International Journal of Innovative Technologies in Social Science

e-ISSN: 2544-9435

Scholarly Publisher
RS Global Sp. z O.O.
ISNI: 0000 0004 8495 2390

Dolna 17, Warsaw,
Poland 00-773
+48 226 0 227 03
editorial_office@rsglobal.pl

ARTICLE TITLE	INFLUENCE OF RESISTANCE TRAINING ON MITIGATING TYPE 1 DIABETES MELLITUS COMPLICATIONS: A NARRATIVE REVIEW
ARTICLE INFO	Łukasz Bialic, Karol Demel, Małgorzata Wasilewska, Alicja Toczyłowska, Jacek Sitkiewicz, Julia Kwiecińska, Katarzyna Krzyżanowska, Lidia Mądrzak, Marta Korchowiec, Mateusz Muras, Wiktor Chrzanowski, Władysław Hryniuk. (2025) Influence of Resistance Training on Mitigating Type 1 Diabetes Mellitus Complications: A Narrative Review. *International Journal of Innovative Technologies in Social Science*. 2(46). doi: 10.31435/ijitss.2(46).2025.3438
DOI	https://doi.org/10.31435/ijitss.2(46).2025.3438
RECEIVED	06 May 2025
ACCEPTED	27 June 2025
PUBLISHED	30 June 2025
LICENSE	The article is licensed under a **Creative Commons Attribution 4.0 International License.**

INFLUENCE OF RESISTANCE TRAINING ON MITIGATING TYPE 1 DIABETES MELLITUS COMPLICATIONS: A NARRATIVE REVIEW

Łukasz Bialic *(Corresponding Author, Email: lukasz.bialic@gmail.com)*
Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warszawa, Poland
ORCID ID: 0000-0003-4837-5920

Karol Demel
Medical University of Silesia, Poniatowskiego 15, 40-055, Katowice, Poland
ORCID ID: 0009-0005-5485-7987

Małgorzata Wasilewska
University Hospital of Zielona Góra, Zyty 26, 65-046, Zielona Góra, Poland
ORCID ID: 0009-0008-0375-1391

Alicja Toczyłowska
University Clinical Hospital in Opole, aleja Wincentego Witosa 26, 46-020 Opole, Poland
ORCID ID: 0009-0007-3155-0573

Jacek Sitkiewicz
Silesian Centre for Heart Diseases in Zabrze, Marii Skłodowskiej-Curie 9, 41-800 Zabrze, Poland
ORCID ID: 0009-0006-0889-0652

Julia Kwiecińska
University Clinical Hospital in Opole, aleja Wincentego Witosa 26, 46-020 Opole, Poland
ORCID ID: 0009-0004-0924-6063

Katarzyna Krzyżanowska
Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warszawa, Poland
ORCID ID: 0009-0009-3306-0804

Lidia Mądrzak
Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warszawa, Poland
ORCID ID: 0009-0005-9516-911X

Marta Korchowiec
Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warszawa, Poland
ORCID ID: 0009-0008-3365-4728

Mateusz Muras
University Clinical Hospital in Opole, aleja Wincentego Witosa 26, 46-020 Opole, Poland
ORCID ID: 0009-0003-4536-6006

Wiktor Chrzanowski
Medical University of Warsaw, Żwirki i Wigury 61, 02-091 Warszawa, Poland
ORCID ID: 0009-0008-0820-1452

Władysław Hryniuk
University Clinical Hospital in Opole, aleja Wincentego Witosa 26, 46-020 Opole, Poland
ORCID ID: 0009-0009-8653-468X

ABSTRACT

Objective and methods. This narrative review synthesizes current research on the influence of RT on glycaemic control and major T1DM-related complications, including cardiovascular disease, neuropathy, nephropathy, and retinopathy.
Material and methods. PubMed, Google Scholar and Scopus databases were searched for existing publications concerning influence of resistance training or anaerobic training on glycaemia and prevention of typical complications of Type 1 Diabetes Mellitus among human patients and animal specimens if human based research is lacking.
Results. The evidence indicates that RT can improve glycaemic control by enhancing insulin-independent glucose uptake through increased GLUT4 expression and muscle mass. However, its effect on long-term glycaemic markers like HbA1c is inconsistent, with more significant benefits often seen when combined with aerobic training. In terms of cardiovascular health, RT may offer improvements in lipid profiles, endothelial function, and cardiac autonomic function, though findings are not uniformly positive and research is limited. RT shows promise in mitigating peripheral neuropathy by enhancing neural plasticity and muscle strength. Conversely, the direct impact of RT on autonomic neuropathy, nephropathy, and retinopathy in T1DM patients is under-researched, with most data on nephropathy stemming from animal models and significant safety precautions advised for patients with retinopathy.
Conclusions. Overall, while RT presents a valuable intervention for managing T1DM, the current body of evidence is marked by inconsistencies and a notable lack of long-term human studies, underscoring the need for further rigorous investigation.

