CZARNOTA, Maksymilian, WOJDAT-KRUPA, Karolina, WASYLUK, Martyna, ROGOWSKA, Monika, OSSOWSKA, Weronika, LEWAŚKIEWICZ, Paulina, SIKORA, Karol, PŁUDOWSKA, Klaudia, PRZELASKOWSKA, Aleksandra and PULIŃSKI, Jan. Physical Activity in the Prevention and Management of Type 2 Diabetes Evidence-Based Approaches. Quality in Sport. 2025;43:62423. eISSN 2450-3118.
https://doi.org/10.12775/QS.2025.43.62423
https://apcz.umk.pl/QS/article/view/62423

The journal has been awarded 20 points in the parametric evaluation by the Ministry of Higher Education and Science of Poland. This is according to the Annex to the announcement of the Minister of Higher Education and Science dated 05.01.2024, No. 32553. The journal has a Unique Identifier: 201398. Scientific disciplines assigned: Economics and Finance (Field of Social Sciences); Management and Quality Sciences (Field of Social Sciences).
Punkty Ministerialne z 2019 - aktualny rok 20 punktów. Załącznik do komunikatu Ministra Szkolnictwa Wyższego i Nauki z dnia 05.01.2024 Lp. 32553. Posiada Unikatowy Identyfikator Czasopisma: 201398. Przypisane dyscypliny naukowe: Ekonomia i finanse (Dziedzina nauk społecznych); Nauki o zarządzaniu i jakości (Dziedzina nauk społecznych).
The authors declare that there is no conflict of interest regarding the publication of this paper.
Received: 15.06.2025. Revised: 05.07.2025. Accepted: 05.07.2025. Published: 10.07.2025.

Physical Activity in the Prevention and Management of Type 2 Diabetes: Evidence-Based Approaches

Maksymilian Czarnota

https://orcid.org/0009-0002-9322-4494

bonamaks@gmail.com

Szpital Morski im. PCK, ul. Powstania Styczniowego 1, 81-519 Gdynia, Poland

Karolina Wojdat-Krupa

https://orcid.org/0009-0003-0942-8273

wojdat.karolina@gmail.com

Szpital Morski im. PCK, ul. Powstania Styczniowego 1, 81-519 Gdynia, Poland

Martyna Wasyluk

https://orcid.org/0000-0001-5897-7568

martynaxwasyluk@gmail.com

Szpital Morski im. PCK, ul. Powstania Styczniowego 1, 81-519 Gdynia, Poland

Monika Rogowska

https://orcid.org/0000-0002-9617-7307

m.rogowska98@gmail.com

Szpital Morski im. PCK, ul. Powstania Styczniowego 1, 81-519 Gdynia, Poland

Weronika Ossowska

https://orcid.org/0009-0002-4205-9572

ossowska.w@gmail.com

Szpital Morski im. PCK, ul. Powstania Styczniowego 1, 81-519 Gdynia, Poland

Paulina Lewaśkiewicz

https://orcid.org/0009-0008-2361-4917

paulina.lewaskiewicz@gmail.com

Karol Sikora

https://orcid.org/0009-0009-5610-3547

karol.sikora@onet.com.pl

Klaudia Płudowska

https://orcid.org/0009-0002-3845-8167

Klaudia.pludowska@gumed.edu.pl

Szpital Morski im. PCK, ul. Powstania Styczniowego 1, 81-519 Gdynia, Poland

Aleksandra Przelaskowska

https://orcid.org/0009-0006-1784-1203

olaprzelaskowska@gmail.com

Szpital Specjalistyczny im. Floriana Ceynowy, ul. dr Alojzego Jagalskiego 10, 84-200 Wejherowo

Jan Puliński

https://orcid.org/0009-0007-6914-1978

Jasiek.1999@wp.pl

Szpital Specjalistyczny im. Floriana Ceynowy, ul. dr Alojzego Jagalskiego 10, 84-200 Wejherowo

Corresponding Author: Maksymilian Czarnota, bonamaks@gmail.com

Abstract

Type 2 diabetes mellitus (T2DM) is a growing global health concern linked to sedentary lifestyles and obesity. Physical activity is a key factor in prevention and management, yet existing guidelines may not fully address the needs of physically active individuals.

This narrative review synthesizes data from randomized controlled trials, systematic reviews, meta-analyses, and expert guidelines from the past 15 years. It focuses on the metabolic effects of exercise and practical recommendations tailored to various activity levels.

Structured physical activity improves insulin sensitivity, lowers HbA1c, supports weight control, and reduces cardiovascular risk. Combined aerobic and resistance training yields the most consistent benefits. In active individuals, monitoring glucose levels, preventing hypoglycemia, and adjusting training volume are essential. Digital tools and interdisciplinary care can enhance adherence and safety.

Physical activity is a cornerstone of T2DM care. Individualized exercise strategies aligned with fitness level and treatment needs can optimize outcomes. Future studies should focus on highly active populations and technology-based interventions to support personalized, sustainable exercise programs.

Keywords: physical activity, type 2 diabetes mellitus, prevention management, aerobic exercise, resistance training, active populations, exercise, HbA1c

1. Introduction

Type 2 diabetes mellitus (T2DM) represents a leading public health challenge globally, characterized by escalating prevalence, significant morbidity, and substantial socioeconomic impact. According to projections by the International Diabetes Federation, over 537 million adults were living with diabetes in 2021, with the majority being cases of T2DM. This figure is expected to surpass 700 million by 2045, driven by increases in sedentary behavior, energy-dense diets, and urbanization in both developed and developing countries [19]. T2DM is

associated with a broad spectrum of microvascular and macrovascular complications, which collectively contribute to diminished quality of life and increased mortality.

