CYCLING AND DIABETES

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Working with a diabetic cyclist can at first be intimidating simply owing to ones unfamiliarity with the disease. However, a few basic guidelines will help both coaches and athletes effectively manage this situation. The primary focus of this article is to provide coaches with a general overview of the needs of the diabetic cyclist. With this in mind, one should understand that an important key to effectively coaching these athletes is the ability to work cooperatively with the athlete, the athlete's family and the athlete's physician. As this is an overview of the subject, coaches working with diabetic cyclists, and the cyclists themselves, should consult the references in the back for a more complete understanding of the topic. Excellent reviews in book form are also available to outline the needs of the diabetic athlete across several sporting disciplines.[1]

When discussing diabetes and cycling, it is important for coaches to fully understand a few basic definitions. Like most endurance sports, cycling shares several commonalities with regard to the use of energy systems. In general, cycling stresses the aerobic energy system in order to meet energy demand through the use of carbohydrates (CHO), fat and protein. The intensity and duration of an activity will also affect fuel use. Therefore, a clarity of terminology will better assist coaches in understanding the need of a the diabetic cyclist.

Definitions:

- Carbohydrate (CHO): Any of a group of sugars or starches that serves as a major energy source in the diet. In essence, CHO is what the athletes eats and can be either complex or simple sugars that provide energy.
- Glucose: The circulating form of CHO *in the blood* and a major energy source of the body.
- Insulin: A hormone secreted by the pancreas that regulates the metabolism of CHO and fats, and has the primary function of *converting glucose to glycogen*, and decreasing blood glucose levels. Insulin works by driving the glucose from the blood into the cells of the body, whether they are fat cells (adipocytes), muscle cells, or other tissue.

- Glycogen: The storage form of CHO in animals, occurring primarily in the muscle and liver.
- Hypoglycemia: An abnormally low level of glucose in the blood. Signs and symptoms of hypoglycemia are presented in Table 1.
- Hyperglycemia: An abnormally high concentration of glucose in the blood.

Table 1. Signs and Symptoms of Hypoglycemia

Buzzing in the ears	Inability to do basic math	Restlessness
Cold or clammy skin	Insomnia	Shakiness
Dizziness or lightheadedness	Irritability	Slurred speech
Double or blurred vision	Mental confusion	Sweating
Elevated pulse rate	Nausea	Tingling of hands or tongue
Fatigue	Nervousness	Tiredness
Hand tremors	Nightmares	Visual spots
Headache	Poor physical coordination	Weakness

Adopted from Colberg S. The Diabetic Athlete. Champaign: Human Kinetics; 2001.

Sequentially, CHO is ingested in the diet, is absorbed in the small intestine, circulates in the blood as glucose, is regulated by the hormone insulin and is stored in the muscle and liver as glycogen. As it pertains to the diabetic cyclist, the following terms are also essential for the coach to understand. Diabetes refers to a metabolic disease where the athlete either produces an insufficient amount of insulin, or none at all, resulting in abnormal metabolism of CHO, fats, and proteins. Diabetes mellitus is the most common type and takes two forms.

Type I Diabetes: This form of diabetes typically, but not always, appears in childhood or adolescence and is characterized by increased glucose levels in the blood and urine, excessive thirst, frequent urination, acidosis, and wasting. It is also called *insulin-dependent diabetes* because the pancreas has ceased to produce insulin. For the young athlete, this can carry an additional stigma, as a host of psychological implications may be present in a young athlete who develops diabetes, where the young athlete must come to grips with the idea of vulnerability during a seemingly invulnerable period of their life.

Type II Diabetes: This form of diabetes typically appears first in adulthood and is worsened by obesity and an inactive lifestyle. This disease often has no symptoms, is usually diagnosed by tests that indicate glucose intolerance, and is initially treated with changes in diet and an exercise regimen. It is also called *non-insulin-dependent diabetes*, *type 2 diabetes*; however, in some instances, insulin may be required to help regulate glucose. Should insulin become necessary, the guidelines for each is similar. Usually, however, the problem is not from the lack of insulin, but the insensitivity to insulin.

Metabolic Control

Important to the success of the diabetic cyclist is maintaining metabolic control relative to exercise. Metabolic control is defined as insuring adequate levels of glucose in the blood that are largely affected by

both exercise in general *and* insulin administration by the athlete. To this latter point, the timing of insulin use or ingestion of CHO prior to exercise will be a major determinant of the cyclists success. Therefore, a few key points will be helpful for the cyclist in maintaining their metabolic control.

