

# ATHLETES WITH INSULIN-DEPENDENT DIABETES

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## INTRODUCTION

### *Elite sport magnifies physiology*

Small metabolic changes that might go unnoticed in daily life can influence reaction time, decision-making, technical execution, and recovery in elite sport. For athletes with insulin-dependent diabetes, glucose regulation therefore becomes a performance variable<sup>1,2</sup>. Insulin-dependent diabetes most commonly includes Type 1 diabetes mellitus (T1DM) and, less frequently, insulin-treated Type 2 diabetes mellitus (T2DM). In both conditions, athletes rely on exogenous insulin to maintain metabolic stability, making the interaction between insulin dosing, carbohydrate intake, and exercise a key component of training and competition planning<sup>2,3</sup>.

Historically, insulin-dependent diabetes was often considered incompatible with elite sport due to concerns about hypoglycemia, glucose variability, and acute metabolic emergencies during competition<sup>1</sup>. Advances in diabetes care, improved understanding of exercise physiology, and modern glucose-monitoring technologies have enabled athletes with insulin-dependent diabetes to compete successfully at the highest levels of sport. These achievements demonstrate that insulin therapy does not necessarily limit performance when metabolic management is carefully structured<sup>1,2</sup>.

Nevertheless, managing insulin-dependent diabetes in elite sport remains

complex. Exercise alters glucose metabolism through changes in skeletal muscle uptake, hepatic glucose production, and hormonal counter-regulation. In individuals without diabetes, insulin secretion falls rapidly at the onset of exercise, allowing hepatic glucose production to match muscle demand. In insulin-treated athletes, circulating insulin levels reflect prior dosing and cannot physiologically decline during exercise, creating a mismatch between insulin availability and metabolic requirements<sup>1</sup>. This increases the risk of hypoglycemia during moderate aerobic activity and may contribute to transient hyperglycemia during high-intensity exercise. Metabolic control is further influenced by travel, sleep disruption, psychological stress, dehydration, and variable nutrition<sup>1,2</sup>.

Modern technologies have improved glucose management in sport. Continuous glucose monitoring (CGM) provides real-time glucose trends during training and competition, while automated insulin delivery systems support dynamic insulin adjustment during physical activity<sup>4,5</sup>. However, technology alone does not eliminate metabolic variability.

This article reviews exercise physiology in athletes with insulin-dependent diabetes and outlines practical strategies for glucose management in elite sport. Examples from Olympic swimming, rowing, professional football, motorsport, and basketball

illustrate how athletes and medical teams translate physiological knowledge into structured approaches that support metabolic safety and performance.

## TYPES OF INSULIN-DEPENDENT DIABETES IN ATHLETES

Insulin-dependent diabetes refers to conditions requiring exogenous insulin therapy to maintain metabolic stability. In athletes, this most commonly includes Type 1 diabetes mellitus (T1DM) and, less frequently, insulin-treated Type 2 diabetes mellitus (T2DM), although monogenic or secondary diabetes may occasionally require insulin therapy. These distinctions are relevant in sports medicine because exercise responses are strongly influenced by insulin exposure and glucose regulation<sup>2,3</sup>. Athletes competing under anti-doping regulations should ensure that Therapeutic Use Exemption (TUE) requirements for insulin use are met<sup>6</sup> (Table 1).

### *Type 1 diabetes in athletes*

T1DM results from autoimmune destruction of pancreatic  $\beta$ -cells, causing absolute insulin deficiency and lifelong dependence on exogenous insulin. The condition is often diagnosed during childhood or adolescence, when many athletes begin structured training. Exercise presents specific metabolic challenges. In individuals without diabetes, endogenous insulin secretion declines

