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MANAGEMENT OF ATHLETES WITH TYPE 2 DIABETES – THERAPEUTIC AND EDUCATIONAL STRATEGIES IN CLINICAL PRACTICE

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ABSTRACT

Purpose of the study: The aim of this literature review is to synthesize current knowledge on the clinical management of athletes with T2DM, focusing on pharmacological strategies, exercise recommendations, nutritional interventions, self-monitoring technologies, and interdisciplinary education to ensure safety and performance optimization.
Materials and methods: A literature review was conducted using databases such as PubMed, Google Scholar, and Scopus. Articles published between 2000 and 2024 were included if they addressed physical activity, training strategies, medication management, or patient education in individuals with T2DM—particularly in athletic or physically active populations. Key publications included guidelines from the American College of Sports Medicine (ACSM), American Diabetes Association (ADA), and peer-reviewed reviews from Diabetes Spectrum, MDPI Sports, and Medical Sciences Sports Exercise.
Results: The reviewed literature confirms that regular physical activity improves insulin sensitivity and glycemic control in patients with T2DM. However, exercise regimens must be personalized to avoid glycemic complications. Pharmacotherapy should consider the risk of hypoglycemia and dehydration, especially when using insulin or SGLT2 inhibitors. Nutritional strategies, such as pre-exercise carbohydrate intake and hydration protocols, are critical. Technological tools like continuous glucose monitoring (CGM) enhance real-time decision-making. Multidisciplinary education increases adherence and safety in diabetes care among athletes.
Conclusions: Athletes with T2DM can achieve excellent glycemic control and high levels of performance if therapeutic strategies are personalized, evidence-based, and supported by education and technology. Further clinical studies are needed to develop sport-specific recommendations for this unique population.

KEYWORDS

Policy Development, School Management, Indiscipline, Leadership, Challenges and Strategies

CITATION

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1. Introduction

Type 2 diabetes mellitus (T2DM) is one of the most prevalent chronic metabolic diseases globally and increasingly affects younger individuals, including those who maintain high levels of physical activity or compete in sports [1, 2]. Physical activity is not only safe for individuals with T2DM, but is also a key component of non-pharmacological therapy, improving insulin sensitivity, glucose control, and cardiovascular health [2, 3]. However, when diabetes coexists with regular or competitive training, the management of glycemia becomes more complex.

Athletes with T2DM face specific challenges, including an increased risk of exercise-induced hypoglycemia, dehydration (especially when taking sodium-glucose cotransporter-2 inhibitors), post-exercise hyperglycemia, and altered insulin requirements due to variable energy expenditure [4]. Moreover, intense physical activity can interact with antidiabetic pharmacotherapy in ways that require thoughtful, often individualized adjustments [3, 5].

As noted in the ACSM 2022 consensus statement, while general guidelines for diabetes management exist, they are rarely tailored to the physiological demands of athletes or those engaged in regular structured physical activity [2]. Inadequate glucose monitoring, insufficient knowledge about peri-exercise nutrition, and poor interdisciplinary coordination may increase the risk of acute complications or suboptimal performance outcomes [1, 4].

Given these complexities, an interdisciplinary and education-oriented approach is crucial. This includes not only individualized pharmacological strategies and structured exercise prescriptions, but also targeted nutrition, self-monitoring technologies such as continuous glucose monitoring (CGM), and athlete-centered health education. The purpose of this literature review is to synthesize the current evidence on managing physically active individuals and athletes with T2DM, with particular emphasis on safe and effective therapeutic and educational strategies.

2. Methodology

This literature review was conducted with the objective of identifying, analyzing, and synthesizing evidence-based strategies for managing athletes with type 2 diabetes mellitus (T2DM). A comprehensive search was performed in three major academic databases: PubMed, Google Scholar, and Scopus. The search included English-language publications from January 2000 to April 2024.

The inclusion criteria were as follows:

- Peer-reviewed articles, consensus statements, or guidelines discussing clinical management of individuals with T2DM engaged in regular physical activity;
- Studies addressing pharmacotherapy, exercise physiology, sports nutrition, diabetes education, or technological tools in the context of athletic populations;
- Articles involving both recreationally active individuals and professional athletes.

The following key search terms and Boolean combinations were used:

"type 2 diabetes" AND ("athletes" OR"sports" OR"exercise") AND ("management" OR"treatment" OR"monitoring" OR"pharmacotherapy" OR"nutrition" OR"technology").