KEYWORDS

Type 1 Diabetes Mellitus, Diabetes Complications, Resistance Training, Diabetic Microangiopathy, Diabetic Macroangiopathy

CITATION

Łukasz Bialic, Karol Demel, Małgorzata Wasilewska, Alicja Toczyłowska, Jacek Sitkiewicz, Julia Kwiecińska, Katarzyna Krzyżanowska, Lidia Mądrzak, Marta Korchowiec, Mateusz Muras, Wiktor Chrzanowski, Władysław Hryniuk. (2025) Influence of Resistance Training on Mitigating Type 1 Diabetes Mellitus Complications: A Narrative Review. *International Journal of Innovative Technologies in Social Science*. 2(46). doi: 10.31435/ijitss.2(46).2025.3438

Methodology

PubMed, Google Scholar and Scopus databases were consulted to identify studies on resistance training exercise and Type 1 Diabetes Mellitus. To narrow research we implemented specific "MeSH terms" such as "resistance training", "strength training", "type 1 diabetes mellitus", "cardiovascular complications", "glycaemia", "inflammation", "nephropathy", "neuropathy", "retinopathy", "hypertension", "aerobic training", "anaerobic training" etc. Studies were evaluated based on type of investigation, type of physical activity, methodology and results. Type 2 Diabetes Mellitus research were excluded from analysis and animal trails were included only in absence of human trials.

1. Introduction

Type 1 Diabetes Mellitus (T1DM) is chronic autoimmune disease caused by destruction of insulin producing β-cells located in Langerhans isles of the pancreas [1] as a result of CD4+ and CD8+ T-cells and macrophages infiltration of that region [2] and production of anti-islets antibodies. [3] Destruction of β-cells leads to absolute insulin deficiency, disruption of metabolic homeostasis and hyperglycaemia. Long-term complications are usually divided into 2 groups: microvascular complications such as nephropathy, retinopathy, neuropathy and macrovascular- coronary heart disease, cerebrovascular disease, peripheral artery disease, heart failure. [4] T1DM requires lifelong exogenous insulin treatment. Physical activity is widely known to have beneficial effects on lipid profile, endothelial function, insulin sensitivity, quality of life and general well-being. [5] There are many models of physical activity, most commonly used division points out aerobic and anaerobic (resistance) exercises. [5] Aerobic exercise together with diet control is considered cornerstone of T1DM therapy and it is proven that can improve insulin sensitivity and lipid metabolism which affects better

glycaemic control and allows insulin dose reduction. [6] Regular exercise improve overall health and support individuals in achieving their target lipid profile, body composition, and fitness and glycaemic goals. [7] Some studies have shown potential contribute of resistance training on better glycaemic control but there exist also contradictory results in that matter. [8] Guidelines recommend that patients should engage in minimum 150 minutes of moderate or vigorous aerobic physical activity for at least 3 days a week with no more than 2 consecutive days without activity and engage in 2-3 sessions/week of resistance training on non-consecutive days [9] starting with moderate intensity, involving 10–15 repetitions per set [10] gradual increases in weight or resistance, with a lower number of repetitions (8–10), only after the target number of repetitions per set can consistently be exceeded. [11] This study aims to examine the impact of resistance training on glycaemic control in patients with type 1 diabetes mellitus and its potential role in mitigating or accelerating the progression of diabetes-related complications.

2. Aerobic training and Resistance Training

2.1. There exist various types of physical activity and numerous methods of differentiating them. For the purposes of this review we will be operating on most common division for Aerobic Training (AT) and Anaerobic Training known as Resistance Training (RT or RET). Here is a short characteristic of each one of mentioned.

2.2. Aerobic Training involves repetitive and continuous movements of large muscle groups with minimum of moderate intensity, main source of energy in that type of movement comes from aerobic respiration. It includes activities such as: walking, cycling, jogging or swimming.

2.3. Anaerobic training or resistance training encompasses physical exercises that engage specific skeletal muscles by applying high loads through external resistance, such as weight lifting, elastic resistance bands, or workout machines. It is fuelled by energy released in anaerobic respiration reactions. [12] Other authors define resistance training as exercise that involves of free weights lifting, resistance machines training and circuit training. [13]

3. Mechanisms of Resistance Training in T1DM

3.1. **Muscle Glucose Uptake and Insulin Sensitivity**: Resistance training promotes hypertrophy, which enhances skeletal muscle mass and increases glucose uptake and utilization, thereby contributing to improved glycaemic control. [8,12,13] RT enhances the expression of glucose transporter type 4 (GLUT4) in skeletal muscle, facilitating increased glucose uptake independent of insulin. This adaptation is particularly beneficial for T1DM patients, as it can lead to improved insulin sensitivity and better blood glucose management. [14,15]

3.2. **Anti-inflammatory Effects**: Elevated levels of inflammatory markers such as C-reactive protein (CRP), tumour necrosis factor-α (TNF-α) or interleukin-6 (Il-6) are heavily implicated in inflammaging and the development of age-related conditions. [16] Chronic low-grade inflammation is associated with T1DM complications, for example higher CRP corresponds with microalbuminuria in T1DM patients. [17] The same marker elevations correlate with development of atherosclerosis and coronary disease and it manifests itself earlier than in healthy population. [18] Researchers from Norway suggest that other inflammatory process markers such as IL-18, P-selectin, E-selectin and TIMP-1 are associated with low-grade inflammation and development of atherosclerosis and even accelerating the process. [19] Other researchers emphasise that low-grade inflammatory markers such as CRP and Il-6 elevation was present with T1DM patients suffering from diabetic nephropathy and microalbuminuria, this research showed correlation between this phenomena. [17] It is proven that higher RT modulates inflammatory markers, potentially reducing disease progression in Type 2 Diabetes patients. [20] Research concerning the same topic in T1DM patients is not as broad. So far experiments with laboratory rats suffering from diabetes show that animals undergoing 4-weeks RT training have lower levels of pro-inflammatory cytokines than the control group. [21] However there are some contradictory evidence concerning influence of Il-6 on post-RT glucose levels. In study of Turner exercise-induced elevation of Il-6 cytokine correlated with reduction of post-exercise hyperglycaemia. [22]