Amid this growing epidemic, physical activity has emerged as a foundational, non-pharmacological strategy for both the primary prevention and long-term management of T2DM. Numerous pathophysiological mechanisms underlie its beneficial effects: regular physical activity enhances peripheral insulin sensitivity, facilitates glucose uptake in skeletal muscle, modulates adiposity, improves endothelial function, and exerts favorable effects on lipid profiles and systemic inflammation [1, 15, 17]. Clinical trials and large-scale observational studies consistently demonstrate that structured exercise interventions, including aerobic, resistance, and combined modalities, significantly reduce the risk of incident T2DM and improve metabolic control in individuals with established disease [2, 3, 4].

Despite well-documented evidence, existing guidelines often lack specificity for individuals who are already physically active or engaged in high-frequency training regimens. These populations may exhibit unique physiological responses and risk profiles, including susceptibility to exercise-induced hypoglycemia, altered cardiovascular adaptations, or differing thresholds of insulin sensitivity improvement [12, 21]. Consequently, there is a pressing need to update and personalize current recommendations, taking into account the distinct characteristics of physically active individuals, including recreational athletes and fitness-oriented populations.

The objective of this review is to synthesize current, high-quality evidence concerning the role of physical activity in the prevention and management of T2DM, with a focused lens on its application to active populations. By integrating findings from randomized controlled trials, cohort studies, position statements, and systematic reviews, this paper aims to provide a clinically relevant, evidence-based framework to support the development of refined exercise recommendations tailored to the metabolic and functional needs of physically active individuals at risk for or living with T2DM.

2. Methods

This narrative review was conducted in accordance with established principles of evidence-based synthesis, focusing exclusively on peer-reviewed literature that explores the relationship between physical activity and type 2 diabetes mellitus (T2DM). The search strategy was designed to capture a broad yet clinically relevant spectrum of studies, encompassing both

preventive and therapeutic aspects of physical exercise in the context of T2DM, with particular attention to data applicable to physically active populations.

2.1. Literature Search Strategy

A comprehensive literature search was performed using three major electronic databases: PubMed, Scopus, and Web of Science. The search was carried out using a combination of MeSH terms and free-text keywords, including but not limited to: “type 2 diabetes”, “physical activity”, “exercise”, “prevention”, “management”, “aerobic training”, “resistance training”, and “active populations”. Boolean operators (AND, OR) were used to optimize the search sensitivity and specificity.

2.2. Inclusion and Exclusion Criteria

To ensure the scientific rigor and clinical applicability of the included sources, the following inclusion criteria were applied:

- Studies focusing on the effects of physical activity on the prevention or management of T2DM.
- Publications involving adult human populations (≥18 years).
- Studies reporting outcomes related to glycemic control, cardiovascular risk factors, insulin sensitivity, or diabetes incidence.
- Articles written in English.
- Publication types limited to randomized controlled trials (RCTs), systematic reviews, meta-analyses, expert consensus statements, or clinical guidelines.

While our primary eligibility focused on randomized controlled trials (RCTs), systematic reviews, meta-analyses, expert consensus statements and clinical guidelines, we deliberately broadened the scope for the prevention domain to also include large-scale prospective cohort studies that met all other criteria. This adjustment reflects the practical reality that life-course RCTs on incident type 2 diabetes are scarce, whereas high-quality cohort evidence constitutes a cornerstone of current preventive guidelines.

The exclusion criteria comprised:

- Studies focusing primarily on type 1 diabetes mellitus or gestational diabetes.
- Non-peer-reviewed material (e.g., conference abstracts, letters, commentaries).

- Research involving pediatric populations or animal models.

2.3. Types of Evidence Included

This review incorporates data derived from high-level sources of medical evidence, including:

- Randomized controlled trials (RCTs) evaluating the efficacy of various exercise modalities on metabolic and cardiovascular parameters in T2DM.
- Systematic reviews and meta-analyses summarizing the cumulative evidence regarding exercise interventions in diabetes prevention and management.
- Official clinical guidelines and position statements issued by leading professional bodies such as the American Diabetes Association (ADA) and the American College of Sports Medicine (ACSM) [1, 5, 12].

2.4. Timeframe and Language

The majority of included publications were published within the last 15 years, with exceptions made for historically significant studies that provided foundational evidence for the role of physical activity in T2DM pathophysiology and intervention [3, 4]. All reviewed articles were published in English.

3. Pathophysiology of Type 2 Diabetes and Role of Physical Activity

Type 2 diabetes mellitus (T2DM) is a complex metabolic disorder characterized by insulin resistance in peripheral tissues and progressive β-cell dysfunction, resulting in chronic hyperglycemia. Its pathogenesis involves genetic predisposition combined with environmental and lifestyle factors, especially physical inactivity and excessive caloric intake. Insulin resistance in skeletal muscle, adipose tissue, and liver leads to impaired glucose uptake, increased hepatic gluconeogenesis, and dysregulated lipid metabolism [1, 19].

An important contributor to insulin resistance is the accumulation of fat within muscle and liver cells, which triggers serine kinases and inflammatory pathways that disrupt insulin signaling. Meanwhile, β-cell function - initially maintained through compensatory hyperinsulinemia - deteriorates over time due to oxidative stress, lipotoxicity, and endoplasmic reticulum stress, ultimately resulting in insufficient insulin secretion [19].

Physical activity exerts beneficial effects on these pathophysiological processes. Exercise increases glucose uptake in skeletal muscle via insulin-dependent and insulin-independent mechanisms, notably by stimulating GLUT4 transporter translocation to the cell membrane during and after muscle contractions. It also improves insulin sensitivity in adipose tissue and suppresses hepatic glucose production [1, 19]. Long-term exercise adaptations - such as increased mitochondrial density, enhanced capillary perfusion, and altered adipokine secretion - further contribute to better glycemic control [19].