- In general, the more intense the activity is, the more one relies on muscle glycogen.
- Less intense activities such as touring, baseline training and recovery rides use a greater amount of circulating blood fats, though maintaining adequate glucose levels in the blood is essential as muscle glycogen does become depleted after ~90-120 minutes.
- Moderate to intense activities have a greater reliance on muscle glycogen and blood glucose and use them both at a faster rate.
- Very intense efforts use glycogen sources almost exclusively.

With all of these scenarios, you can delay fatigue during prolonged bouts of endurance exercise by ingesting CHO during the activity. For the diabetic cyclist, insulin and blood sugar levels before exercise will affect blood sugar responses during exercise as insulin and exercise both lower glucose. Therefore, if a diabetic athlete injects too much insulin prior to exercise, they will become hypoglycemic much faster owing to the combined effects of insulin and exercise. Fortunately, this scenario can be easily avoided with a due diligence by the athlete and their familiarity with how each influences their own blood glucose levels. How rapidly an athlete uses CHO during exercise may require that they initially measure their blood sugar (glucose) response to exercise. When first diagnosed, this may take more frequently monitoring as the athlete becomes "tuned in" to how their body uses CHO during exercise. Specifically, insulin dosages are typically reduced prior to exercise. If they are too high, CHO can be ingested immediately to offset this problem.

Important to diabetes management is the knowledge that physical activity and muscle contraction has an insulin-like effect and increases one's risk for hypoglycemia both during and after the activity. Fortunately, through the combined work of the American Diabetes Association and adaptations by the American College of Sports Medicine, clinical recommendations exist for exercising people with diabetes.[2] These and other guidelines focus on the metabolic control of the athlete before exercise, blood glucose monitoring before and after exercise, and food intake.[3, 4]

1. Metabolic Control Before Exercise:

- Avoid exercising if fasting glucose levels are >250 mg/dl (14 mM) and ketosis is present.
- Use caution if glucose levels are >300 mg/dl (17 mM) and no ketosis is present. Ketosis is a pathological increase in the production of ketone bodies that result from the metabolism of fat and muscle protein for energy and are due to inadequate or inefficient metabolism.
- Ingest CHO if glucose levels are <100 mg/dl (5.5 mM).

2. Blood Glucose Monitoring Before and After Exercise**:**

- Identify when changes in insulin or food intake are necessary.
- Learn the glycemic response to different exercise conditions.

3. Food Intake:

- Consume CHO as needed to avoid hypoglycemia.
- Keep CHO-based foods readily available during and after exercise

Metabolic Control Before Exercise

Metabolic control before exercise aims at reducing conditions that may exacerbate conditions of hyperglycemia and potential hypoglycemia. The first guideline states that people should avoid exercising if fasting glucose levels are more than 250 mg/dl (14 mM) and ketosis is present and use caution if glucose levels are more than 300 mg/dl (17 mM) with no ketosis present. When this occurs, it is likely that the athlete has just consumed a meal. Fortunately, exercise itself reduces blood sugars and exercise can be combined with a small dose of short acting insulin to bring insulin under control. A common practice under these conditions is to administer 1 to 2 units of rapid-acting insulin before exercising, wait 10 to 15 minutes, and then begin normal exercise (Table 2). Though the combination of insulin and exercise will likely bring blood sugars down to normal by the end of the activity, a potential risk does exist if insulin needs are overestimated, thus ending up in hypoglycemia during the activity. Therefore, it is better to *underestimate* insulin dosage than to experience a large drop in blood glucose and be forced to contend with rapid-onset hypoglycemia.

Table 2: Guidelines for percentage reduction in insulin administration before exercise based on time and intensity of exercise.

	Percentage Decrease		
Duration (Minutes)	**Low Intensity**	**Moderate Intensity**	**High Intensity**
15	none	5-10	0-15
30	none	10-20	10-30
45	5-15	15-30	20-45
60	10-20	20-40	30-60
90	15-30	30-55	45-75
120	20-40	40-70	60-90
180	30-60	60-90	75-100

Modified from Colberg S. The Diabetic Athlete. Champaign: Human Kinetics; 2001.

When ketones are a result of illness or infection (versus insulin deficiency) it is probably wise to have athletes not exercise until they recover from illness or infection and their blood sugars are under better control. When ketosis is present due to severe insulin deficiency, exercise can lead to the development of diabetic ketoacidosis, a potentially serious and life threatening condition that usually requires hospitalization. When blood glucose levels are less than 100 mg/dl (5.5 mM) prior to exercise, the ingestion of CHO is important to restore glucose to a more acceptable range.