3.3. **Hormonal Adaptations**: Resistance training elicits significant hormonal adaptations that can positively influence metabolic control and mitigate complications in individuals with Type 1 Diabetes Mellitus (T1DM). During and after RT, there is an acute elevation in anabolic hormones such as growth hormone (GH) and insulin-like growth factor 1 (IGF-1). GH has a dualistic influence on glycaemia. On one hand it plays antagonistic role to insulin stimulating gluconeogenesis in liver and lowering the tissues insulin sensitivity, on the other GH and IGF-1 play crucial roles in promoting muscle protein synthesis and enhancing glucose uptake

to muscle cells. In T1DM patients, RT has been shown to increase GH levels, which may contribute to improved glycaemic control and reduced insulin requirements. [23–25] Moreover, RT influences the secretion of counter-regulatory hormones, including catecholamines and cortisol, which are involved in glucose metabolism causing rise in plasma glucose levels. The modulation of these hormones through RT can aid in maintaining glucose homeostasis and reducing the risk of hypoglycaemic episodes during and after exercise.[26] Collectively, these hormonal adaptations induced by RT contribute to improved metabolic outcomes and may play a role in mitigating the progression of T1DM-related complications.

4. Effects of Resistance Training on Glycaemic Control

4.1. **Impact on Blood Glucose Levels**: Increased glucose uptake causes less hyperglycaemia episodes during physical activity and is considered to longer-lasting post-activity blood glucose reductions in comparison to aerobic activities.[8,12,13]. Other researchers suggest that anaerobic activity is related to transient increase in blood glucose concentrations and it is recommendable to combine it with aerobic exercises. [7] Särnblad in his research on adolescent males concluded that RT did not show any change of plasma glucose level during exercise and period of 1 hour after exercise opposite to aerobic exercise which caused drop in PG levels. [5] In Khalafi et al. meta-analysis Fasting glucose levels reduction corresponds with RET especially in younger individuals.

4.2. **Reduction in Glycaemic Variability**: Increased muscle mass causes more glucose uptake which allows to reduce doses of insulin to achieve satisfying blood glucose levels. Some research suggests that RET is prone to cause less hypoglycaemic episodes [8,12]. Regular RT sessions contribute to more predictable blood glucose patterns, reducing the risk of hyperglycaemia and hypoglycaemia. [12,13]. Khalafi in his systematic review points out that RT strengthens insulin-independent glucose uptake paths by activating AMP-activated protein kinase pathway which enhances glucose transport to myocytes during exercise which facilitates a reduction in insulin doses. In this research he also noticed that RET causes increase in translation of GLUT-4 transporter to muscle cell membrane what promotes higher insulin sensitivity. [13] One investigation revealed existing corelation between post- RT elevated Interleukin-6 levels which occur both in healthy and T1DM individuals and better glycaemic control. Patients that conducted RT had higher Il-6 levels and also less post-exercise hyperglycaemic events than patients with sedentary lifestyle. [27] . RET influence on HbA1c levels which are considered a gold standard in long-term glycemia control assessment is less investigated than aerobic exercise and the existing study results are controversial. [8] In randomized clinical trial among Patients with Diabetes Mellitus Type 1 who were already performing aerobic exercises inclusion on resistance training did not significantly change the level of HbA1c in participants, however the decrease in glycated haemoglobin was more noticeable among adolescent which is considered to be due to the higher basal insulin resistance in this age group. [28] Also in 2006 experiment resistance training did not improve glycated haemoglobin in type-1 Diabetes patient. [29] In the meta-analisis by Khalafi et al. contribution to HbA1c levels was found when RET combined with aerobic training. Isolated RET training presents less contribution when compared with AET and combined exercise training (CET). [13]

5. Cardiovascular Benefits of Resistance Training in T1DM

5.1. **Improvement in Endothelial Function**: Endothelial dysfunction is a key early marker in the pathogenesis of vascular complications in individuals with Type 1 Diabetes Mellitus (T1DM), often preceding structural atherosclerotic changes. There exist evidence showing positive influence of AT on improving the endothelial function and at the same time connecting lack of physical activity to development of endothelial dysfunction in this group of patients. [3031] However research concerning RT impact on Endothelium Function is limited. Mota et al. in his work shows promising results on T1DM rat. Results of this study suggest that RT might restore endothelial function and lower arterial blood pressure. [32] Contradictory results were presented in research on humans with T1DM, in the research exploring the influence of RT on release of endothelial progenitor cells which promote stability of vascular system and lower the cardiovascular risk. In this study RT both with AT showed zero effect among diabetic patients in comparison to healthy individuals. [33]