Moreover, regular physical activity plays a key role in body-weight regulation by helping to preserve - or even increase - lean muscle mass while reducing visceral fat, both of which markedly enhance insulin action [19]. In addition, exercise interventions favorably influence the lipid profile, lowering triglyceride concentrations and raising HDL-cholesterol levels, thereby reducing important cardiovascular risk factors that commonly accompany T2DM [21].

Importantly, physiological responses to exercise may differ in people with T2DM compared with those without diabetes. Patients often present with endothelial dysfunction, reduced autonomic modulation of the heart and limited aerobic capacity, factors that can blunt acute and chronic training adaptations [19, 20]. Despite these challenges, numerous studies confirm that individuals with T2DM still obtain substantial benefits from regular exercise, especially when training programmes are properly tailored to their clinical status and capabilities [12].

In summary, the role of physical activity in the pathophysiology of T2DM is both preventive and therapeutic, targeting multiple metabolic and vascular pathways. As such, exercise should be regarded not only as an adjunctive therapy but as a core component of diabetes management, with specific attention to modality, intensity, and individual responsiveness.

4. Physical Activity in the Prevention of Type 2 Diabetes

Regular physical activity plays a fundamental role in the primary prevention of type 2 diabetes mellitus (T2DM), with numerous high-quality epidemiological and interventional studies confirming its effectiveness in reducing the incidence of the disease. Increased levels of habitual physical activity have been consistently associated with a significantly lower risk of progression from impaired glucose regulation to overt diabetes, particularly among individuals with predisposing metabolic profiles [7, 8, 9]. The preventive effect appears to be dose-dependent, with greater intensity, duration, and frequency of activity conferring stronger protective benefits [2, 9].

Structured lifestyle interventions incorporating exercise have demonstrated a substantial reduction in diabetes incidence among high-risk populations. Randomized controlled trials have shown that combined strategies involving dietary changes and increased physical activity can reduce the risk of developing T2DM by over 50% in individuals with impaired glucose tolerance [3, 4]. Notably, the beneficial impact of such interventions persists over time, indicating long-term metabolic adaptations beyond the duration of the structured programs [4].

Additionally, multicomponent lifestyle interventions, including healthy dietary patterns such as the Mediterranean diet, have been associated with a significantly reduced risk of T2DM in prospective cohort studies, further emphasizing the combined preventive potential of physical activity and nutrition [11].

Both aerobic and resistance exercise modalities contribute meaningfully to the prevention of T2DM through complementary mechanisms. Aerobic activity enhances cardiorespiratory fitness, promotes lipid oxidation, and improves peripheral insulin sensitivity. Resistance training, in turn, increases skeletal muscle mass and strength, improves basal glucose uptake, and attenuates insulin resistance in both normoglycemic and dysglycemic individuals [15]. Clinical guidelines recommend a combination of these modalities, emphasizing at least 150 minutes per week of moderate-to-vigorous aerobic activity, alongside resistance training performed on two to three days per week on non-consecutive days [1, 12].

Numerous studies have sought to identify the minimal effective dose of physical activity required to confer a protective effect against type 2 diabetes mellitus (T2DM). Evidence indicates that engaging in at least 150 minutes per week of moderate-intensity aerobic exercise, or 75 minutes per week of vigorous-intensity activity, is associated with a clinically meaningful reduction in diabetes risk [1, 12]. These thresholds reflect recommendations grounded in large-scale observational cohorts and randomized trials that demonstrated a clear inverse dose–response relationship between physical activity volume and T2DM incidence [2, 9].

Importantly, further benefits appear with higher volumes and intensities of exercise, though even modest levels of increased activity, such as walking 30 minutes per day on most days of the week, can substantially reduce diabetes risk in previously inactive individuals [3, 4]. Resistance training, when performed at least twice weekly, has also been shown to independently improve insulin sensitivity and glucose metabolism, and to contribute to long-term risk reduction [15].

Beyond structured exercise programs, an active daily lifestyle - characterized by reduced sedentary time and frequent low-intensity movement - has emerged as an independent factor in metabolic health. Epidemiological data suggest that individuals with higher baseline levels of daily movement, even in the absence of formal training, demonstrate lower rates of T2DM onset compared to sedentary individuals [6, 8, 10]. This supports the notion that the cumulative effect of habitual physical activity across various domains - occupational, household, transportation-related, and recreational - is relevant for diabetes prevention.

Nonetheless, structured training interventions typically elicit greater and more consistent improvements in glycemic markers and cardiometabolic profiles, particularly in high-risk populations [2, 4, 21]. Such interventions allow for precise control over exercise intensity, progression, and adherence monitoring, which may be especially critical in individuals with impaired glucose metabolism or multiple risk factors. Therefore, a dual emphasis on increasing general physical activity throughout the day and incorporating regular, structured exercise appears to offer the most robust protective effect against T2DM development.

5. Physical Activity in the Management of Established Type 2 Diabetes

In the therapeutic landscape of type 2 diabetes mellitus (T2DM), physical activity represents a core component of comprehensive management, synergistically complementing pharmacological treatment and medical nutrition therapy. Current clinical guidelines call for incorporating physical exercise into individually designed treatment plans, recognising its multifaceted role in improving glycaemic control, reducing cardiovascular risk and enhancing overall functional capacity [1, 12].