Preference was given to high-quality evidence, including position statements from the American Diabetes Association (ADA), the American College of Sports Medicine (ACSM), systematic reviews, and meta-analyses. Grey literature and non-peer-reviewed sources were excluded.

Each article was screened for relevance, and the final selection included 68 publications. Data were extracted based on the following domains:

1. Physiological mechanisms of exercise in T2DM;
2. Pharmacological implications in physically active populations;
3. Exercise training protocols and safety guidelines;
4. Nutritional and hydration recommendations for athletes;
5. Role of diabetes technologies (CGM, wearables, apps);
6. Educational frameworks and interdisciplinary approaches.

This narrative synthesis aimed to integrate clinical recommendations with practical applications to provide a comprehensive framework for the management of athletes with T2DM.

3. Physiological Foundations of Exercise in Individuals with Type 2 Diabetes

Physical activity is one of the most effective non-pharmacological strategies in the management of type 2 diabetes mellitus (T2DM). Regular exercise enhances skeletal muscle glucose uptake independently of insulin, improves insulin sensitivity, and reduces insulin resistance in both muscle and adipose tissues [1]. It also positively affects lipid metabolism, reduces chronic inflammation, and improves endothelial function [5].

The mechanism by which exercise improves glucose metabolism involves the contraction-induced translocation of glucose transporter type 4 (GLUT-4) to the muscle cell membrane. This process occurs independently of insulin, which makes exercise particularly important in individuals with insulin resistance [3]. The metabolic effects of exercise may persist for 24 to 72 hours post-activity [1].

Different types and intensities of physical activity produce varying metabolic outcomes. Aerobic training is effective in lowering HbA1c levels and improving cardiorespiratory fitness, while resistance training helps maintain muscle mass and counteract sarcopenia, a condition that is often accelerated in T2DM [6]. High-intensity interval training (HIIT) is gaining recognition for inducing rapid and significant metabolic benefits in individuals with T2DM [7].

Even short bouts of moderate activity can substantially reduce postprandial glucose levels. Research has shown that engaging in just 15 minutes of post-meal exercise (e.g., brisk walking) leads to a greater reduction in postprandial glycemia than performing a single longer exercise session once daily [8].

The importance of interrupting sedentary behavior has also been highlighted. Dunstan et al. demonstrated that breaking up prolonged sitting every 30 minutes with light activity (e.g., walking, stretching) significantly improves postprandial glucose and insulin profiles in people with T2DM [9].

The effectiveness of physical training in T2DM depends on individual factors such as fitness level, disease progression, medication regimen, and comorbidities including cardiovascular or orthopedic limitations. Therefore, personalization of exercise load and integration with pharmacotherapy are essential to ensure both the safety and efficacy of physical activity as a therapeutic tool.

4. Pharmacotherapy in Sport – How to Adjust Treatment?

The pharmacological management of athletes with type 2 diabetes mellitus (T2DM) presents distinct challenges, particularly due to the interaction between glucose-lowering medications and varying levels of physical exertion. Exercise alters insulin sensitivity, glucose utilization, and hormonal responses, all of which can affect medication efficacy and safety [10].

Metformin, the most commonly prescribed first-line agent, is generally considered safe during exercise. It does not typically induce hypoglycemia and may enhance exercise capacity by improving insulin sensitivity and mitochondrial efficiency [5]. However, it may cause gastrointestinal side effects or lactic acidosis in rare cases of dehydration and extreme exertion—conditions that may be present in high-endurance sports [11].

SGLT2 inhibitors (e.g., empagliflozin, dapagliflozin) have gained popularity for their cardiovascular and renal benefits. However, their mechanism—promoting glycosuria—can lead to increased risk of dehydration, electrolyte imbalances, and, in rare cases, euglycemic ketoacidosis, particularly in athletes training in hot environments or engaging in prolonged endurance activities [12]. As such, adequate hydration and ketone monitoring are essential in physically active users of SGLT2 inhibitors.

GLP-1 receptor agonists (e.g., liraglutide, semaglutide) help with weight loss and glycemic control without increasing the risk of hypoglycemia. Yet, their appetite-suppressing effects can reduce caloric intake, potentially leading to energy deficits in athletes with high energy expenditures [13]. Their use requires dietary adjustment to ensure sufficient carbohydrate availability, especially in the peri-exercise period.