5.2. **Reduction in Hypertension and Dyslipidaemia**: Dyslipidaemia is a modifiable CVD risk factor prevalent in T1DM. RT has been associated with favourable changes in lipid profiles, including reductions in total cholesterol and low-density lipoprotein cholesterol (LDL-C), and increases in high-density lipoprotein cholesterol (HDL-C). These alterations contribute to a decreased atherogenic risk. A 24-week RT program involving middle-aged women with T1DM resulted in significant improvements in lipid parameters. Participants experienced reductions in LDL-C and triglycerides (TG), along with an increase in HDL-C. These

changes were accompanied by decreased fasting blood glucose and HbA1c levels, indicating enhanced glycaemic control. [34] Brazilian researchers in their systematic review and meta-analysis examining the effects of RT on glycaemic control in T1DM patients also reported favourable lipid profile changes. Specifically, two studies within the review highlighted significant reductions in HbA1c and improvements in lipid parameters, including increased HDL-C and decreased LDL-C levels. [8] Beyond T1DM populations, RT has demonstrated efficacy in improving lipid profiles in various groups. A review article noted that both moderate- and high-intensity RT led to significant reductions in total cholesterol and LDL-C, as well as improvements in the total cholesterol to HDL-C ratio. These findings suggest that RT can beneficially modulate lipid metabolism, potentially through mechanisms involving enhanced lipid clearance and altered lipoprotein synthesis. [35] Review by Khalafi et al. concluded that RET alone did not significantly improve lipid profiles (LDL, HDL, triglycerides, total cholesterol) and also that blood pressure did not significantly change with RET-based interventions. [13]

5.3. **Cardiac Autonomic Function**: Evidence from systematic reviews and meta-analyses indicates that resistance training can improve cardiac autonomic control in individuals with chronic diseases, as measured by significant improvements in HRV parameters such as the root mean square of successive differences (RMSSD), the low-frequency to high-frequency (LF/HF) ratio, and sample entropy. These changes suggest enhanced parasympathetic activity and reduced sympathetic dominance, which are beneficial for cardiovascular health in diseased populations, including those with T1DM. While the majority of studies have focused on various chronic diseases, the beneficial effects of RT on cardiac autonomic function appear consistent across different conditions characterized by autonomic dysfunction. However, it is important to note that the number of studies specifically targeting T1DM is limited, and findings are often generalized from broader diseased populations. Despite this, the available evidence supports the notion that RT can induce favourable changes in cardiac autonomic modulation in T1DM patients, potentially reducing cardiovascular risk. [36]One research was found to confirm that combination of resistance and high intensity interval trainings improve HRV parameters among adolescent boys with T1DM what leads to enhanced vagal variability and more adequate autonomic system response in heart rate control. [37]

5.4. **Maximal Oxygen Uptake (VO_2 max):** while traditionally associated with aerobic training, limited improvements in maximal oxygen uptake (VO_2 max) have also been observed with combination of RT and AT. Enhanced VO_2 max reflects better cardiorespiratory fitness, which is inversely related to CVD mortality**.** [38] Meta-analysis from 2012 didn't revealed any significant changes in VO_2 max among T1DM patients undergoing sessions of RT. [39] It is important to remark that role of RT in that matter require further research and most probably isolated resistance training has no effect on changes in maximal oxygen uptake.

6. Resistance Training and Neuropathy

6.1. **Peripheral Neuropathy**: Patients with T1DM developing peripheral neuropathy face motoneuron loss, impaired neuromuscular junction (NMJ) signalling, and neurogenic muscle atrophy, reducing muscle strength, power, and endurance. Scientists observed positive effects of resistance training in prophylaxis of neuron loss of function facilitated by activating large muscle groups and motoneurons stimulations. Comprehensive review published in The Journal of Physiology in 2025 remarks that resistance training enhances neural plasticity, muscle strength, and muscle size, which are important for counteracting muscle loss and maintaining independence in daily activities. These adaptations help mitigate the neuromuscular decline associated with diabetic neuropathy and myopathy in type 1 diabetes. RT can improve nerve conduction and reduce symptoms of neuropathy, as seen in studies with diabetic patients. Improved nerve function is linked to better sensorimotor performance and reduced risk of further nerve damage. Also regular resistance training helps manage blood glucose levels, which is crucial for preventing or slowing the progression of neuropathy in type 1 diabetes. [40] Also meta-analysis from 2021 revealed that RT increases maximum muscle strength among T1DM individuals which might be useful countermeasure in prevention of muscle loss. [41]

6.2. **Autonomic Neuropathy**: While exercise, including resistance training, is known to benefit autonomic function in type 2 diabetes, direct evidence for its effects specifically in T1DM and autonomic neuropathy is not existent.