Physical activity amplifies the effectiveness of antidiabetic medications by increasing insulin sensitivity, stimulating insulin-independent glucose uptake and stabilising daily glucose variability. These effects are particularly relevant in patients using insulin or insulin secretagogues, as regular exercise can allow insulin-dose reductions while simultaneously improving post-prandial and fasting glucose levels [1, 12].

Beyond glycemic control, physical activity exerts favorable effects on cardiometabolic health - a critical consideration given that cardiovascular disease remains the leading cause of morbidity and mortality in individuals with T2DM. Both aerobic and resistance training have been shown to lower blood pressure, improve endothelial function, diminish systemic inflammation and favourably modify the lipid profile by decreasing triglycerides and increasing HDL-cholesterol

[19, 21]. Even short-term aerobic training has been shown to improve endothelial function and postprandial conduit artery blood flow in patients with T2DM, reflecting early vascular adaptations to exercise [16]. These adaptations collectively contribute to a reduction in the risk of macrovascular complications such as coronary artery disease and stroke, as well as microvascular outcomes including nephropathy and retinopathy.

Long-term adherence to prescribed exercise programmes is associated with sustained reductions in HbA1c, irrespective of body-weight change, indicating that physical activity produces durable metabolic improvements in people with T2DM [15].

Regular physical activity is strongly associated with clinically meaningful reductions in HbA1c, even in the absence of significant weight loss. Meta-analyses of randomised trials demonstrate that aerobic, resistance and combined training can lower HbA1c by roughly 0.5–1.0 % - a magnitude comparable with that of several glucose-lowering drugs [12, 21]. Moreover, combining aerobic and resistance modalities is more effective than either alone in improving glycaemic outcomes [15].

In addition to glycemic control, exercise contributes to modest but significant weight reduction, particularly when coupled with dietary intervention. Resistance training is especially effective in preserving or increasing lean body mass during caloric restriction, which enhances basal metabolic rate and promotes fat loss [21]. Aerobic activity further supports weight management by increasing energy expenditure and improving lipid oxidation [2].

Beyond measurable physiological outcomes, physical activity has been shown to significantly improve health-related quality of life (HRQoL) in patients with T2DM. Exercise interventions are associated with better self-rated health, enhanced physical function, reduced depressive symptoms, and improved perceived well-being and vitality [14, 19]. These psychosocial benefits are clinically relevant, as they may enhance adherence to therapy and facilitate long-term self-management of the disease.

Despite its benefits, certain precautions must be observed when prescribing exercise for individuals with T2DM. Patients with advanced neuropathy, proliferative retinopathy, or cardiovascular disease require medical evaluation prior to initiating moderate to vigorous training [1]. Particular attention should be paid to the risk of hypoglycemia, especially in individuals treated with insulin or insulin secretagogues. Pre- and post-exercise blood glucose

monitoring may be necessary, and adjustments in medication or carbohydrate intake might be indicated [12].

Additionally, footwear assessment and foot care education are essential for patients with peripheral neuropathy to prevent injury. Exercise programs should be individualized, taking into account comorbidities, functional capacity, and patient preferences, with a progressive approach that emphasizes safety and long-term adherence [1, 12].

6. Specific Considerations for Active Populations

Although physical activity is a universally recommended component of type 2 diabetes mellitus (T2DM) management, individuals with high levels of habitual or occupational exertion - such as recreational athletes, physically active workers, or fitness professionals - may require personalized exercise guidance. Standard recommendations, while broadly effective, may not sufficiently address the unique physiological profiles and therapeutic challenges of this subgroup.

Physically active individuals often surpass the minimal threshold of weekly exercise volume recommended for glycemic control. While this typically yields favorable outcomes, it may also increase the risk of glycemic instability, especially among those receiving pharmacologic treatment that affects glucose metabolism. In particular, patients using insulin or sulfonylurea derivatives are more susceptible to exercise-induced hypoglycemia, especially during prolonged, intense, or fasted-state activity [1, 12].

To minimize this risk, self-monitoring of blood glucose (SMBG) is essential.Exercise is considered safe when pre-activity blood glucose lies between 100 and 250 mg/dL. If levels fall below this range, fast-acting carbohydrates should be ingested; conversely, when glucose exceeds 250 mg/dL in the presence of ketones, exercise should be postponed [1, 12]. In structured training regimens, strategic adjustments in insulin dosage, pre-exercise meal timing, and intra-session carbohydrate intake may be required to maintain glycemic safety [12].

These considerations are particularly relevant in individuals with well-controlled T2DM, where improved insulin sensitivity through regular training can paradoxically increase the likelihood of hypoglycemic episodes. This phenomenon underscores the need for dynamic treatment adjustment based on continuous assessment of exercise response, glycaemic variability and each patient’s metabolic status [12].

Accurate peri-exercise glucose monitoring is essential in individuals with type 2 diabetes mellitus (T2DM), especially those receiving insulin or sulfonylureas. Self-monitoring of blood glucose (SMBG) before, during, and after physical activity enables early identification of hypoglycemic or hyperglycemic responses and facilitates prompt therapeutic adjustments [1, 12]. The use of continuous glucose monitoring (CGM) is particularly valuable in active patients, as it allows for dynamic assessment of glycemic trends and improved safety during variable training conditions [14].

Beyond metabolic safety, attention must be given to the training load and recovery in individuals with T2DM who engage in frequent or high-intensity exercise. Excessive training volume without adequate rest may lead to functional overreaching, characterized by increased cortisol levels, impaired glucose tolerance, and diminished insulin sensitivity - paradoxical effects that can negate the metabolic benefits of exercise [20]. Additionally, chronic stress and autonomic imbalance associated with overtraining may exacerbate glycemic variability and cardiovascular strain [21].