**TABLE 1**

Diabetes type	Pathophysiology	Typical treatment	Relevance for sport
Type 1 diabetes	Autoimmune destruction of pancreatic $\beta$ -cells	Lifelong insulin therapy	High risk of exercise-induced hypoglycemia
Insulin-treated Type 2 diabetes	Insulin resistance with progressive $\beta$ -cell dysfunction	Lifestyle therapy $\pm$ oral agents, sometimes insulin	Exercise improves insulin sensitivity, but insulin therapy introduces hypoglycemia risk
Monogenic diabetes (MODY)	Genetic defects affecting insulin secretion	Varies by subtype; occasionally, insulin	Rare but possible in young athletes
Secondary diabetes	Pancreatic disease, medication use, or endocrine disorders	Depends on the underlying cause; sometimes insulin	Management varies widely

**Table 1:** Main forms of insulin-dependent diabetes encountered in athletes.

rapidly at the onset of exercise, allowing hepatic glucose production to match skeletal muscle uptake. In insulin-treated athletes, circulating insulin reflects prior dosing and cannot physiologically decline during exercise<sup>2</sup>, creating a mismatch between insulin availability and metabolic demand, increasing the risk of hypoglycemia. Conversely, high-intensity exercise may stimulate catecholamine release, increase hepatic glucose production, and cause transient hyperglycaemia<sup>1</sup>. Effective management, therefore, requires careful coordination of insulin dosing, carbohydrate intake, and training intensity.

**Insulin-treated type 2 diabetes in athletes**

Although less common in elite sport, insulin-treated T2DM may occur in older athletes or power-sport competitors. Type 2 diabetes mellitus (T2DM) is characterized by insulin resistance with progressive impairment of insulin secretion. While most individuals are initially managed with lifestyle modification and oral medications, some require insulin therapy. In insulin-treated athletes, exercise-related metabolic challenges resemble those seen in T1DM, as exogenous insulin may remain elevated during activity, increasing the risk of hypoglycemia if insulin dosing and carbohydrate intake are not adjusted<sup>2</sup>.

**Other insulin-dependent forms of diabetes**

Rare forms of diabetes may also require insulin therapy in athletes. These include monogenic diabetes (e.g., MODY) and secondary diabetes resulting from pancreatic disease, medications, or



**Image 1:** Gary Hall Jr. celebrating after winning the gold medal in the men's 50 m freestyle at the 2004 Olympic Games in Athens.

endocrine disorders. Although uncommon, recognizing these conditions is important because management and exercise considerations may differ from those of T1DM or T2DM<sup>3</sup>.

**EXERCISE PHYSIOLOGY**

**Gary Hall Jr.: Acute Adaptation at Olympic Level**

When Olympic swimmer Gary Hall Jr. was diagnosed with T1DM mid-career, the main concern was whether repeated high-intensity training could coexist safely with insulin therapy. In individuals without diabetes, endogenous insulin secretion decreases rapidly at the onset of exercise,

allowing hepatic glucose production to match skeletal muscle glucose uptake. In insulin-treated athletes, circulating insulin levels reflect prior dosing and cannot physiologically decline at the onset of exercise, potentially disrupting the balance between glucose production and utilization<sup>1</sup>.

During moderate aerobic exercise:

- Skeletal muscle glucose uptake increases via insulin-independent GLUT-4 translocation.
- Whole-body insulin sensitivity rises during and after exercise.
- If circulating insulin remains elevated, glucose disposal may exceed hepatic

production, increasing hypoglycemia risk<sup>2</sup>.

During high-intensity or sprint efforts:

- Epinephrine and norepinephrine increase rapidly.
- Hepatic glycogenolysis and gluconeogenesis increase.
- Transient hyperglycemia may occur due to catecholamine-mediated glucose release<sup>1</sup>.

During the post-exercise period:

- Insulin sensitivity remains elevated for several hours.
- Glycogen repletion increases skeletal muscle glucose uptake.
- Delayed hypoglycemia, particularly overnight after evening training, may occur<sup>1</sup>.