Insulin and sulfonylureas are associated with a significant risk of hypoglycemia, particularly during and after exercise. Physical activity enhances insulin sensitivity and glucose uptake by muscle cells, which may result in unanticipated glycemic declines. Therefore, athletes on insulin often require individualized dose reductions, carbohydrate supplementation before and during prolonged exercise, and frequent glucose monitoring using CGM systems [4, 14].

Timing of medication administration is another crucial consideration. For example, administering insulin too close to a training session may compound the risk of hypoglycemia. Athletes are often advised to perform moderate-intensity activity when insulin levels are lower or to adjust basal rates when using insulin pumps [15].

Importantly, all pharmacological interventions must be integrated with nutrition and training schedules, and adapted dynamically based on training intensity, frequency, and recovery cycles. Clinical decisions should involve close cooperation between endocrinologists, sports physicians, and the athlete to reduce risks and ensure both metabolic control and optimal performance.

5. Training Strategies and Practical Recommendations

Exercise plays a central role in the management of type 2 diabetes mellitus (T2DM), not only for glycemic control but also for improving cardiovascular fitness, reducing visceral fat, and enhancing overall metabolic health. For athletes with T2DM, structured and well-monitored training programs are essential to achieving both therapeutic and performance goals [1].

According to the joint position statement of the American College of Sports Medicine (ACSM) and the American Diabetes Association (ADA), individuals with T2DM should engage in at least 150 minutes of moderate to vigorous aerobic activity per week, distributed over at least 3 days, with no more than 2 consecutive days without exercise [2]. Aerobic training improves cardiorespiratory fitness and insulin sensitivity, and is effective in reducing HbA1c by 0.6–0.9% [16].

Resistance training is equally recommended, with a frequency of 2–3 nonconsecutive days per week, involving major muscle groups. Studies suggest that resistance training may improve glycemic control independently of aerobic exercise and is particularly beneficial for preserving muscle mass, which is often reduced in individuals with long-standing diabetes [17].

High-Intensity Interval Training (HIIT) has gained attention for its time-efficient metabolic benefits. HIIT sessions, involving short bursts of intense effort followed by active recovery, can lead to improvements in mitochondrial function, glucose uptake, and insulin action within a shorter total exercise duration [7]. However, HIIT should be cautiously introduced in deconditioned or cardiovascularly compromised individuals.

The timing of exercise is another critical consideration. Performing moderate-intensity aerobic exercise within 30–60 minutes after a meal can help reduce postprandial glucose excursions, as shown in crossover studies comparing postprandial vs. fasting training [8].

Athletes should also avoid prolonged sedentary periods, which have been independently associated with poorer glycemic profiles. Short activity breaks (e.g., standing, walking) every 30 minutes are recommended, particularly for individuals who spend extended periods seated due to work or travel [9].

Pre-exercise blood glucose monitoring is recommended to determine the appropriate action before starting a workout. The ADA suggests the following thresholds:

- <90 mg/dL: ingest fast-acting carbohydrates.
- 90–250 mg/dL: safe to proceed with caution.
- 250 mg/dL: test for ketones before exercising; if positive, delay activity [18].

Training programs should also account for diurnal glucose fluctuations, insulin or medication timing, and carbohydrate intake. For endurance events, individualized protocols for glucose supplementation, hydration, and pacing are critical to prevent hypoglycemia and optimize performance.

Finally, progression and periodization—adjusting the intensity, duration, and type of exercise over time—are key to long-term adherence, safety, and physiological adaptation in diabetic athletes.

6. Nutrition and Hydration in Athletes with Type 2 Diabetes

Optimal nutrition and hydration are fundamental pillars in the performance and safety of athletes with type 2 diabetes mellitus (T2DM). Macronutrient composition, timing of intake, and fluid balance must be closely aligned with medication schedules and exercise demands to maintain glycemic stability and prevent hypo- or hyperglycemia [19].

Carbohydrate Management and Glycemic Control

Carbohydrates are the primary energy source during moderate to high-intensity exercise. For individuals with T2DM, consuming low glycemic index (GI) meals 1–3 hours before exercise can help maintain euglycemia throughout training sessions [20]. During prolonged efforts (>60 minutes), 15–30 g of fast-absorbing carbohydrates per hour may be required, especially for those on insulin or insulin secretagogues [4].