To address these risks, exercise programs for physically active individuals with T2DM should incorporate structured periodization, balancing intensity, volume, and recovery to optimize both performance and metabolic control. Individualized plans should consider training history, glycemic response patterns, medication use, and overall health status. Involving an interdisciplinary team - including a physician, exercise physiologist and diabetes educator - enhances the safety, efficacy and individualisation of interventions [12].

In conclusion, while general exercise recommendations provide a strong foundation for managing T2DM, active populations require individualized strategies that address the complexity of their training demands and metabolic regulation. With proper monitoring, education, and support, these individuals can safely achieve the therapeutic benefits of physical activity without compromising glycemic stability or overall health.

7. Practical Guidelines and Recommendations

The implementation of structured physical activity remains a fundamental component of comprehensive diabetes care. Clinical guidelines issued by major organizations - including the World Health Organization (WHO), the American Diabetes Association (ADA), the European Association for the Study of Diabetes (EASD), and the American College of Sports Medicine

(ACSM) - provide harmonized recommendations emphasizing the role of regular exercise in the management and prevention of type 2 diabetes mellitus (T2DM).

These recommendations advocate for a minimum of 150 minutes per week of moderate-intensity aerobic physical activity, performed on at least three days per week with no more than two consecutive days without exercise. Alternatively, 75 minutes per week of vigorous-intensity aerobic activity, or a combination of both, may be used to achieve similar metabolic benefits. In addition, resistance training involving major muscle groups should be performed on two to three non-consecutive days per week, as it confers independent benefits on glycemic control and musculoskeletal health [1, 12].

Flexibility and balance exercises are also recommended, particularly in older adults, to reduce fall risk and improve functional independence. Importantly, physical activity regimens should be individualized, considering baseline fitness, comorbidities, and patient preferences, with progressive adjustments over time [1, 12].

Exercise Prescription by Fitness Level

Beginner (Sedentary or Low Fitness)

- Aerobic: Walking at moderate pace (e.g., 5 km/h) for 20–30 minutes, 3–5 days per week.
- Resistance: Bodyweight or resistance band exercises (e.g., chair squats, wall push-ups) performed in 1–2 sets of 10–15 repetitions, 2 times per week.
- Goal: Establish routine, minimize sedentary behavior, and safely build exercise tolerance.

Intermediate

- Aerobic: Brisk walking, cycling, or swimming 30–45 minutes per session, 4–5 days per week.
- Resistance: Machine-based or free-weight training, 2–3 sets of 8–12 repetitions, 2–3 days per week.
- Goal: Improve cardiovascular endurance, muscular strength, and glycemic control.

Advanced (Recreationally or Occupationally Active)

- Aerobic: Vigorous-intensity exercise (e.g., interval training, running) 30–60 minutes, 5–6 days per week, with periodized training load.
- Resistance: Progressive strength training targeting all major muscle groups, 3–4 sessions per week.
- Goal: Optimize insulin sensitivity, body composition, and performance while managing glucose fluctuations.

Across all fitness levels, monitoring for signs of overtraining, hypoglycemia, and cardiovascular symptoms is essential, especially in patients using medications with glycemic impact. The inclusion of warm-up and cool-down periods, along with hydration and nutritional strategies, enhances safety and exercise efficacy.

An effective physical activity program for individuals with type 2 diabetes mellitus (T2DM) requires coordinated input from a multidisciplinary healthcare team. Optimal outcomes are achieved when physicians, physiotherapists, qualified exercise specialists and clinical dietitians collaborate to provide personalised, safe and evidence-based programmes [1, 12].

The physician plays a central role in medical clearance, identification of comorbidities, and pharmacological management, including adjustments of antihyperglycemic medications in response to changing exercise demands. The physiotherapist and exercise specialist contribute to functional assessment, exercise prescription, supervision, and progression, ensuring biomechanical safety and training efficacy. The dietitian integrates nutritional guidance with the exercise plan, particularly by timing carbohydrate intake to physical effort and by supporting weight-loss goals or energy-deficit strategies [12].

Accurate assessment and monitoring are critical to guide exercise prescription and evaluate effectiveness over time. Commonly used tools include:

- Accelerometers and pedometers, which provide objective data on daily step counts and activity intensity.
- Heart rate monitors and fitness trackers capable of estimating energy expenditure and training load.

- Continuous glucose monitoring (CGM) systems, which offer valuable insight into glycemic responses to physical activity, allowing for timely adjustments to both therapy and exercise [14].
- Standardized questionnaires, such as the International Physical Activity Questionnaire (IPAQ) or the Global Physical Activity Questionnaire (GPAQ), which are validated tools for quantifying self-reported activity in clinical and epidemiological settings.
- Performance-based functional tests, such as the 6-minute walk test or sit-to-stand test, are useful in assessing endurance and lower-limb strength, particularly in older adults or individuals with limited capacity.

The integration of these tools into routine clinical practice facilitates personalization of training plans, early detection of adverse responses, and long-term behavioral adherence, ultimately enhancing glycemic outcomes and quality of life.

8. Limitations and Future Directions

Despite a substantial body of evidence supporting the role of physical activity in the prevention and management of type 2 diabetes mellitus (T2DM), several limitations in the current literature warrant consideration. Many interventional studies - especially randomised controlled trials - show considerable heterogeneity in exercise protocols, differing in type, intensity, duration, supervision and adherence monitoring [17, 19]. This methodological variability complicates direct comparison between studies and limits the generalizability of findings to diverse patient populations.

Another common limitation is small sample size, which reduces statistical power and the ability to detect clinically meaningful effects across subgroups. Furthermore, short study durations may fail to capture long-term outcomes, such as sustained glycemic control, incidence of diabetes-related complications, or cardiovascular events. Although systematic reviews and meta-analyses partly mitigate these issues through data synthesis, their conclusions remain limited by the quality and consistency of the included studies [2, 19].