7. Nephropathy and Resistance Training

Similar to other issues covered by this paper, also Most studies on nephropathy have been conducted among type 2 diabetes mellitus patients. [42–44] The investigation concerning prevention of renal disfunction in T1DM patients concentrates mainly on aerobic exercise trainings. So far RT influence in preventing nephropathy in type 1 diabetes mellitus individuals was examined in laboratory conditions mostly on diabetic rats models. In 2021 publication by Ralmony de Alcantara Santos emphasizes that T1DM rodents undergoing RT in form of climbing vertical ladder while carrying progressively loads attached to their tails presented positive effects on renal tissue by modulating internal RAS and cytokines of the tissue through enhanced blood circulation which led to reduced inflammatory activity that damage kidneys. [45] Available evidence on human patients suggests that RT ensures better glycaemic stability what prevents microangiopathy affecting vessels in kidneys and that among patients on dialysis improved creatinine levels in plasma. [46] Other human based research encourages to involve RT into the physical activity on T1DM patients [47] basing on the interventional study in patients with renal failure (not exclusively diabetic nephropathy) that demonstrated reduced inflammatory markers and Improved estimated glomerular filtration rate (eGFR) when exposed to RT and low-protein diet. [48]

8. Retinopathy and Resistance Training: Safety Considerations

Research including impact of resistance exercise training on prevalence of diabetic retinopathy (DR) in type 1 diabetes mellitus patients is lacking. Most of available literature concentrates on RT mitigating effect on other parameters which maintenance prevent retinopathy development. [49] For example decreased HbA1c levels and better glycaemic control which is the most important factor in prevention of DR. [50] However there exist safety considerations associated with performing RET among individuals with already present proliferative or non-proliferative diabetic retinopathy. It is advisable to avoid very strenuous activities, heavy lifting, or exercises that involve breath-holding (Valsalva manoeuvre), as these can increase intraocular pressure and risk of retinal complications. [7,51]

Table 1.

Investigated aspect	Evidence of positive influence	Evidence of negative influence	Evidence of no influence	No human based studies
Glycaemic control	+	+	+	-
Cardiovascular complications	+	-	+	-
Neuropathy	+	-	+	-
Nephropathy	-	-	-	+
Retinopathy	-	+	-	+

Table 1. presents limitations of existing studies concerning influence of RET among T1DM patients. Term “positive influence” covers all the research showing improved glycaemic control and prevention of mentioned condition. Term “negative influence” refers to inducing hypo- or hyperglycaemia or causing safety issues.

9. Results

Based on the evidence reviewed, the influence of resistance training (RT) on type 1 diabetes mellitus (T1DM) complications yields varied and, in some areas, inconclusive results.

Glycaemic Control

The impact of RT on glycaemic control presents a complex picture. Resistance training promotes muscle hypertrophy, which enhances glucose uptake and can improve glycaemic control. It facilitates increased glucose uptake independent of insulin by enhancing the expression of GLUT4 in skeletal muscle. This may lead to improved insulin sensitivity and better blood glucose management. Some studies suggest RT is

associated with fewer hyperglycaemic episodes during activity and longer-lasting post-activity blood glucose reductions compared to aerobic exercise. It has been proposed that RT contributes to more predictable blood glucose patterns, thereby reducing the risk of both hyperglycaemia and hypoglycaemia. An insulin-independent glucose uptake pathway is strengthened through the activation of the AMP-activated protein kinase pathway during RT.

However, there is conflicting evidence. Some researchers suggest anaerobic activity can cause a transient increase in blood glucose levels , while another study on adolescent males found no change in plasma glucose during or for one hour after RT. The effect of RT on HbA1c levels, a key long-term glycaemic marker, is also ambiguous. Several studies and reviews have found that RT alone did not significantly improve HbA1c levels , though a more noticeable decrease was seen in adolescents. Meaningful contributions to HbA1c levels were primarily observed when RT was combined with aerobic training.

Cardiovascular Complications

The cardiovascular benefits of RT in T1DM are promising but not yet fully substantiated. While aerobic training is known to improve endothelial function, research on RT's impact is limited. One study on diabetic rats indicated that RT might restore endothelial function and lower arterial blood pressure , but research on humans showed no effect on the release of endothelial progenitor cells, which are important for vascular health.

Regarding dyslipidaemia, some studies report favourable changes, including reductions in total cholesterol and LDL-C, and increases in HDL-C. A 24-week RT program in middle-aged women with T1DM led to significant improvements in lipid profiles and glycaemic control. However, a meta-analysis by Khalafi et al. concluded that RT alone did not significantly improve lipid profiles or blood pressure.

Evidence suggests RT can improve cardiac autonomic function in individuals with chronic diseases, indicating enhanced parasympathetic activity. One study confirmed that combining RT with high-intensity interval training improved heart rate variability in adolescent boys with T1DM. Conversely, a 2012 meta-analysis did not find significant changes in maximal oxygen uptake (VO2 max) among T1DM patients after RT sessions.

Neuropathy, Nephropathy, and Retinopathy

Resistance training shows potential for mitigating neuromuscular decline associated with peripheral neuropathy. It can enhance neural plasticity and muscle strength, which helps counteract muscle loss. Studies have shown that RT can improve nerve conduction, reduce symptoms of neuropathy , and increase maximum muscle strength in individuals with T1DM. However, direct evidence for the effects of RT on autonomic neuropathy specifically in T1DM is lacking.

Research on RT's influence on nephropathy in T1DM is sparse and mainly limited to animal models. Studies on diabetic rats suggest RT has positive effects on renal tissue by limiting inflammatory processes. In human patients, the primary benefit appears to be indirect, through better glycaemic stability which prevents microangiopathy in the kidneys.

There is a significant lack of research on the direct impact of RT on diabetic retinopathy. The available literature focuses on RT's ability to improve factors that prevent retinopathy, such as glycaemic control. Safety is a key consideration, and strenuous activities or those involving the Valsalva manoeuvre should be avoided in patients with existing retinopathy to prevent increased intraocular pressure.