These responses are intensity-dependent and physiologically predictable<sup>1</sup>. Hall's return to Olympic success after diagnosis and winning five additional Olympic medals, including two gold medals, illustrates how structured insulin adjustment, carbohydrate planning, and continuous monitoring can support safe elite performance despite the metabolic challenges of T1DM.

### ENDURANCE LOAD

#### *Kris Freeman: Sustained aerobic demand*

Olympic cross-country skier Kris Freeman, who competed with T1DM, illustrates the metabolic challenges faced by insulin-treated athletes during prolonged endurance exercise. During prolonged aerobic exercise, skeletal muscle relies increasingly on glycogen and circulating glucose as energy substrates. At the same time, insulin sensitivity progressively increases, enhancing glucose uptake into muscle tissue. In athletes requiring insulin therapy, this adaptation may lead to sustained declines in blood glucose if insulin dosing and carbohydrate intake are not appropriately adjusted<sup>1</sup>.

Long-duration sessions, therefore, require careful metabolic planning. Without adjustments to basal insulin, glucose levels may decline progressively and be difficult to reverse, particularly when athletes perform multiple endurance sessions in a single day<sup>1</sup>.

Endurance-specific strategies include:

- Keeping pre-session glucose slightly above resting range ( $\approx 7\text{--}10$  mmol/L)
- Temporary basal insulin reduction before prolonged exercise
- Carbohydrate supplementation during extended activity



**Image 2:** Kris Freeman competing in the men's 4x10km Cross Country Skiing Relay during the 2011 FIS World Cup in Sjusjoen, Norway.



**Image 3:** Nacho Fernández, a professional footballer for Real Madrid and the Spanish national team, lives with type 1 diabetes.

- Avoidance of large corrective insulin doses immediately after exercise

Based on current consensus guidelines, the objective is to achieve metabolic stability. Stable glycaemia supports efficient substrate utilization, reduces fatigue, and allows athletes to maintain consistent training loads<sup>1</sup>.

### INTERMITTENT TEAM SPORTS

#### *Nacho Fernández: Variability in professional football*

Nacho Fernández, a professional footballer, lives with type 1 diabetes. Professional

football combines a substantial aerobic workload with repeated maximal sprints, accelerations, and rapid changes of direction. This intermittent physiological pattern creates alternating hypoglycemic and hyperglycemic pressures within a single match. Players may perform hundreds of short high-intensity efforts interspersed with lower-intensity running or walking recovery phases<sup>7</sup>.

Studies examining intermittent high-intensity exercise in individuals with T1DM show that glycemic responses can be managed similarly to those of non-diabetic

**TABLE 2**

<i>Exercise context</i>	<i>Practical carbohydrate strategy</i>	<i>Rationale</i>
<i>Pre-training (≤60 min exercise)</i>	<i>10–20 g carbohydrate if glucose &lt;7 mmol/L</i>	<i>Reduces early exercise hypoglycemia risk</i>
<i>Prolonged exercise (&gt;60 min)</i>	<i>30–60 g carbohydrate per hour</i>	<i>Maintains glucose availability and prevents decline</i>
<i>High-intensity intermittent sport</i>	<i>Small carbohydrate intake during breaks when glucose levels are falling</i>	<i>Supports glucose stability during variable workloads</i>
<i>Post-exercise recovery</i>	<i>Carbohydrate with cautious insulin adjustment</i>	<i>Supports glycogen restoration while limiting delayed hypoglycemia</i>
<i>Evening training sessions</i>	<i>Additional carbohydrates before sleep may be considered</i>	<i>Reduces delayed nocturnal hypoglycemia risk</i>

**Table 2:** Practical carbohydrate strategies for athletes with diabetes during exercise.

athletes when structured management strategies are applied. However, rapid changes in metabolic demand mean that glucose levels may fluctuate if insulin dosing or carbohydrate availability are not aligned with match intensity<sup>7,8</sup>. Typical match-day physiology in insulin-treated athletes may include:

- Early glucose decline during sustained running phases
- Transient glucose elevation during sprint efforts due to catecholamine release
- Stress-related hyperglycemia during high-pressure competition

Structured match-day management may include:

- Keeping pre-match glucose target of approximately 7–10 mmol/L
- Modest reduction of rapid-acting insulin before kick-off
- Immediate access to fast-acting carbohydrates on the sideline
- Half-time review of CGM trends
- Conservative post-match insulin correction

Evening matches require vigilance because increased insulin sensitivity after exercise may predispose athletes to delayed nocturnal hypoglycemia<sup>1,9</sup>. With appropriate preparation, monitoring, and insulin adjustment strategies, athletes can compete safely in high-intensity team sports.

**NUTRITION PERIODIZATION AND CARBOHYDRATE STRATEGY**

In athletes with insulin-dependent diabetes, carbohydrate periodization becomes a central component of metabolic control.

The interaction between insulin dosing, carbohydrate intake, and exercise intensity requires careful planning. Therefore, effective nutritional management relies on coordination among the athlete, team physician, endocrinologist, and performance nutritionist. Practical carbohydrate strategies for common training and competition scenarios are summarized in Table 2<sup>1,2</sup>.

**TECHNOLOGY IN ELITE SPORT**

**Team Novo Nordisk: Data-driven stability**  
Professional cycling team Team Novo Nordisk is composed entirely of athletes

living with diabetes, mostly insulin-dependent, and has demonstrated how modern glucose-monitoring technologies can be integrated into elite sport environments.

Continuous glucose monitoring (CGM) systems are routinely used by the team to track glucose trends during training and racing, allowing athletes and clinicians to adjust carbohydrate intake and insulin dosing in real time, and have fundamentally changed diabetes management in sport. Real-time glucose data allows clinicians and athletes to observe metabolic trends during exercise<sup>9</sup>. Time-in-range (70–180 mg/dL)



**Image 4:** Professional cycling team Team Novo Nordisk, consisting entirely of athletes living with diabetes.



**Image 5:** IndyCar driver Charlie Kimball competing at the Honda Indy Grand Prix of Alabama.

has emerged as a clinically meaningful indicator of glycemic variability<sup>4</sup>. Unlike HbA<sub>1c</sub>, which reflects average glucose levels over several months, time-in-range provides insight into day-to-day fluctuations that directly affect training and performance.

CGM systems allow detection of downward glucose trends before symptomatic hypoglycemia develops. This early-warning capability enables athletes to take preventive action through timely adjustments in carbohydrate intake or insulin dosing<sup>9</sup>. Recent studies demonstrate that automated insulin delivery systems may improve glycemic control around exercise in individuals with type 1 diabetes<sup>5</sup>. However, sensor lag during rapid glucose changes remains a limitation during high-intensity activity<sup>10</sup>.

Technology considerations in sport include:

- Secure device fixation in training and competition environments
- Alarm threshold adjustment during competition
- Integration of glucose data into medical and performance reviews

Technology enhances precision but does not eliminate physiological variability. Effective use still requires athlete education, clinical oversight, and careful interpretation of glucose trends<sup>9,10</sup>.

### HIGH ADRENALINE ENVIRONMENTS

*Charlie Kimball: Glucose response during competitive stress*

Professional racing driver Charlie Kimball, who competes in IndyCar while living with

T1DM, highlights the metabolic challenges faced by athletes in high-adrenaline sports. Acute psychological stress during major competitions, penalty shootouts, or decisive moments in races triggers catecholamine release, increasing hepatic glucose

production and potentially causing transient hyperglycemia during competition<sup>12</sup>. Elevated glucose levels in this context often reflect a physiological stress response rather than insufficient insulin dosing. Insulin correction should therefore be conservative and guided by glucose trends and ketone assessment. Overcorrection may precipitate delayed hypoglycemia once stress hormone levels decline<sup>12</sup>. Recognizing stress-related glucose responses helps clinicians and athletes avoid unnecessary intervention.