Factors that may influence how much CHO to ingest will include how much exercise time is planned or remains, how much insulin they took and how long before exercise the insulin was injected. Environmental conditions may also apply to temperature extremes. Hot and humid conditions may cause glucose to fall lower than normal. Depending on the time of day and the activity duration and intensity, a good goal would be to eat enough to increase blood sugars to a certain level (e.g., 150 to 180 mg/dL) before the activity to prevent hypoglycemia during exercise. However, not all diabetics are created equal, so some alterations in these schema may be necessary. Athletes using and insulin pump may modify their basal insulin delivery rates by reducing their insulin instead of eating extra CHO.

Blood Glucose Monitoring

When changes in insulin or food intake are necessary, glucose monitoring is essential in establishing a pattern for making changes as the optimal technique for each athlete may need to be learned through trial and error. Minimally, athletes should check their blood glucose before and after exercise. Once on track, the athlete will become comfortable with an established routine. However, when new challenges are undertaken, more frequent monitoring may become necessary. Much of this will be trial and error as the athlete deals with the multitude of variables that affect blood sugar. Initially, this will entail learning individual responses to all of the factors by checking blood sugar levels before, during, and after exercise.

Food Intake

A key component to which types and amounts of CHO consumed for various types of exercise will depend on the type of CHO ingested and the insulin dosage necessary to manage it. For example, the consumption of rapidly absorbed CHO to prevent and treat hypoglycemia would include regular soda, many sport drinks, hard candy, glucose tablets, dried fruits, skim milk, bread, and CHO bars. These types of foods are typically classed as high glycemic index foods as they spend a minimal amount of time in the athletes gut and appear rapidly in the blood following ingestion.

Two strategies exist to assist the athlete with the amount of CHO they eat. One strategy is to manipulate CHO intake according to glycemic index. A second strategy is to time doses of insulin according

to starting blood sugar levels or adjusting insulin dose instead of consuming extra food (Table 3). However, this latter choice is probably best facilitated in those using an insulin pump where pump users can readily lower or stop insulin use during an activity. Regardless of strategy, a key to maintaining consistent glucose levels will be to have a consistent supply of CHO based foods readily available before, during and after exercise.

Injection Sites and Timing of Exercise

Previous guidelines advised diabetics to avoid exercising for one hour those muscles where short-acting insulin would be injected. Though most individuals inject insulin into a subcutaneous fat layer, athletes with little fat may want to avoid that area prior to exercising. Research has actually shown that exercise can increase insulin absorption rates from any subcutaneous depot, so the choice of insulin injection site may not affect the potential increase in circulating insulin levels that result from exercising.

EXERCISE PRECAUTIONS

People with diabetes who are in good metabolic control and do not have serious diabetic complications can engage in any type of exercise, whether a professional sport or a recreational physical activity. However, some valid concerns exist that are more relevant to people with diabetes, such as the potential for hypoglycemia during and following the activity, hyperglycemia, and dehydration. Actual problems may arise when a person has diabetes-related complications.

Prevention of Hypoglycemia or Hyperglycemia Following Exercise:

Hypoglycemia during or after exercise is preventable with appropriate changes in insulin and food intake. Consuming CHO after exercise allows for the more efficient repletion of muscle glycogen stores and may actually help prevent post-exercise late-onset hypoglycemia that can occur up to 24 hours following exercise. To optimize repletion of glycogen following exercise, it is best to consume CHO within 30 minutes after exercise. During this time, uptake of glucose into muscle to reform glycogen can be accomplished with a minimal amount of insulin as the insulin sensitivity of the muscle is heightened. Furthermore, with more effective glycogen repletion early on, there is less of a risk for late-onset hypoglycemia. A low CHO intake after exercise or CHO intake without sufficient insulin may compromise or delay the normal course of glycogen repletion after exhaustive exercise.

Prevention of Dehydration

People with diabetes may be more prone to dehydration than people without diabetes, especially when higher blood sugar levels cause more water loss in the urine or in people with autonomic neuropathy.

Autonomic neuropathy is a chronic complication of diabetes affecting the autonomic nervous system that may cause an abnormal cardiac function (heart rate changes), dizziness upon standing, or impaired movement of food through the digestive system. Dehydration may not be immediately evident because thirst centers are not activated until 1% percent or more loss of body water has occurred.