10. Conclusions and further directions

Resistance training may play important role as an supplement to aerobic training in maintaining glycaemia and preventing development of complications among Type 1 Diabetes Mellitus Patients and is recommended to be included in patient’s exercise schedule. Some of available research show promising results however further investigation is necessary since the number of publications with representative number of participants and restricted only to RET and T1DM is limited. Also safety issues need to be taken into account especially among cases with present retinopathy.

Disclosures

Author's contribution:

Conceptualization: Łukasz Bialic

Methodology: Karol Demel, Alicja Toczyłowska

Software: Łukasz Bialic, Małgorzata Wasilewska

Check: Lidia Mądrzak, Julia Kwiecińska, Małgorzata Wasilewska

Formal analysis: Karol Demel, Marta Korchowiec, Jacek Sitkiewicz

Investigation: Łukasz Bialic, Julia Kwiecińska, Katarzyna Krzyżanowska, Władysław Hryniuk, Wiktor Chrzanowski

Resources: Łukasz Bialic, Wiktor Chrzanowski

Data curation: Marta Korchowiec, Katarzyna Krzyżanowska

Writing-rough preparation: Łukasz Bialic, Julia Kwiecińska, Katarzyna Krzyżanowska, Lidia Mądrzak, Władysław Hryniuk, Wiktor Chrzanowski, Marta Korchowiec, Jacek Sitkiewicz, Alicja Toczyłowska, Mateusz Muras

Writing review and editing: Łukasz Bialic, Karol Demel, Alicja Toczyłowska, Mateusz Muras

Project administration: Łukasz Bialic

All authors have read and agreed with the published version of the manuscript.

Funding Statement:

The study did not receive special funding.

Institutional Review Board Statement:

Not applicable.

Informed Consent Statement:

Not applicable.

Data Availability Statement:

Not applicable.

Acknowledgments:

Not applicable.

Conflict Of Interest:

The authors declare no conflict of interest

REFERENCES

1. Wu N. *MOVEMENT BEHAVIOURS AND CARDIOVASCULAR RISK FACTORS IN INDIVIDUALS LIVING WITH TYPE 1 DIABETES*.; 2012.
2. Gillespie KM. Type 1 diabetes: Pathogenesis and prevention. *CMAJ Canadian Medical Association Journal*. 2006;175(2):165-170. doi:10.1503/cmaj.060244
3. Kawasaki E. Anti-Islet Autoantibodies in Type 1 Diabetes. *Int J Mol Sci*. 2023;24(12). doi:10.3390/ijms241210012
4. Katsarou A, Gudbjörnsdottir S, Rawshani A, et al. Type 1 diabetes mellitus. *Nat Rev Dis Primers*. 2017;3. doi:10.1038/nrdp.2017.16
5. Särnblad S, Ponsot E, Leprêtre PM, Kadi F. Acute effects of aerobic continuous, intermittent, and resistance exercise on glycemia in adolescents males with type 1 diabetes. *Pediatr Diabetes*. 2021;22(4):610-617. doi:10.1111/pedi.13194
6. Lu X, Zhao C. Exercise and Type 1 Diabetes. In: *Advances in Experimental Medicine and Biology*. Vol 1228. Springer; 2020:107-121. doi:10.1007/978-981-15-1792-1_7
7. Riddell MC, Gallen IW, Smart CE, et al. Exercise management in type 1 diabetes: a consensus statement. *Lancet Diabetes Endocrinol*. 2017;5(5):377-390. doi:10.1016/S2213-8587(17)30014-1
8. de Lima V de A, de Menezes Júnior FJ, Celli L da R, et al. Effects of resistance training on the glycemic control of people with type 1 diabetes: a systematic review and meta-analysis. *Arch Endocrinol Metab*. 2022;66(4):533-540. doi:10.20945/2359-3997000000487
9. Elsayed NA, Aleppo G, Aroda VR, et al. 5. Facilitating Positive Health Behaviors and Well-being to Improve Health Outcomes: Standards of Care in Diabetes—2023. *Diabetes Care*. 2023;46:S68-S96. doi:10.2337/dc23-S005

