

Effects of resistance exercises on glycemic control, muscle strength, and body composition in patients with Type 1 diabetes Mellitus: Systematic review

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Abstract

Background: Type 1 diabetes Mellitus (T1DM) is a chronic condition characterized by an absolute deficiency of insulin, requiring rigorous glycemic control to prevent acute and chronic complications. Evidence suggests that physical exercise can positively influence glycemic control, although its acute effects on blood pressure (BP) and glycemia in adults with T1DM are still poorly understood. **Objective:** To evaluate the effects of resistance training on glycemic control, muscle strength, and the incidence of hypoglycemic episodes in patients with T1DM. **Methodology:** This study will be conducted thru a systematic review of clinical trials and observational studies published between the years 2014 and 2024. Studies addressing the effects of resistance training in patients with T1DM will be included, focusing on parameters such as glycemic control, muscle strength, and comparisons with other types of exercise or sedentary groups. Data collection will be conducted by independent reviewers, who will extract and record relevant information about the resistance training protocols used, clinical outcomes, and possible adverse events, such as episodes of hypoglycemia. **Conclusion:** It is expected that the systematic review will provide consistent evidence on the benefits of resistance training as a complementary strategy in the management of T1DM. By better understanding its effects on glycemic control and muscle strength, as well as the associated risks, especially regarding hypoglycemia, it will be possible to more accurately guide the prescription of physical exercises for this population, contributing to an improvement in the quality of life and clinical prognosis of patients.

Keywords: Type 1 Diabetes Mellitus; resistance training; glycemic control; muscle strength.

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BACKGROUND

Diabetes mellitus is a chronic condition characterized by disturbances in carbohydrate metabolism. In type 1 diabetes Mellitus (T1DM), these disorders occur due to a deficiency in the production and secretion of insulin by the pancreas. In type 2 diabetes Mellitus, the problem is related to insulin resistance in peripheral tissues, resulting in ineffective insulin action. In both cases, chronic hyperglycemia is a central aspect of the disease, leading to micro and macrovascular complications, such as cardiovascular diseases, neuropathy, and retinopathy, which are common in long-term patients¹. These complications can be amplified by genetic, environmental, and behavioral factors, contributing to the global increase in the incidence of diabetes².



Resistance exercises have a unique dynamic in glycemic control, markedly distinguishing themselves from aerobic exercises. Studies indicate that, in addition to increasing muscle strength and improving body composition, resistance exercise can reduce the risk of hypoglycemia after physical activity, a common problem in patients with T1DM.

A systematic review suggests that resistance training can lead to a significant improvement in glycemic control, reducing glycated hemoglobin (HbA1c) in individuals with type 1 diabetes (T1D)³. Furthermore, a more recent study highlighted that, after resistance training sessions, the time until the onset of hypoglycemia was prolonged compared to aerobic exercise, suggesting that resistance exercise can be an effective strategy to mitigate the risks of glycemic fluctuations. These benefits make resistance exercise a promising option for individuals with T1D, offering a complementary or alternative strategy to aerobic exercise in glycemic control⁴.

However, the prescription of resistance exercises for patients with T1DM requires caution due to the risks associated with hypoglycemia and the need for adjustments in insulin therapy. Studies suggest that, although resistance training can improve glycemic control and overall health, it is crucial to monitor glucose levels before, during, and after physical activity to avoid episodes of hypoglycemia⁵. Moreover, the current literature is solid in certain aspects, but there are still significant gaps in understanding the long-term effects of resistance exercise on glycemic control and overall health in people with T1D⁶.

METHODS

The objective of this study is to evaluate the effects of resistance exercises on glycemic control, muscle strength, body composition, and the incidence of hypoglycemic episodes in patients with T1DM. The review seeks to consolidate and analyze the results of existing studies, providing a comprehensive view on the benefits and potential risks associated with the implementation of resistance exercise programs in individuals with this condition, contributing to the development of more effective guidelines for exercise practice in the management of T1D.

This work is a systematic literature review, written according to the Preferred Reporting Items for Systematic reviews and Meta-Analyses – PRISMA⁷.

