and 10-year coronary heart disease risk scores implies that while higher intensity may lead to specific improvements, it may not be sufficient to produce comprehensive cardiovascular benefits for sedentary individuals with type 2 diabetes. The implications of these findings suggest that while HI training can offer some advantages in managing certain cardiovascular risk factors, it may not be necessary to focus solely on intensity for low-fitness individuals. This population might still achieve substantial health benefits from LI training, which could be more sustainable and accessible. Furthermore, the results highlight the importance of encouraging regular physical activity, regardless of intensity, as a critical component of diabetes management and cardiovascular health. Overall, the study reinforces the idea that a tailored approach to exercise, considering individual fitness levels and preferences, may be the most effective strategy for improving health outcomes in patients with type 2 diabetes. In the 2012 study by Bachi et al. [4] the comparison of acute blood glucose changes after aerobic (AER) and resistance (RES) training in patients with type 2 diabetes revealed several significant trends and implications. Both training modalities resulted in comparable long-term reductions in HbA1c levels, indicating that both AER and RES can effectively contribute to overall glycemic control in this population. However, the differences in acute blood glucose responses highlight important considerations for exercise prescription. During AER sessions, participants experienced a significant decrease in glucose levels, as indicated by the time-by-group interaction (p=0.04). This acute response is beneficial, suggesting that aerobic exercise is effective for immediate glycemic management, potentially aiding in postprandial glucose control. Conversely, the RES training did not elicit the same acute decrease in glucose levels, suggesting a different metabolic response to resistance exercise that may not provide the same immediate benefits for blood glucose control. The nocturnal glucose response further illustrates the differences between the two modalities. The AER group exhibited an increase in the nocturnal low blood glucose index (LBGI), with a significant p-value of 0.012, indicating a heightened risk for hypoglycemia during the night following AER sessions. In contrast, the RES group did not show any significant changes in nocturnal glucose levels (p=0.62), suggesting that resistance training may provide a more stable glycemic profile post-exercise, potentially reducing the risk of hypoglycemia during the night. Overall, these findings suggest that while both aerobic and resistance training can contribute to long-term glycemic control in patients with type 2 diabetes, the acute effects on blood glucose levels differ markedly. AER may be more effective for immediate glucose lowering, while RES may be advantageous for maintaining stable glucose levels and reducing the risk of late-onset hypoglycemia. These insights can inform individualized exercise prescriptions, emphasizing the need for patients to be cautious of hypoglycemia, especially after aerobic sessions. In the 2012 study by Dijk et al., [15] the analysis of the data reveals several key trends regarding the effects of endurance and resistance exercise on blood glucose homeostasis in individuals with impaired glucose tolerance (IGT) and type 2 diabetes. Both forms of exercise led to significant reductions in average 24-hour blood glucose concentrations. Specifically, the endurance group showed a slightly lower final blood glucose level at 6.8±0.2 mmol/L compared to the resistance training group, which had a level of 6.9±0.2 mmol/L in participants with IGT. Similarly, in the group of orally medicated type 2 diabetes participants, blood glucose levels decreased from 9.6±0.5 to 8.6±0.4 mmol/L for resistance training, while levels remained unchanged at 8.6±0.5 mmol/L for endurance training. Another important finding was the reduction in the incidence of hyperglycemia, defined as blood glucose levels exceeding 10 mmol/L. Both exercise modalities significantly decreased this incidence, with resistance exercise resulting in a 35±7% reduction and endurance exercise a 33±11% reduction over 24 hours. This indicates that both types of exercise effectively mitigate hyperglycemia. While both exercise modalities improved blood glucose levels, endurance exercise appeared to yield slightly better results in lowering blood glucose levels for the IGT group compared to resistance exercise, though the difference was not statistically significant enough to assert a superior effect. The implications of these findings suggest that both endurance and resistance training should be incorporated into exercise intervention programs for individuals with IGT and type 2 diabetes. The capacity of both exercise types to enhance glycemic control indicates that individuals can benefit from a varied exercise