10. Colberg SR, Sigal RJ, Yardley JE, et al. Physical activity/exercise and diabetes: A position statement of the American Diabetes Association. *Diabetes Care*. 2016;39(11):2065-2079. doi:10.2337/dc16-1728
11. Colberg SR. Key points from the updated guidelines on exercise and diabetes. *Front Endocrinol (Lausanne)*. 2017;8(FEB). doi:10.3389/fendo.2017.00033
12. Nowocień P, Rokicka D, Wróbel M, et al. Training under normoxia and normobaric hypoxia in patients with type 1 diabetes. *Endokrynol Pol*. 2024;75(4):403-411. doi:10.5603/ep.99346
13. Khalafi M, Dinizadeh F, Rosenkranz SK, Symonds ME, Fatolahi S. The Effects of Exercise Training on Body Composition and Cardiometabolic Risk Factors in Type 1 Diabetes Mellitus: A Systematic Review and Meta-Analysis. *Healthcare (Switzerland)*. 2025;13(3). doi:10.3390/healthcare13030246
14. Tabata I, Suzuki Y, Fukunaga T, Yokozeki T, Akima H, Funato K. *Resistance Training Affects GLUT-4 Content in Skeletal Muscle of Humans after 19 Days of Head-down Bed Rest*.; 1999. http://www.jap.org
15. Richter EA, Hargreaves M. EXERCISE, GLUT4, AND SKELETAL MUSCLE GLUCOSE UPTAKE. *Physiol Rev*. 2013;93:993-1017. doi:10.1152/physrev.00038.2012.-Glucose
16. Ferrucci L, Fabbri E. Inflammageing: chronic inflammation in ageing, cardiovascular disease, and frailty. *Nat Rev Cardiol*. 2018;15(9):505-522. doi:10.1038/s41569-018-0064-2
17. Saraheimo M, Teppo AM, Forsblom C, Fagerudd J, Groop PH. Diabetic nephropathy is associated with low-grade inflammation in Type 1 diabetic patients. *Diabetologia*. 2003;46(10):1402-1407. doi:10.1007/s00125-003-1194-5
18. Snell-Bergeon JK, Dabelea D. Inflammation in pediatric patients with type 1 diabetes-An early predictor of complications? *US Endocrinol*. 2009;5:85-89. doi:10.17925/use.2009.05.1.85
19. Simeunovic A, Brunborg C, Heier M, Seljeflot I, Dahl-Jørgensen K, Margeirsdottir HD. Sustained low-grade inflammation in young participants with childhood onset type 1 diabetes: The Norwegian atherosclerosis and childhood diabetes (ACD) study. *Atherosclerosis*. 2023;379. doi:10.1016/j.atherosclerosis.2023.05.020
20. AL-Mhanna SB, Batrakoulis A, Ghazali WSW, et al. Effects of combined aerobic and resistance training on glycemic control, blood pressure, inflammation, cardiorespiratory fitness and quality of life in patients with type 2 diabetes and overweight/obesity: a systematic review and meta-analysis. *PeerJ*. 2024;12(6). doi:10.7717/peerj.17525
21. Talebi-Garakani E, Safarzade A. Resistance training decreases serum inflammatory markers in diabetic rats. *Endocrine*. 2013;43(3):564-570. doi:10.1007/s12020-012-9786-9
22. Turner D, Luzio S, Kilduff LP, et al. Reductions in resistance exercise-induced hyperglycaemic episodes are associated with circulating interleukin-6 in Type 1 diabetes. *Diabetic Medicine*. 2014;31(8):1009-1013. doi:10.1111/dme.12462
23. Ghanaat F, Tayek JA. Growth hormone administration increases glucose production by preventing the expected decrease in glycogenolysis seen with fasting in healthy volunteers. *Metabolism*. 2005;54(5):604-609. doi:10.1016/j.metabol.2004.12.003
24. Ivandic M, Cigrovski Berkovic M, Ormanac K, et al. Management of Glycemia during Acute Aerobic and Resistance Training in Patients with Diabetes Type 1: A Croatian Pilot Study. *Int J Environ Res Public Health*. 2023;20(6). doi:10.3390/ijerph20064966
25. Rizza RA, Mandarino LJ, Gerich JE. *Effects of Growth Hormone on Insulin Action in Man Mechanisms of Insulin Resistance, Impaired Suppression of Glucose Production, and Impaired Stimulation of Glucose Utilization*. http://diabetesjournals.org/diabetes/article-pdf/31/8/663/352173/31-8-663.pdf
26. Martin-Rivera F, Maroto-Izquierdo S, García-López D, Alarcón-Gómez J. Exercise interventions for patients with type 1 diabetes mellitus: A narrative review with practical recommendations. *World J Diabetes*. 2023;14(5):539-548. doi:10.4239/wjd.v14.i5.539
27. Turner D, Luzio S, Kilduff LP, et al. Reductions in resistance exercise-induced hyperglycaemic episodes are associated with circulating interleukin-6 in Type 1 diabetes. *Diabetic Medicine*. 2014;31(8):1009-1013. doi:10.1111/dme.12462
28. Sigal RJ, Yardley JE, Perkins BA, et al. The Resistance Exercise in Already Active Diabetic Individuals (READI) Randomized Clinical Trial. *Journal of Clinical Endocrinology and Metabolism*. 2023;108(5):E63-E75. doi:10.1210/clinem/dgac682
29. Ramalho AC, de Lourdes Lima M, Nunes F, et al. The effect of resistance versus aerobic training on metabolic control in patients with type-1 diabetes mellitus. *Diabetes Res Clin Pract*. 2006;72(3):271-276. doi:10.1016/j.diabres.2005.11.011
30. Seeger JPH, Thijssen DHJ, Noordam K, Cranen MEC, Hopman MTE, Nijhuis-Van Der Sanden MWG. Exercise training improves physical fitness and vascular function in children with type 1 diabetes. *Diabetes Obes Metab*. 2011;13(4):382-384. doi:10.1111/j.1463-1326.2011.01361.x
31. Fuchsj¨agerfuchsj¨ager-Mayrl G, Pleiner J, G¨unther G, et al. *Exercise Training Improves Vascular Endothelial Function in Patients with Type 1 Diabetes*. Vol 25.; 2002. http://diabetesjournals.org/care/article-pdf/25/10/1795/589488/dc1002001795.pdf
32. Mota MM, da Silva TLTB, Fontes MT, et al. Resistance exercise restores endothelial function and reduces blood pressure in type 1 diabetic rats. *Arq Bras Cardiol*. 2014;103(1):25-32. doi:10.5935/abc.20140087