Post-exercise nutrition is equally important for restoring muscle glycogen and stabilizing blood glucose. A combination of carbohydrates (1.0–1.2 g/kg body weight) and protein (0.3–0.4 g/kg) within 30–60 minutes after training is recommended to enhance recovery and facilitate metabolic adaptation [21].

Athletes using GLP-1 receptor agonists may require adjusted meal frequency or energy density due to appetite suppression, which could otherwise lead to under-fueling and increased risk of hypoglycemia or fatigue [13].

Hydration and Electrolyte Balance

Maintaining adequate hydration is critical, especially in hot or humid environments. SGLT2 inhibitors pose a unique challenge by promoting osmotic diuresis, increasing the risk of dehydration and electrolyte loss [12]. This may impair performance and heighten the danger of heat illness or hypotension during endurance activities.

Athletes with T2DM should follow individualized hydration plans, often requiring 500–1000 mL of fluid per hour of exercise, depending on sweat rate, climate, and body size. Including sodium in rehydration beverages (e.g., 300–600 mg/L) can help prevent hyponatremia and support fluid retention [22].

Supplementation Considerations

While there is limited evidence on supplements specific to diabetic athletes, caffeine, creatine, and branched-chain amino acids (BCAAs) may be considered under professional guidance. Importantly, supplements should not interfere with glycemic control or interact adversely with prescribed medications [23].

Practical Recommendations

- Monitor pre- and post-exercise glucose to guide carbohydrate intake.
- Never begin high-intensity or prolonged activity in a fasted state without assessing glucose.
- Adjust nutrition for training phase: energy needs may vary significantly between off-season, competition, and recovery periods.
- Use continuous glucose monitoring (CGM) to better align meals with glycemic responses.
- Consult with a sports dietitian familiar with diabetes management.

7. Technologies Supporting Self-Management

Effective self-management of type 2 diabetes mellitus (T2DM) in athletes requires more than traditional glucose monitoring and symptom tracking. Advances in digital health technologies, especially continuous glucose monitoring (CGM), wearable fitness trackers, and mobile health (mHealth) apps, have created new opportunities to support real-time decision-making and optimize performance while maintaining metabolic control [24].

Continuous Glucose Monitoring (CGM)

CGM systems provide real-time glucose readings and trends, which are particularly useful during exercise when glucose levels can fluctuate unpredictably. These systems reduce the risk of both hypoglycemia and hyperglycemia by allowing athletes to make immediate adjustments to carbohydrate intake, exercise intensity, or insulin dosage [10]. Studies have shown that CGM use is associated with improved time-in-range (TIR) metrics and fewer glycemic excursions in physically active individuals with diabetes [25].

Athletes benefit from trend arrows and alarm settings that warn of impending hypo/hyperglycemia, allowing preventive action. Integration with smartwatches and smart insulin pens further facilitates user-friendly, hands-free monitoring during training and competition.

Wearable Fitness Devices and Smart Sensors

Modern wearable devices such as heart rate monitors, GPS-enabled watches, and accelerometers help athletes monitor exercise duration, intensity, and energy expenditure. When synchronized with glucose data from CGMs, these tools provide a comprehensive picture of how different types of training affect glycemic control [14].

Some platforms now offer algorithm-based glucose prediction models, which combine training load, dietary intake, medication, and prior glucose trends to forecast potential glycemic responses during future sessions. This predictive capability is valuable for pre-emptively managing risks and optimizing fueling strategies [26].

Mobile Health Applications

mHealth apps offer features such as training logs, food diaries, insulin and medication trackers, and data visualization dashboards. These platforms allow both patients and healthcare teams to analyze patterns, identify risks, and make data-driven decisions regarding training schedules and therapeutic adjustments [43].

Athletes can also benefit from telemedicine and cloud-based data sharing with endocrinologists, coaches, and dietitians, fostering interdisciplinary coordination and personalized feedback.

Practical Implications

- Use CGM during all training sessions longer than 30 minutes.
- Set alarms for glucose thresholds relevant to your sport's duration and intensity.
- Sync wearable data with glucose metrics to assess how training impacts metabolic status.
- Share data with health professionals for collaborative adjustment of treatment plans.