regimen. Additionally, the significant reductions in blood glucose levels and hyperglycemia incidence imply that regular participation in these exercises may contribute to better long-term management of blood glucose and overall metabolic health. Future research could explore the specific mechanisms through which these exercise modalities exert their effects, as well as the long-term benefits of regular participation in such exercise interventions. A 2014 study by Barzegari and Mahdirejei [7] examined the impact of resistance training on plasma vaspin and lipid profile levels in 30 patients with type 2 diabetes. The findings from this investigation reveal significant trends and comparisons between the resistance training group and the control group, shedding light on the implications of resistance training for managing diabetes-related metabolic issues. The study demonstrated notable reductions in plasma vaspin levels in the resistance training group, with levels decreasing from 330.50±82.51 to 251.62±107.28 ng/ml (p=0.03). This reduction is particularly important, as vaspin is an adipokine associated with insulin resistance, and lower levels may indicate improved insulin sensitivity. In contrast, the control group exhibited an increase in vaspin levels from 344±78.64 to 436±70.47 ng/ml (p=0.03), highlighting the potential detrimental effects of a sedentary lifestyle on vaspin regulation. Additionally, the study found that resistance training led to significant improvements in lipid profiles, with total cholesterol (TC) levels decreasing from 185.21±47.51 to 171.10±37.91 mg/dL (p=0.02) and HDL cholesterol (HDL-C) levels increasing from 38.20±20.65 to 43.80±7.87 mg/dL (p=0.01). These changes indicate a healthier lipid profile, which is critical for reducing cardiovascular risks associated with type 2 diabetes. The observed improvements in both vaspin and lipid profiles suggest that resistance training may play a crucial role in enhancing metabolic health among patients with type 2 diabetes. By reducing vaspin levels and improving cholesterol metrics, resistance training can help mitigate the risk of complications related to insulin resistance and cardiovascular disease. This study underscores the importance of incorporating resistance training into diabetes management strategies to achieve better overall health outcomes. In the 2014 study by Ghalavand *et al*., [21] the data indicates that resistance training can significantly enhance metabolic control and cardiovascular health in adult males with type 2 diabetes. The investigation focused on the impact of an eight-week resistance training program on key health metrics, specifically blood glucose levels, glycosylated hemoglobin (HbA1c), systolic blood pressure, and resting heart rate. The results reveal that participants in the resistance training group experienced significant reductions in fasting blood sugar levels, indicating improved glycemic control. The reported p-value of 0.002 suggests a strong statistical significance, underscoring the effectiveness of resistance training in lowering blood glucose concentrations. Similarly, the reduction in HbA1c (p=0.005) further supports the notion that structured resistance training can lead to long-term improvements in blood glucose management. Moreover, the findings also highlighted a notable decrease in systolic blood pressure (p=0.022) among participants, which is particularly important given the increased cardiovascular risk associated with type 2 diabetes. This suggests that resistance training not only aids in managing blood glucose levels but also contributes to better overall cardiovascular health. When comparing the resistance training group to the control group, significant differences in blood sugar (p=0.003) and HbA1c (p=0.031) reinforce the conclusion that resistance training has a more beneficial impact on these metabolic parameters than no exercise. This distinction implies that incorporating resistance training could be a critical component of diabetes management strategies, potentially leading to improved health outcomes for individuals with type 2 diabetes. Overall, the findings from the study [21] highlight the importance of resistance training as an effective adjunct therapy for managing type 2 diabetes, emphasizing its role in improving blood glucose control and reducing cardiovascular risk factor. The studies conducted by Bweir *et al*. [9] and Jin, Park, & So [26] contribute to the growing body of evidence that supports the effectiveness of resistance exercise in improving blood glucose levels in individuals with diabetes. Bweir et al. [9] conducted an RCT employing a parallel-group design with matched participants, comprising a total of 20 respondents. The intervention lasted for 10 weeks, with each exercise session lasting 30-35 minutes. The study showed a significant decrease in blood glucose levels in both the treadmill and resistance exercise groups, but the decrease was more pronounced in the resistance