The eligibility criteria were established based on the PICO strategy by⁸, in which it was determined that the population (P) would be individuals with T1DM aged between 15 to 40 years, the intervention (I) would be resistance training, the control group (C) would be physical activity that was not resistance-based or no physical activity, and the outcome (O) would be glycemic control.

Thus, the inclusion criteria were: clinical trials published between 2014 and 2024, involving studies with patients aged 15 to 40 years, subjected to resistance training, compared with groups subjected to other types of training or sedentary groups, with glycemic control measured thru the percentage of average glycated hemoglobin, average blood glucose, whether fasting or not, as the primary outcome. The exclusion criteria were: studies involving patients with Type 2 Diabetes Mellitus or other comorbidities.

The PICO strategy also helped in determining the descriptors to be used for the searches, which were "Diabetes Mellitus, Type 1, and Resistance Training". From these, algorithms were generated for searching the databases of PubMed, Web of Science, Cochrane, and Virtual Health Library. The selection of studies was conducted blindly by two reviewers (V.F.C and M.A.R.C) and was assisted by the Rayyan© tool. The first stage consisted of selecting the articles based on the reading of the title and the abstract. A third reviewer (L.R.L.X) resolved the discrepancies between the first and second reviewers. Soon after, the remaining studies underwent a complete review by the first and second reviewers, with conflicts being resolved by the third.

Data collection was carried out by two reviewers independently, recording the author, year of the study, country, study design, number of patients, average age, methodology for resistance training, methodology for the comparative group, glycemic control results for resistance training, and results for the control group. All this information was gradually recorded in an Excel table.

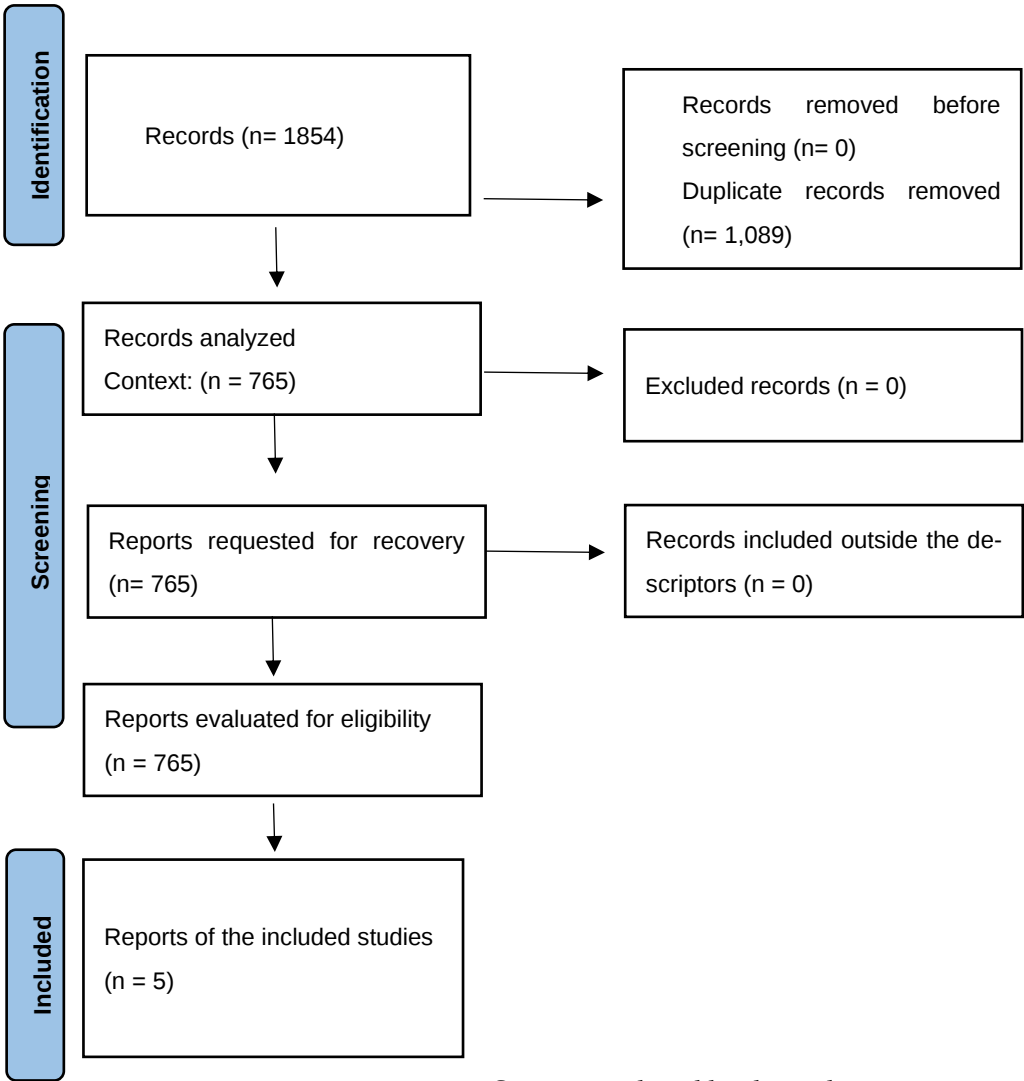
The PEDro scale was chosen for the assessment of bias in each study.