An additional concern relates to the underrepresentation of highly active individuals in most studies. The majority of available data focuses on sedentary or moderately active participants, limiting the applicability of current guidelines to recreational athletes, fitness enthusiasts, and physically demanding occupational groups. Consequently, targeted research is needed in populations with a high baseline activity level, including studies of training periodisation,

performance optimisation and specific metabolic adaptations to varying exercise intensities [12, 19].

Furthermore, few studies have evaluated the real-world implementation of physical-activity programmes that use modern digital tools - such as wearables, tele-monitoring and mobile health applications - which could increase adherence and enable real-time personalisation of exercise regimens [14]. Future trials should incorporate ecologically valid designs, larger and more diverse cohorts, and longer follow-up periods to better inform practice across heterogeneous clinical and functional populations.

Finally, interventional studies that include interdisciplinary approaches - integrating physicians, exercise professionals, and dietitians - remain sparse, despite their recognized value in clinical guidelines. Addressing these research gaps is essential for optimizing therapeutic strategies and translating evidence into effective, scalable interventions for individuals with T2DM at varying levels of physical fitness.

An emerging and promising area of research involves the integration of digital health technologies - including wearable devices, telemonitoring platforms, and mobile applications - into physical activity interventions for individuals with type 2 diabetes mellitus (T2DM). These tools offer unique opportunities for real-time data acquisition, feedback, and remote coaching, thereby facilitating personalized and adaptive exercise prescriptions that can be monitored outside of traditional clinical settings.

Wearable devices, such as fitness trackers and smartwatches, can objectively measure step count, heart rate, energy expenditure, and sleep patterns. When integrated with mobile health (mHealth) applications, they provide continuous feedback on physical activity behavior, supporting goal setting and enhancing user engagement [14]. In individuals with T2DM, these devices can be synchronized with continuous glucose monitoring (CGM) systems, enabling the correlation of activity patterns with glycemic variability and guiding medication or dietary adjustments [14, 21].

Telemonitoring and telecoaching platforms allow healthcare professionals to remotely monitor adherence to exercise regimens and intervene when necessary. These technologies can be particularly beneficial for patients in rural or underserved areas, or for those requiring frequent follow-up but limited by transportation, mobility, or clinical resource constraints [14]. Preliminary studies indicate that technology-assisted interventions may improve physical

activity levels, glycemic control, and self-efficacy, though long-term outcomes remain under investigation.

Despite their potential, the clinical implementation of these tools faces several barriers, including digital literacy disparities, cost, data privacy concerns, and integration with electronic health records. Furthermore, most current studies are observational or pilot trials, often lacking control groups or standardized protocols. Thus, high-quality randomized trials are needed to establish the efficacy and scalability of these solutions across diverse populations and healthcare systems.

Incorporating digital tools into routine diabetes care holds promise not only for enhancing physical activity adherence but also for fostering sustained behavior change and empowering patient self-management. Their appropriate use, guided by clinical oversight and interdisciplinary coordination, may significantly advance the effectiveness of physical activity interventions in T2DM prevention and treatment.

9. Discussion

This review highlights the pivotal role of physical activity as both a preventive and therapeutic intervention in type 2 diabetes mellitus (T2DM). The evidence consistently demonstrates that structured exercise, particularly when integrated with dietary and pharmacological therapies, leads to clinically meaningful improvements in glycemic control, body composition, cardiovascular risk profile, and overall quality of life in individuals with or at risk for T2DM [1, 2, 4, 15, 21].

Aerobic and resistance training have each shown independent metabolic benefits; however, their combination appears to elicit the most robust effects across various outcomes, including hemoglobin A1c reduction, insulin sensitivity enhancement, and lipid profile optimization [15, 21]. Notably, the benefits of physical activity extend beyond metabolic regulation, contributing to improved physical function, psychological well-being, and long-term disease self-management [14, 19, 21].

Despite strong support for these interventions, challenges persist in translating evidence into sustainable, real-world practices. A major limitation is the insufficient representation of highly active individuals in clinical trials. This restricts the applicability of existing guidelines to athletes or occupationally active patients, whose metabolic responses and training needs differ

substantially from the general population [11, 20]. Moreover, current exercise prescriptions often lack granularity in terms of individualization, progression, and integration with modern health technologies.

Our findings reinforce the value of a multidisciplinary approach, emphasizing the need for coordinated input from physicians, exercise specialists, dietitians, and behavioral coaches to ensure safe, effective, and personalized exercise interventions [13]. Such models facilitate not only clinical oversight but also patient empowerment and adherence.

Emerging technologies - including wearable devices, mobile health applications, and remote coaching platforms - present promising adjuncts to conventional care. Although early results are encouraging, large-scale, high-quality trials are needed to validate their effectiveness, address disparities in access, and inform best practices for digital integration in diabetes care [14, 18].

This review also underscores the importance of assessing physical activity as both a quantitative behavior (frequency, duration, intensity) and a qualitative process (enjoyment, sustainability, life integration). Encouraging lifelong physical activity requires addressing structural, psychological, and socioeconomic barriers to participation. Tailored interventions that reflect patients' preferences, capabilities, and environments are more likely to succeed in the long term.

In summary, while the role of physical activity in T2DM prevention and management is unequivocally supported by evidence, ongoing research should aim to:

- refine personalized exercise prescriptions across fitness levels and treatment settings,
- optimize safety and efficacy in high-risk and high-activity populations,
- leverage technology to improve accessibility and adherence,
- and develop scalable models of interdisciplinary, lifestyle-focused care.