exercise group. This suggests that resistance exercise may have a greater impact on reducing blood glucose levels compared to treadmill exercise in individuals with diabetes. On the other hand, Jin, Park, & So [26] used a randomized controlled trial design with 16 respondents. The intervention lasted for 12 weeks, and each exercise session lasted 60 minutes. The results of this study demonstrated a significant decrease in blood glucose levels after the intervention. The findings indicate that resistance exercise, performed 3 times/week for 3 months, can lead to a meaningful reduction in blood glucose levels in individuals with diabetes. These two studies contribute to the evidence that resistance exercise can be an effective approach to managing blood glucose levels in individuals with diabetes. The differences in study design and exercise duration provide valuable insights into the potential variations in the effectiveness of resistance exercise interventions. Additionally, it highlights the importance of incorporating regular resistance exercise as part of diabetes management programs. However, it is essential to consider individual differences and tailor exercise interventions to each person's specific needs and capabilities. Further research in this area can help establish optimal exercise protocols for diabetes management and provide more targeted recommendations for patients and healthcare professionals. The study conducted by Luh, Inca, and Agustini [28] explored the effects of a short-duration exercise intervention on random blood glucose levels in 15 respondents with diabetes. The research design used was a one-group pretest-post-test study. The intervention involved daily exercise for 30 minutes each day for a total of 7 days (210 minutes). The findings revealed that there was a statistically significant decrease in blood sugar levels post-experiment. The pre-exercise mean sugar level was 201, with an SD of 100.15, while the post-exercise mean sugar level was 176.47, with an SD of 88.19. Parametric tests (t-test) showed a significant difference between before & after exercise blood sugar levels. The study's strength lies in its regular and consistent exercise regimen, which led to a notable reduction in blood sugar levels. However, it is essential to note that this study had a small sample size (15 respondents), which may limit the generalizability of the findings to a larger population. Nevertheless, the results suggest that short-duration daily exercise can be effective in reducing blood glucose levels in individuals with diabetes. Indeed, regular physical activity, including resistance exercise, is an essential aspect of diabetes management.

CONCLUSION

Based on the information presented in the four articles about blood glucose levels, it is evident that the study conducted by Bweir *et al*. [9] led to a significant reduction of 100 points in blood glucose levels by the 10th week. Remarkably, following resistance exercise in the 10th week, Eighty percent of the participants achieved plasma glucose levels that met the recommended normal range after their exercise session. In contrast, only twenty percent of the participants in the treadmill group (control group), which was comprised of individuals with type 2 diabetes characterized by insulin resistance within skeletal muscle, experienced a beneficial impact on glucose control compared to aerobic or treadmill exercise. The findings from the five articles discussing HbA1C levels suggest that moderate-intensity resistance exercises conducted over a span of three months have been demonstrated to be effective. Notably, the two-month intervention yielded significant results in reducing HbA1C levels ($p < 0.05$), with a decrease from 8.9 to 8.4, a reduction of 5 points. It is worth noting that the 8-week training duration was shorter in comparison to the 12-week regimens investigated in previous studies. The decision to opt for an 8-week duration was made to minimize or eliminate any potential impact from medication adjustments during the trial. It's worth noting that HbA1c levels reflect sugar control over the preceding two to three months [24]. Based on the findings from the studies discussed, particularly the significant improvements in HbA1c levels observed in studies such as Misra et al. [30] and Ng et al. [31], which focused on resistance exercise interventions, it seems reasonable to suggest that resistance training can be an effective component of exercise programs for individuals with diabetes. Moreover, the study by Church et al. [11] suggests that incorporating both aerobic and resistance training can lead to improvements in metabolic parameters such as maximum oxygen consumption. Hence, it is reasonable to suggest that an optimal exercise regimen for individuals with diabetes should incorporate both resistance training and aerobic exercise components. Resistance training has shown promising results in improving blood sugar control and metabolic profiles