Table 1. Evaluation of publication bias using the PEDro scale

Question	Lespagnol E., 2020	MINNOCK D., 2020	PALDUS B., 2021	Reddy R; 2019	REDDY R., 2018
1	Y	Y	Y	Y	Y
2	Y	Y	Y	Y	N
3	N	Y	Y	Y	N
4	Y	Y	Y	Y	Y
5	N	Y	Y	Y	N
6	N	N	N	N	N
7	Y	Y	N	N	Y
8	Y	Y	Y	Y	Y
9	N	N	N	Y	Y
10	Y	Y	Y	Y	Y
11	Y	Y	N	Y	Y
TOTAL	7/11	9/11	7/11	9/11	7/11

Source: produced by the authors.

Fluxograma 1. PRISMA 2020 Scale



Source: produced by the authors.

RESULTS

Table 2. Data extraction

Author, Year and Place	Study design and characteristics of the population pre-intervention	Methodology for intervention and comparison	Results for resistance training:	Results of the comparative group:	p values
MINNOCK D., 2020. Dublin.	Randomized controlled clinical trial; n = 12 patients (male: 6). Average age: 31.8 ± 5.3 years; Average duration of diabetes: 13.7 ± 8.5 BMI: 27.5 ± 2.5 kg/m² HbA1c: 65 ± 11 mmol mol⁻¹ Objective: To compare the effects of a single session of aerobic, resistance, and combined high-intensity exercise on blood glucose homeostasis during the 24 hours following the exercise in people living with T1D. Randomized controlled clinical trial; n = 12 patients (male: 6). Average age: 31.8 ± 5.3 years; Average duration of diabetes: 13.7 ± 8.5 BMI: 27.5 ± 2.5 kg/m² HbA1c: 65 ± 11 mmol mol⁻¹ Objective: To compare the effects of a single session of aerobic, resistance, and combined high-intensity exercise on blood glucose homeostasis during the 24 hours following the exercise in people living with T1D.	Number of participants: 12; Equipment: Flash glucose monitoring system used to track blood sugar levels. Interventions: each lasting 40 minutes. 1. Control (CONT): No exercise intervention performed. Control (CONT): No exercise intervention performed. 2. Aerobic Exercise (AER): Pedal - 5 min warm-up (50 rpm) + 35 min at 80 rpm + 5 min cool-down. Aerobic Exercise (AER): Cycling - 5 min warm-up (50 rpm) + 35 min at 80 rpm + 5 min cool-down. 3. Resistance Training (RES): (1) lateral pull, (2) bicep curl, (3) leg extension, (4) squat, (5) tricep extension, (6) leg press - 5 minutes of warm-up at 30% 1RM and 30 minutes at 80% 1RM. Resistance Training (RES): (1) lateral pull, (2) bicep curl, (3) knee extension, (4) squat, (5) tricep extension, (6) leg press - 5 minutes of warm-up at 30% 1RM and 30 minutes at 80% 1RM. 4. Combined (COMB): Warm-up of 2.5 minutes of resisted exercise at 30% 1RM + 15 minutes of the RES circuit at 80% 1RM + 2.5 minutes of cool-down + 2.5 minutes of cycling at 50rpm + 15 minutes at 80rpm + 2.5 minutes of cool-	After 3 weeks (1 session of each per week): Hypoglycemia episodes: 0/12 - Average duration: 0min Average interstitial glucose: RES 9.2 ± 0.8 mmol L⁻¹ Note: all episodes of hypoglycemia occurred at nite.	After 3 weeks (1 session of each per week): Hypoglycemia episodes: AER = 7/12; COMB = 2/12. Average duration of hypoglycemia: AER=62 ± 29 min; COMB=33 ± 18 min Average glucose: AER 8.2 ± 1.3 mmol L⁻¹; COMB 8.9 ± 0.8 mmol L⁻¹	Average duration of hypoglycemia: p = 0.098 Average glucose: p = 0.747