33. Waclawovsky G, Umpierre D, Figueira FR, et al. Exercise on progenitor cells in healthy subjects and patients with type 1 diabetes. *Med Sci Sports Exerc*. 2016;48(2):190-199. doi:10.1249/MSS.0000000000000764
34. Gharani H, Rahmati M, Mansouri R. *The Effect of 24 Weeks of Resistance Training on Lipid Profile, HBA1c, and Insulin Resistance in Middle-Aged Women with Type 1 Diabetes*.; 2022.
35. Mann S, Beedie C, Jimenez A. Differential effects of aerobic exercise, resistance training and combined exercise modalities on cholesterol and the lipid profile: review, synthesis and recommendations. *Sports Medicine*. 2014;44(2):211-221. doi:10.1007/s40279-013-0110-5
36. Bhati P, Moiz JA, Menon GR, Hussain ME. Modulation of cardiac autonomic control by resistance training in human participants. *Clinical Autonomic Research*. 2019;29(1):121-122. doi:10.1007/s10286-018-0574-3
37. Saki H, Nazem F, Fariba F, Sheikhsharbafan R. A High intensity Interval training (running and swimming) and resistance training intervention on heart rate variability and the selected biochemical factors in boys with type 1 diabetes. *Diabetes Res Clin Pract*. 2023;204. doi:10.1016/j.diabres.2023.110915
38. Wu N, Bredin SSD, Guan Y, et al. Cardiovascular health benefits of exercise training in persons living with type 1 diabetes: A systematic review and meta-analysis. *J Clin Med*. 2019;8(2). doi:10.3390/jcm8020253
39. Tonoli C, Heyman E, Roelands B, et al. *Effects of Different Types of Acute and Chronic (Training) Exercise on Glycaemic Control in Type 1 Diabetes Mellitus A Meta-Analysis*. Vol 42.; 2012.
40. Lecce E, Bellini A, Greco G, et al. Physiological mechanisms of neuromuscular impairment in diabetes-related complications: Can physical exercise help prevent it? *J Physiol*. Published online 2025:1-28. doi:10.1113/JP287589#support-information-section
41. Flores E, Reichert T, Farinha J, Kruel L, Costa R. Exercise Training and Neuromuscular Parameters in Patients With Type 1 Diabetes: Systematic Review and Meta-Analysis. *J Phys Act Health*. Published online 2021:1-9. doi:10.1123/jpah.2020-0797
42. García-Hermoso A, Ramírez-Vélez R, Díez J, González A, Izquierdo M. Exercise training-induced changes in exerkine concentrations may be relevant to the metabolic control of type 2 diabetes mellitus patients: A systematic review and meta-analysis of randomized controlled trials. *J Sport Health Sci*. 2023;12(2):147-157. doi:10.1016/J.JSHS.2022.11.003
43. Pan B, Ge L, Xun Y qin, et al. Exercise training modalities in patients with type 2 diabetes mellitus: A systematic review and network meta-analysis. *International Journal of Behavioral Nutrition and Physical Activity*. 2018;15(1). doi:10.1186/s12966-018-0703-3
44. Li S, Yuan S, Zhang J, Xu F, Zhu F. The effect of periodic resistance training on obese patients with type 2 diabetic nephropathy. *Sci Rep*. 2024;14(1). doi:10.1038/s41598-024-53333-4
45. de Alcantara Santos R, Guzzoni V, Silva KAS, et al. Resistance exercise shifts the balance of renin-angiotensin system toward ACE2/Ang 1–7 axis and reduces inflammation in the kidney of diabetic rats. *Life Sci*. 2021;287:120058. doi:10.1016/J.LFS.2021.120058
46. Amaral LS de B, Souza CS, Lima HN, Soares T de J. Influence of exercise training on diabetic kidney disease: A brief physiological approach. *Exp Biol Med*. 2020;245(13):1142-1154. doi:10.1177/1535370220928986
47. Pongrac Barlovic D, Tikkanen-Dolenc H, Groop PH. Physical Activity in the Prevention of Development and Progression of Kidney Disease in Type 1 Diabetes. *Curr Diab Rep*. 2019;19(7). doi:10.1007/s11892-019-1157-y
48. Castaneda C, Gordon PL, Parker RC, Uhlin KL, Roubenoff R, Levey AS. Resistance Training to Reduce the Malnutrition-Inflammation Complex Syndrome of Chronic Kidney Disease. *American Journal of Kidney Diseases*. 2004;43(4):607-616. doi:10.1053/j.ajkd.2003.12.025
49. Chong DD, Das N, Singh RP. Diabetic retinopathy: Screening, prevention, and treatment. *Cleve Clin J Med*. 2024;91(8):503-510. doi:10.3949/ccjm.91a.24028
50. Reddy R, Wittenberg A, Castle JR, et al. Effect of Aerobic and Resistance Exercise on Glycemic Control in Adults With Type 1 Diabetes. *Can J Diabetes*. 2019;43(6):406-414.e1. doi:10.1016/j.jcjd.2018.08.193
51. *EVIDENCE-BASED CLINICAL PRACTICE GUIDELINE Eye Care of the Patient with Diabetes Mellitus Second Edition*.; 2019.