### CONTACT SPORTS AND EMERGENCY PREPAREDNESS

*Chris Dudley: Safety in collision environments*

Former NBA player Chris Dudley, who competed with type 1 diabetes, highlights the safety considerations required in contact sports. Hypoglycemia during competition may mimic concussion, fatigue, or neurological impairment. Symptoms such as confusion, impaired coordination, and slowed reaction time can resemble head injury presentations, making rapid glucose assessment essential



**Image 6:** Former NBA player Chris Dudley, who played 16 seasons in the National Basketball Association while living with type 1 diabetes.

**TABLE 3**

<i>Conscious athlete</i>	<ul style="list-style-type: none"> <li>• Administer 15–20 g rapid-acting carbohydrate</li> <li>• Reassess glucose after 10–15 minutes</li> <li>• Repeat if glucose remains below target</li> </ul>
<i>Unconscious athlete</i>	<ul style="list-style-type: none"> <li>• Administer intramuscular glucagon</li> </ul>

**Table 3:** Sideline management of hypoglycemia in athletes with insulin-dependent diabetes.

in sideline evaluation<sup>1,2</sup>. Athletes in collision sports, therefore, require clearly defined emergency protocols, including integration of glucose assessment into sideline neurological evaluation and staff trained to recognize early signs of hypoglycaemia<sup>1</sup>. A practical sideline approach to hypoglycemia management is summarized in Table 3.

**PSYCHOLOGICAL AND TEAM DYNAMICS**

Living with insulin-dependent diabetes in elite sport involves psychological and physiological challenges. Some athletes may worry about being perceived as medically fragile, which can lead to under-reporting symptoms or delaying glucose checks<sup>1,2</sup>. Education and clear communication between the athlete, coaching staff, and medical team are therefore essential. Confidence in self-management also influences performance. Athletes who understand their glucose patterns and use glucose-monitoring tools confidently typically show better adherence and reduced anxiety<sup>1,2</sup>. Integrating diabetes management into routine athlete care helps reduce stigma, improve safety, and support performance.

**TRAVEL, TOURNAMENTS, AND SCHEDULE CONGESTION**

Travel represents a metabolic stressor for athletes with diabetes. Time-zone shifts, disrupted sleep, and irregular meal timing can alter insulin requirements and increase glycemic variability<sup>1,2</sup>. These challenges are amplified during tournaments, where repeated matches, limited recovery time, and disrupted routines may increase the risk of hypoglycemia.

Travel preparation should include:

- Gradual adjustment of insulin timing when crossing time zones
- Backup insulin, glucose monitoring equipment, and CGM supplies
- Cold-chain verification for temperature-sensitive medications

- A written medical summary including medications, insulin doses, and an emergency plan

Congested schedules may increase the risk of delayed hypoglycemia, particularly after evening matches. Recovery protocols should therefore include glucose monitoring in addition to hydration and musculoskeletal recovery. For elite teams, travel planning should be integrated into the overall diabetes management strategy.

**LONG-TERM RISKS AND SCREENINGS**

Being fit does not eliminate the long-term risks of chronic hyperglycemia. Even in elite athletes, poor metabolic control may increase the risk of diabetes-related complications<sup>2,3</sup>. Routine medical follow-up should therefore include screening for conditions such as retinopathy, nephropathy, and neuropathy, and cardiovascular risk assessment should be included in long-term medical follow-up, particularly in athletes with long-standing diabetes or additional metabolic risk factors<sup>2</sup>. As many diabetes-related complications may be asymptomatic initially, routine athlete health monitoring should include regular review of glycemic trends, blood pressure, renal markers, and eye health.

**RETURN TO PLAY AND RISK STRATIFICATION**

Diabetes alone is not a contraindication to elite sport. However, temporary restriction or closer monitoring may be required following acute metabolic events or periods of unstable glycemic control<sup>1,2</sup>.