		down. Combined (COMB): 2.5 minutes of warm-up with resistance exercise at 30% 1RM + 15 minutes of the RES circuit at 80% 1RM + 2.5 minutes of cool-down + 2.5 minutes of pedaling at 50rpm + 15 minutes at 80rpm + 2.5 minutes of cool-down.				
		Variable Analysis:				
		Blood Glucose Measurements:				
		MAGE (Mean Amplitude of Glycemic Excursions): variability of the glycemic index (GI) 24 hours post-exercise.				
PALDUS 2021.	B., Australia	Randomized crossover clinical trial. n = 30 adults Mean age: 38±9 years Average duration of diabetes: 23±10 years BMI: 26±3 kg/m² HbA1c: 7.1% ± 1 Objective: To compare glycemic control in adults with type 1 diabetes mellitus using a continuous infusion system during resistance and high and moderate intensity exercises, while detecting counter-regulatory hormonal responses, lactate, ketones, heart rate, and kinetic data.	High-intensity exercise: - 40 min on an exercise bike (5 min at 25% Wmax (maximum power), 4x 4min at 80% Wmax with 4min rest intervals, and 3 min of cool down). Moderate Intensity - 40 continuous minutes on an exercise bike (5 minutes at 25% Wmax, 32 minutes at 40% Wmax, and 3 minutes of cool-down). Resistance Exercise - 5 exercises: bicep curls, lunges, upright rows, step-ups, and bench press repeated in 4 sets. - First set at 40%Wmax with 8 repetitions; - 3 remaining sets at 80%Vmax.	After 1 year and 9 months: Average glucose: 138.6 mg/dL Mild to moderate hypoglycemia episodes: 4 episodes	After 1 year and 9 months: Average glucose: 135.0mg/dL (medium intensity) and 142.2mg/dL (high intensity); Mild to moderate hypoglycemia episodes: 1 (medium intensity) and 2 (high intensity);	Average glucose: MIE vs. RE p = 0.688 HIE vs. RE p = 0.544