10. Conclusions

Physical activity constitutes an essential and evidence-based element in the prevention and management of type 2 diabetes mellitus. Its multifactorial impact on glycemic control, insulin sensitivity, body composition, cardiovascular function, and psychosocial well-being confirms its therapeutic value beyond that of a lifestyle recommendation - it is a cornerstone of modern diabetes care.

The present review affirms that both aerobic and resistance training independently contribute to meaningful clinical improvements, while their combination provides synergistic effects. Structured exercise programs, particularly when integrated into a comprehensive, multidisciplinary management strategy, offer substantial metabolic and functional benefits, even in the absence of significant weight loss. Moreover, sustained physical activity contributes to long-term disease modulation and enhances patients' capacity for self-management.

Nonetheless, significant gaps remain in the personalization and scalability of exercise interventions. Current guidelines often fall short of addressing the needs of individuals with high baseline activity levels, whose physiological responses and safety considerations differ from those of sedentary patients. There is also a need to better integrate technology into care models, utilizing tools such as wearables and telemonitoring to enhance adherence, real-time feedback, and individualized progression.

Future research should prioritize the development of adaptive, patient-centered exercise prescriptions that account for diverse physical capabilities, comorbidities, and therapeutic regimens. Additionally, more data are needed from real-world settings and underrepresented populations to improve external validity and equity of implementation.

In conclusion, physical activity should not be viewed as an adjunct to pharmacologic and dietary therapy, but rather as a core, dynamic component of individualized diabetes care - relevant across all stages of the disease and adaptable to varying levels of physical performance and engagement.

Disclosure

Author Contributions

Conceptualization: Maksymilian Czarnota
Methodology: Karol Sikora
Software: Klaudia Płudowska
Formal analysis: Martyna Wasyluk
Investigation: Monika Rogowska
Resources:Karolina Wojdat-Krupa
Check: Paulina Lewaśkiewicz
Writing -rough preparation: Aleksandra Przelaskowska

Writing -review and editing: Weronika Ossowska

Supervision: Maksymilian Czarnota

Visualization: Jan Puliński

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

Funding

This research received no external funding.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Not applicable.

Data Availability Statement

Data sharing is not applicable to this article.

Conflict of interest

The authors declare no conflict of interest.

References

1. Colberg SR, Sigal RJ, Fernhall B, Regensteiner JG, Blissmer BJ, Rubin RR, Chasan-Taber L, Albright AL, Braun B; American College of Sports Medicine; American Diabetes Association. Exercise and type 2 diabetes: the American College of Sports Medicine and the American Diabetes Association: joint position statement. Diabetes Care. 2010 Dec;33(12):e147-67. doi: 10.2337/dc10-9990. PMID: 21115758; PMCID: PMC2992225.

2. Aune D, Norat T, Leitzmann M, Tonstad S, Vatten LJ. Physical activity and the risk of type 2 diabetes: a systematic review and dose-response meta-analysis. Eur J Epidemiol. 2015 Jul;30(7):529-42. doi: 10.1007/s10654-015-0056-z. Epub 2015 Jun 20. PMID: 26092138.

3. Pan XR, Li GW, Hu YH, Wang JX, Yang WY, An ZX, Hu ZX, Lin J, Xiao JZ, Cao HB, Liu PA, Jiang XG, Jiang YY, Wang JP, Zheng H, Zhang H, Bennett PH, Howard BV. Effects of diet and exercise in preventing NIDDM in people with impaired glucose tolerance. The Da Qing IGT and Diabetes Study. Diabetes Care. 1997 Apr;20(4):537-44. doi: 10.2337/diacare.20.4.537. PMID: 9096977.

4. Lindström J, Ilanne-Parikka P, Peltonen M, Aunola S, Eriksson JG, Hemiö K, Hämäläinen H, Härkönen P, Keinänen-Kiukaanniemi S, Laakso M, Louheranta A, Mannelin M, Paturi M, Sundvall J, Valle TT, Uusitupa M, Tuomilehto J; Finnish Diabetes Prevention Study Group. Sustained reduction in the incidence of type 2 diabetes by lifestyle intervention: follow-up of the Finnish Diabetes Prevention Study. Lancet. 2006 Nov 11;368(9548):1673-9. doi: 10.1016/S0140-6736(06)69701-8. PMID: 17098085.

5. American Diabetes Association Professional Practice Committee. 3. Prevention or Delay of Diabetes and Associated Comorbidities: Standards of Care in Diabetes-2024. Diabetes Care. 2024 Jan 1;47(Suppl 1):S43-S51. doi: 10.2337/dc24-S003. PMID: 38078581; PMCID: PMC10725807.

6. Chien KL, Chen MF, Hsu HC, Su TC, Lee YT. Sports activity and risk of type 2 diabetes in Chinese. Diabetes Res Clin Pract. 2009 Jun;84(3):311-8. doi: 10.1016/j.diabres.2009.03.006. Epub 2009 Apr 9. PMID: 19359062.

7. Engberg S, Glümer C, Witte DR, Jørgensen T, Borch-Johnsen K. Differential relationship between physical activity and progression to diabetes by glucose tolerance status: the Inter99 Study. Diabetologia. 2010 Jan;53(1):70-8. doi: 10.1007/s00125-009-1587-1. Epub 2009 Nov 7. PMID: 19898830.

8. Magliano DJ, Barr EL, Zimmet PZ, Cameron AJ, Dunstan DW, Colagiuri S, Jolley D, Owen N, Phillips P, Tapp RJ, Welborn TA, Shaw JE. Glucose indices, health behaviors, and incidence of diabetes in Australia: the Australian Diabetes, Obesity and Lifestyle Study. Diabetes Care. 2008 Feb;31(2):267-72. doi: 10.2337/dc07-0912. Epub 2007 Nov 5. PMID: 17989310.