8. Education and Interdisciplinary Collaboration

Effective management of type 2 diabetes mellitus (T2DM) in athletes is not solely the responsibility of the patient or physician. It requires an integrated, interdisciplinary approach involving healthcare providers, coaches, dietitians, diabetes educators, and the athletes themselves [28]. Education is a cornerstone of diabetes care, and in the athletic context, it must be tailored to the physiological, psychological, and performance-related demands of sport.

Patient-Centered Diabetes Education

Educational programs for athletes with T2DM should go beyond the standard curriculum. In addition to covering blood glucose monitoring, nutrition, and medication, they must include sport-specific modules such as:

- Adjusting insulin or oral medications based on training intensity,
- Recognizing and treating exercise-induced hypoglycemia and delayed-onset hypoglycemia,
- Planning carbohydrate intake before, during, and after exercise,
- Managing hydration and electrolyte loss in varying environmental conditions [10].

Athletes must also be trained in interpreting CGM data, understanding glucose trend arrows, and applying this information during real-time decision-making in training or competition [25].

Role of the Multidisciplinary Team

The complexity of diabetes management in physically active individuals necessitates the involvement of multiple professionals:

- Endocrinologists or sports physicians provide overall clinical supervision and medication management.
- Dietitians specialize in sport-specific nutrition periodization, fueling, and recovery strategies.
- Exercise physiologists or athletic trainers help individualize training intensity and structure based on glucose response and physical capacity.
- Psychologists may assist with motivational strategies, body image issues, or performance anxiety that may affect disease control [29].

This team-based approach ensures that no aspect of diabetes care is addressed in isolation and that the athlete receives unified guidance rather than conflicting advice from different disciplines.

Communication and Shared Decision-Making

Regular communication between the athlete and their care team is essential. This may include shared access to CGM data, training logs, nutrition plans, and treatment protocols, often via telemedicine or app-based platforms. Shared decision-making empowers the athlete, improves adherence, and promotes a sense of autonomy and ownership of health outcomes [27].

Collaborative care models have been shown to improve glycemic outcomes, reduce acute complications, and enhance quality of life, particularly when integrated early in the athlete's diagnosis and training journey [30].

9. Conclusions and Recommendations

The management of type 2 diabetes mellitus (T2DM) in athletes presents unique clinical, nutritional, and physiological challenges. However, when properly addressed through an individualized, evidence-based, and interdisciplinary approach, these challenges can be transformed into opportunities for improved glycemic control, enhanced performance, and long-term health promotion [1].

Exercise remains a cornerstone of diabetes management and, in athletes, it is not only therapeutic but also performance-driven. Personalized training plans—combining aerobic, resistance, and interval components—have been shown to optimize metabolic outcomes and reduce HbA1c levels without increasing the risk of hypoglycemia when appropriately monitored [7].

Pharmacotherapy in the athletic context requires special consideration of exercise timing, insulin sensitivity, hydration status, and energy demands. Adjustments to insulin or oral medications, particularly SGLT2 inhibitors and GLP-1 receptor agonists, must be integrated with the athlete's training load and nutritional intake [4].

Nutrition and hydration strategies must address not only metabolic control but also performance and recovery. Pre-exercise fueling, intra-exercise carbohydrate provision, post-exercise recovery nutrition, and fluid-electrolyte balance are all critical components of a successful plan [19].

Technology—especially continuous glucose monitoring (CGM), smart sensors, and digital platforms—has revolutionized diabetes self-management. These tools allow athletes and clinicians to anticipate, detect, and respond to glycemic fluctuations in real-time, enhancing both safety and performance outcomes [25].

Ultimately, education and interdisciplinary collaboration serve as the foundation of effective T2DM care in athletes. Structured, sport-specific diabetes education and close communication between physicians, dietitians, trainers, and the athlete ensure coherence, compliance, and empowerment [28].

Key Recommendations:

1. Implement individualized training programs with regular glucose monitoring.
2. Adjust pharmacological regimens based on activity intensity, timing, and glycemic response.
3. Prioritize carbohydrate periodization and hydration planning in sport-specific contexts.
4. Utilize CGM and mobile health technologies to support self-management and real-time decisions.
5. Foster an interdisciplinary care model with consistent communication among all team members.

With these integrated strategies, athletes with T2DM can thrive both metabolically and athletically, turning a chronic disease into a well-managed condition that coexists with high-level physical activity.

Disclosure

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Software – Katarzyna Urbańska, Izabela Szczap
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