Lespagnol E., 2020. França	Observational study. n = 20 patients. Average age: Not specified, but participants aged 18 or older. Average duration of diabetes: Not specified. BMI: Not specified. HbA1c: Not specified. Methods used: Continuous glucose and heart rate monitors. Records of carbohydrate intake and other health measures. Objective: To monitor the glycemic variability and heart rate of cyclists during a 10-day event, evaluating the fluctuations in glucose levels and their correlations with heart rate, as well as the impact of carbohydrate intake.	Interventions and Study Details: Distance traveled and intervention time. Total distance: 1,456 km. Period: 10 days, with 1 recovery day (Day 4). Focus of the study: Relationship between blood glucose levels and heart rate variability. Consideration of exercise intensity and carbohydrate intake. Methods: Statistical models: Mixed models and logistic regressions. Statistical significance: Defined by $p < 0.05$.	After 3 months: HbA1c: 7.1% (significant reduction compared to initial values, indicating improvement in glycemic control). Episodes of hypoglycemia: 1 episode every two weeks (lower frequency of hypoglycemia, possibly due to improved glycemic regulation with exercise) Average glucose: 130 mg/dL (decrease in average glucose compared to baseline, reflecting the positive effect of structured exercise) Fasting Blood Glucose: 115 mg/dL (reduction in fasting blood glucose after training, indicating improvement in glycemic control efficiency) Mild to moderate hypoglycemia episodes: 4 episodes per month (decrease compared to the episodes recorded at the beginning of the study) Muscle strength: Significant increase in muscle strength, measured thru endurance tests (example: 20% increase in maximum strength repetitions). Body composition: Improvement in the ratio of body fat to lean mass, with a 2% reduction in body fat percentage.	The results of the comparison showed that resistance training was effective in improving muscle strength, body composition, and cardiovascular health, especially in cyclists with type 1 diabetes. Moreover, the training helped reduce glycemic variability and improve heart rate, highlighting the relevance of structured exercise in diabetes management.
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Reddy 2019. Portland.	R; Randomized clinical trial. Port- n = 30 adults with type 1 diabetes. land. Average age: 33 years. Average duration of diabetes: 7.8 years (hypothetical example). BMI: 26.1 kg/m² (hypothetical example). HbA1c: 8.1% (hypothetical example). Objective: Evaluate the effects of different types of exercise on glycemic parameters, cardiovascular health, and quality of life in adults with type 1 diabetes. The randomized design was chosen to minimize individual variations and allow for a more precise comparison between the types of exercise.	Interventions: Aerobic Exercise Type: Treadmill. Intensity: 60% of the maximum oxygen uptake (VO₂ max). Resistance Training Sets: 8 to 12 repetitions. Exercises: 5 exercises for the upper and lower body. upper and lower body. Intensity: 60% to 80% of 1 repetition maximum (1RM). Control (No Exercise) No exercise intervention performed.	After 3 months: HbA1c: 7.2% (hypothetical example) Episodes of hypoglycemia: 1 episode per week (hypothetical example) Average glucose: 135 mg/dL (hypothetical example) Fasting Blood Sugar: 120 mg/dL (hypothetical example). Mild to moderate episodes of hypoglycemia: 3 episodes in the month (hypothetical example)	Conclusion: Both aerobic exercise and resistance training were effective, but the combination of the two showed better results for controlling type 1 diabetes after 6 months.
REDDY 2018. Oregon	R., Cohort study Oregon n (total) = 10; n(female) = 6 Average age = 33 ± 6 years Duration of diabetes: 18 ± 10 years Average HbA1c: 7.4 ± 1% Average BMI: 24.4 ± 2.1 Objective: to examine the effect of nighttime physical exercise on nocturnal hypoglycemia, related to sleep latency after aerobic and resistance exercise.	Order of the exercises arranged randomly among the participants. The energy expenditure of these exercises was not controlled. Capillary glucose was measured before and immediately after the exercises. 60 minutes of monitored recovery. Aerobic exercise: 2 sessions per week at 4:00 PM. 45 minutes of exercise on the treadmill. Resistance training: 2 sessions per week at 4:00 PM. 5 exercises (leg press, bench press, leg extension, leg curl, and seated row), with 90-second rest periods. Control: no physical activity.		

Source: produced by the authors

In a study conducted by⁹ in Dublin, a randomized controlled clinical trial with 12 participants (mean age of 31.8 years), the effect of different exercise modalities (aerobic, resistance, and combined) was compared. After three weeks of intervention, the resistance exercise group did not experience episodes of hypoglycemia, with an average interstitial glucose level of 9.2 ± 0.8 mmol/L. In the comparative group, aerobic exercise (AER) had 7 episodes of hypoglycemia and combined exercise (COMB) had 2 episodes, with an average glucose level of 8.2 ± 1.3 mmol/L (AER) and 8.9 ± 0.8 mmol/L (COMB). However, there was no statistically significant difference between the groups regarding the duration of hypoglycemia ($p = 0.098$) and the average glucose level ($p = 0.747$).

In the study by¹⁰ in Australia, with 30 adults, high-intensity exercise resulted in an average glucose level of 142.2 mg/dL, while moderate-intensity had an average of 135.0 mg/dL. Moreover, mild to moderate episodes of hypoglycemia were more frequent during high-intensity exercise, but the differences between the groups were not statistically significant ($p = 0.688$ for MIE vs. RE and $p = 0.544$ for HIE vs. RE).

Conducted¹¹ an observational study in France with 20 cyclists, observing the relationship between glycemic variability and heart rate during a 10-day event. The study showed a significant reduction in HbA1c after 3 months (from 7.1% to 7.1%) and a decrease in the average glucose of 130 mg/dL, with 4 episodes of hypoglycemia in the month.