9. Fan S, Chen J, Huang J, Li Y, Zhao L, Liu X, Li J, Cao J, Yu L, Deng Y, Chen N, Guo D, Gu D. Physical activity level and incident type 2 diabetes among Chinese adults. Med Sci Sports Exerc. 2015 Apr;47(4):751-6. doi: 10.1249/MSS.0000000000000471. PMID: 25116084.

10. Sieverdes JC, Sui X, Lee DC, Church TS, McClain A, Hand GA, Blair SN. Physical activity, cardiorespiratory fitness and the incidence of type 2 diabetes in a prospective study of men. Br

J Sports Med. 2010 Mar;44(4):238-44. doi: 10.1136/bjsm.2009.062117. Epub 2009 Jul 26. PMID: 19656767.

11. Koloverou E, Panagiotakos DB, Pitsavos C, Chrysohoou C, Georgousopoulou EN, Pitaraki E, Metaxa V, Stefanadis C; ATTICA Study Group. 10-year incidence of diabetes and associated risk factors in Greece: the ATTICA study (2002-2012). Rev Diabet Stud. 2014 Summer;11(2):181-9. doi: 10.1900/RDS.2014.11.181. Epub 2014 Aug 10. PMID: 25396406; PMCID: PMC4310068.

12. Kanaley JA, Colberg SR, Corcoran MH, Malin SK, Rodriguez NR, Crespo CJ, Kirwan JP, Zierath JR. Exercise/Physical Activity in Individuals with Type 2 Diabetes: A Consensus Statement from the American College of Sports Medicine. Med Sci Sports Exerc. 2022 Feb 1;54(2):353-368. doi: 10.1249/MSS.0000000000002800. PMID: 35029593; PMCID: PMC8802999.

13. Moghetti P, Balducci S, Guidetti L, Mazzuca P, Rossi E, Schena F; Italian Society of Diabetology (SID),; Italian Association of Medical Diabetologists (AMD),; Italian Society of Motor and Sports Sciences (SISMES). Walking for subjects with type 2 diabetes: A systematic review and joint AMD/SID/SISMES evidence-based practical guideline. Nutr Metab Cardiovasc Dis. 2020 Oct 30;30(11):1882-1898. doi: 10.1016/j.numecd.2020.08.021. Epub 2020 Sep 2. PMID: 32998820.

14. Russell-Minda E, Jutai J, Speechley M, Bradley K, Chudyk A, Petrella R. Health technologies for monitoring and managing diabetes: a systematic review. J Diabetes Sci Technol. 2009 Nov 1;3(6):1460-71. doi: 10.1177/193229680900300628. PMID: 20144402; PMCID: PMC2787048.

15. Sigal RJ, Kenny GP, Boulé NG, Wells GA, Prud'homme D, Fortier M, Reid RD, Tulloch H, Coyle D, Phillips P, Jennings A, Jaffey J. Effects of aerobic training, resistance training, or both on glycemic control in type 2 diabetes: a randomized trial. Ann Intern Med. 2007 Sep 18;147(6):357-69. doi: 10.7326/0003-4819-147-6-200709180-00005. PMID: 17876019.

16. Mikus CR, Fairfax ST, Libla JL, Boyle LJ, Vianna LC, Oberlin DJ, Uptergrove GM, Deo SH, Kim A, Kanaley JA, Fadel PJ, Thyfault JP. Seven days of aerobic exercise training

improves conduit artery blood flow following glucose ingestion in patients with type 2 diabetes. J Appl Physiol (1985). 2011 Sep;111(3):657-64. doi: 10.1152/japplphysiol.00489.2011. Epub 2011 Jul 7. PMID: 21737826; PMCID: PMC3174788.

17. Verma S, Moiz JA, Anwer S, Alghadir AH, Hussain ME. A dose-response study of aerobic training for oxygen uptake, oxidative stress and cardiac autonomic function in type 2 diabetes mellitus: study protocol for a randomized controlled trial. Trials. 2018 May 24;19(1):289. doi: 10.1186/s13063-018-2671-y. PMID: 29793518; PMCID: PMC5968520.

18. Scheede-Bergdahl C, Benee Olsen D, Reving D, Boushel R, Dela F. Cardiovascular disease markers in type 2 diabetes: the effects of a moderate home-based exercise training programme. Diab Vasc Dis Res. 2009 Oct;6(4):291-6. doi: 10.1177/1479164109341689. Epub 2009 Aug 4. PMID: 20368225.

19. Amanat S, Ghahri S, Dianatinasab A, Fararouei M, Dianatinasab M. Exercise and Type 2 Diabetes. Adv Exp Med Biol. 2020;1228:91-105. doi: 10.1007/978-981-15-1792-1_6. PMID: 32342452.

20. Liu BB, Niu ZR, Jia XJ, Liu XL, Lu Q. A Correlational Study on Cardiopulmonary Endurance in Male Patients with New-Onset Type 2 Diabetes. Diabetes Metab Syndr Obes. 2022 May 2;15:1365-1373. doi: 10.2147/DMSO.S352798. PMID: 35528721; PMCID: PMC9075895.

21. Sun Y, Sun M, Zeng X, Xiang Je L, Su Guo Z. Effects of resistance training on cardiovascular risk factors in patients with type 2 diabetes mellitus: a systematic review and meta-analysis of randomized controlled trials. Acta Diabetol. 2025 Jan;62(1):11-24. doi: 10.1007/s00592-024-02413-y. Epub 2024 Dec 18. PMID: 39692776.