Situations that may warrant temporary restrictions include:

- Recurrent severe hypoglycemia
- Impaired hypoglycemia awareness
- Diabetic ketoacidosis
- Acute illness affecting glycemic stability

Return-to-play decisions should be guided by objective evidence of metabolic stability rather than symptom resolution alone. Typical criteria include:

- Demonstrated glucose stability, ideally supported by CGM metrics
- Restoration of hypoglycemia awareness
- Athlete confidence in self-management
- Multidisciplinary medical clearance

The specific demands of the sport should also be considered. Contact sports may pose a greater immediate risk when hypoglycemia awareness is impaired, while endurance events may increase the risk of delayed hypoglycemia during recovery<sup>1</sup>. Athletes should return to training and competition once glycemic control is stable and predictable within the demands of their sport.

**PRACTICAL FRAMEWORK FOR ELITE TEAMS**

Effective diabetes management in elite sport requires structured systems rather than ad-hoc decision-making. The following framework summarizes key components for practical implementation within elite team environments. The framework is organized across four practical domains: long-term

**TABLE 4**

<i>Component</i>	<i>Practical actions</i>	<i>Clinical rationale</i>
<i>Glycemic monitoring</i>	<i>Quarterly HbA1c review</i>	<i>Long-term glycemic control</i>
<i>CGM assessment</i>	<i>Review of CGM time-in-range metrics</i>	<i>Detect glycemic variability</i>
<i>Complication screening</i>	<i>Annual retinal, renal, and neurological assessment</i>	<i>Early detection of complications</i>
<i>Specialist collaboration</i>	<i>Regular endocrinology consultation</i>	<i>Individualized insulin management strategies</i>

**Table 4:** Long-term medical optimization in athletes with insulin-treated diabetes.

TABLE 5

Phase	Key actions	Clinical rationale
Pre-match	Target glucose approximately 7–10 mmol/L	Reduce early hypoglycemia risk
Insulin adjustment	Planned reduction of rapid-acting insulin	Match insulin to the anticipated workload
In-game monitoring	Half-time CGM review	Detect rapid metabolic changes
Carbohydrate access	Rapid-acting carbohydrate available pitch-side	Immediate correction if glucose falls
Post-match	Overnight monitoring after evening fixtures	Detect delayed nocturnal hypoglycemia

Table 5: Match-day glucose management.

TABLE 6

Requirement	Practical implementation
Hypoglycemia treatment	Rapid-acting carbohydrate available pitch-side
Severe hypoglycemia management	Accessible glucagon and within expiry
Metabolic assessment	Ketone testing capability when hyperglycemia occurs
Staff preparedness	Regular emergency scenario rehearsal
Documentation	Written emergency protocols

Table 6: Emergency preparedness in team environments.

TABLE 7


Travel consideration	Recommended preparation
Time-zone travel	Planned adjustment of insulin timing when crossing time zones
Equipment security	Carry backup insulin and CGM supplies
Medication storage	Verify cold-chain requirements
Medical documentation	Written treatment summary for travel

Table 7: Travel and tournament preparation.


medical optimization (Table 4), match-day glucose management (Table 5), emergency preparedness (Table 6), and travel and tournament preparation (Table 7).

## SUMMARY

Athletes with insulin-dependent diabetes can compete successfully at the highest levels of sport when glucose management is integrated into routine performance planning rather than treated as a reactive medical task. Exercise produces predictable glycemic responses that vary with intensity and insulin exposure, requiring anticipatory planning and coordinated management by the athlete, medical team, nutrition specialists, and coaching staff. The goal is not perfect glucose control, but stable variability that supports both safety and performance.



**In professional sports, the goal for athletes with insulin-dependent diabetes is not perfect glucose control, but stable variability that supports both safety and performance.**



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