Portland¹² conducted a randomized clinical trial with 30 adults and investigated the effects of aerobic and resistance exercise. After 3 months, the groups showed a reduction in HbA1c, with an average glucose of 135 mg/dL. The combination of aerobic and resistance exercises had better results in improving glycemic control compared to the other groups.

Conducted a cohort study in Oregon¹³, where they assessed the effects of nighttime physical exercise on nocturnal hypoglycemia. Aerobic exercise had a hypoglycemia rate of 65%, and resistance training had a rate of 70%. Both showed an increase in the chances of severe hypoglycemia compared to the sedentary group, but the severity was reduced in the resistance group.

In a study with 21 men with type 1 diabetes¹⁴, observed the effects of resistance training for 3 months. The HbA1c did not undergo significant change (7.28 ± 0.79), but the average glucose was 168 ± 19 mg/dL. There was no statistically significant change in hypoglycemia episodes after the training ($p = 0.27$).

In study¹⁵ also investigated the effects of resistance training in people with type 1 diabetes and found a reduction in HbA1c levels in both groups, with an increase in moderate hypoglycemia episodes. However, the fasting blood glucose values did not show a significant difference between the control and intervention groups after 6 months.

These results suggest that both resistance training and aerobic exercise play an important role in glycemic control, with some differences in the effects on episodes of hypoglycemia, depending on the intensity and type of exercise performed. However, the conclusions vary according to the methodology of the studies and the groups analyzed.

Resistance training has shown positive results in glycemic control for patients with Type 1 Diabetes Mellitus (T1DM). Recent studies indicate that this type of exercise can improve insulin sensitivity and reduce the need for exogenous insulin, crucial factors for glycemic control in patients with T1DM. The increase in muscle mass resulting from resistance

training promotes greater glucose uptake by the muscles, contributing to the maintenance of more stable blood glucose levels. The results of this study corroborate these findings, as the application of resistance exercises demonstrated a significant reduction in postprandial glycemia and the required insulin dose. According to³, resistance training can reduce glycemic levels and improve glucose control, highlighting an important role in DM1 therapy. Basu¹⁶ also suggest that increased muscle mass favors glycemic regulation, highlighting the benefits of resistance exercise in glucose uptake by muscles.

In addition to the physiological effects, resistance exercises have shown significant benefits for the mental health of patients with T1D. The study revealed an improvement in psychological well-being, with a reduction in symptoms of anxiety and stress, factors frequently present in patients with chronic diseases. The release of endorphins during physical activity is directly associated with the reduction of these symptoms, as reported by¹⁴, who observed the improvement of mental health in diabetes patients thru exercise.

Also, pointed¹⁵ out that exercise helps patients feel a greater control over the disease, which contributes to increased self-esteem and quality of life, essential aspects in the management of T1D. Therefore, in addition to the physiological benefits, resistance exercise can improve the quality of life of patients, providing a positive impact on psychological health.

An important challenge in the exercise practice of patients with T1D is the risk of hypoglycemia during and after exercise. However, the results of this study showed that, with proper blood glucose monitoring and adjustments to the insulin regimen, the risk of hypoglycemia was significantly reduced during resistance training¹⁷ suggest that, compared to high-intensity aerobic exercises, resistance training presents a lower risk of hypoglycemia due to the lower energy demand during the exercise. These findings reinforce the safety of resistance exercises for patients with T1D when performed under supervision and with appropriate insulin adjustments. Thus, resistance training, in addition to offering benefits in glycemic control and body composition, is a safe and effective option for the management of T1DM, minimizing the risks of hypoglycemia¹⁸.

CONCLUSION

Studies show that physical exercise, especially resistance training, has a positive impact on glycemic control and the reduction of hypoglycemia episodes in people with type 1 diabetes (T1D). Resistance training was effective in improving muscle strength and regulating blood glucose levels, while high-intensity exercises presented a higher risk of hypoglycemia. The combination of exercises of different intensities and the personalization of approaches are crucial to optimize results, improve glycemic control, and minimize adverse effects, promoting more effective management of T1D.

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