in individuals with diabetes, making it a valuable addition to comprehensive diabetes management strategies [8,12,24]. Progressive resistance training (PRT) can indeed enhance insulin sensitivity by promoting an increase in lean body mass, particularly in populations with type 2 diabetes like Asian Indians. Skeletal muscle is a key player in glucose disposal, and augmenting muscle size can lead to improved insulin sensitivity. This increase in muscle bulk is typically achieved through enhancements in muscle strength and mass, which are crucial factors. Additionally, PRT interventions often result in a reduction in intra-myocellular triglyceride content [23]. This reduction has the potential to further enhance insulin sensitivity, as excess intra-myocellular triglycerides are associated with insulin resistance. Therefore, PRT not only promotes muscle growth but also positively impacts metabolic health by reducing intra-myocellular triglyceride content, ultimately contributing to improved insulin sensitivity and glycemic control in individuals with type 2 diabetes. The study by Baaci et al. [4] indeed found that the mean changes in HbA1c levels between the aerobic and resistance exercise groups were not significantly different from the control group. However, when considering the acute effects of single bouts of exercise, resistance exercise demonstrated a more favorable rate of decline compared to the control group. This observation aligns with the known physiological responses to different types of exercise. Aerobic exercise typically leads to a decrease in blood glucose levels during the exercise session [2,15]. However, it also carries an increased risk of exercise-induced hypoglycemia, particularly late-onset hypoglycemia, which can be a concern when exercise is performed in the late afternoon and extends into the nocturnal sleep period [23]. In contrast, resistance exercise may offer benefits in terms of glycemic control without the same risk of hypoglycemia, making it a potentially safer option for individuals with diabetes, especially when considering the timing of exercise sessions. Therefore, while the overall impact on HbA1c levels may not have been significantly different between aerobic and resistance exercise in the study by Baaci *et al*. [4] the acute effects and risk profiles of each type of exercise warrant careful consideration in diabetes management strategies. Indeed, the study by Church *et al*. [11] did not yield statistically significant results regarding changes in HbA1c levels in the resistance training or aerobic training groups compared to the control group over the nine-month intervention period. The group that underwent combined aerobic and resistance training showed a significant improvement in peak oxygen consumption per unit of time compared to both the control group and the group that only underwent resistance training. Additionally, all intervention groups showed improvements in treadmill performance compared to the control group. Specifically, the resistance training group exhibited an increase in work per extension over 30 repetitions compared to all other groups, while the combination training group demonstrated a similar increase compared to the control and aerobic groups. These findings suggest that while the individual effects of resistance training or aerobic training may not have been significant in terms of changes in HbA1c levels, combining both modalities in a comprehensive exercise program may offer benefits in terms of cardiovascular fitness and muscular endurance, as evidenced by improvements in peak oxygen consumption and treadmill performance. The follow-up assessments revealed noteworthy findings regarding the effects of different exercise modalities on various parameters. The group undergoing combined training showed a reduction in average weight compared to both the control and resistance training groups. Participants in the resistance training group saw a decrease in fat mass compared to the control group, whereas those in the combined training group experienced a reduction in fat mass compared to both the control and aerobic exercise groups. Additionally, mean lean mass increased in the resistance training group compared to the aerobic exercise and combined exercise groups. It's noteworthy that all exercise groups were compared to the control group for these findings. Moreover, findings from the per-protocol analysis closely paralleled those of the intent-to-treat analysis. The study concluded that individuals with type 2 diabetes mellitus experienced advantages from a regimen involving both aerobic and resistance training compared to a control group that did not exercise, resulting in enhanced HbA1c levels. This enhancement was not attained through aerobic or resistance training alone, highlighting the potential synergistic benefits of combining both approaches in diabetes management and overall health improvement.

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