As with all athletes, the diabetic cyclist should be adequately hydrated before exercise, and you should drink fluids early and frequently to compensate for sweat losses during exercise. Plain water is the recommended beverage for fluid replacement before, during, and after short-term moderate exercise (up to 60 minutes). Diabetic exercisers may need water and extra CHO for exercise lasting longer than 60 to 90 minutes.

Exercise With Complications for Type I Diabetics

In general, the complications associated with type I diabetes are microvascular or macrovascular in origin. Microvascular complications include neuropathies (periphery and autonomic), retinopathy, and nephropathy.[5] Macrovascular concerns may involve heart or peripheral vascular disease and hypertension and peripheral nervous system loss. If your client has these complications, preventive strategies should be thoroughly discussed with your client's physician. However, a few basic precautions can be easily monitored with your help, as long as athletes are willing to be accountable for their own care.

- One of the primary "target areas" for complications are the feet. Thus, polyester, synthetic blend (such as Coolmax®) or blend (cottonpolyester) socks to prevent blisters and keep feet dry should be used to minimize trauma resulting from exercise. Proper footwear is also essential for the prevention of these problems. Shoes should have a wide toe box and avoid heel/toe height differentials as this may push the toes into an uncomfortable position that compromises circulation.
- *Autonomic neuropathy.* People with autonomic system nerve damage are at high risk for developing complications during exercise, including silent myocardial infarction and sudden death when the heart becomes unresponsive to autonomic nerve impulses. Hypotension (low blood pressure) can occur more easily with rapid changes in body position in these people. With autonomic neuropathy, people can also have difficulty maintaining normal body temperatures and levels of hydration and should use caution in hot or cold environments. With orthostatic hypotension, dizziness or fainting with changes in body position are much more possible and rapid changes are best avoided.Autonomic neuropathy may also increase the likelihood of insulin-induced hypotension that tends to be worse in the morning. A conservative approach to exercise is best for these people. Exercise intensity is best monitored using the Rating of Perceived Exertion (RPE) scale as autonomic neuropathy can blunt maximal and submaximal heart rates.

- With *gastroparesis*, any foods taken to treat or prevent hypoglycemia during exercise may have a delayed or uneven absorption, resulting in first low and later high blood sugar levels during exercise and recovery. Because this metabolic response to exercise can vary widely, blood sugar monitoring is essential for effective and safe exercise for these people.
- *Proliferative retinopathy*. This is the process of the formation of weak and/or abnormal blood vessels in the back of the eyes that can break, tear, or bleed into the fluid filling the eye. Though exercise has not been shown to increase the proliferative process, certain precautions may be important depending on the level of retinopathy as activities that dramatically increase blood pressure should be avoided or modified including heavy weightlifting, powerlifting, or heavy Valsalva maneuvers (breath holding and bearing down).
- *Nephropathy.* In the early stages of kidney disease, there is some evidence that exercise can increase rates of albumin excretion in the urine. Severe or excessive exercise is usually not recommended for people with overt nephropathy, usually because their exercise capacity is limited. Light to moderate exercise is fine for these people and patients on dialysis can often exercise on a stationary cycle during the treatments with no ill effects. Exercise for these people is only contraindicated if hematocrit, calcium, or phosphorus blood levels are unstable due to the need for dialysis. Diabetics who have undergone renal transplantation may safely exercise six to eight weeks after the transplant when they are stable and free of rejection.
- *Heart disease.* Exercise decreases cardiac risk, but people with diabetes are still at higher risk than the general population for cardiovascular complications. Exercise has positive effects on insulin sensitivity and lipid metabolism. It can improve the lipoprotein profile, reduce blood pressure, and improve the fitness of the cardiovascular system as a whole. Exercise-induced ischemia (decreased blood flow to the heart) may be asymptomatic in people with diabetes when any degree of autonomic neuropathy is present.
- Additional risk factors for cardiovascular disease, microvascular disease (retinopathy or nephropathy including microalbuminaria), peripheral vascular disease, or autonomic neuropathy. In general, those with known cardiovascular problems should initially exercise in a medically supervised environment where monitoring is available and progress slowly beginning with low-intensity aerobic exercise. An exercise stress test should be performed periodically to test for the ischemic threshold so that exercise can be done at a lower level to minimize risks for cardiovascular events or arrhythmias. Heavy weight training is contraindicated due to the excessive strain it places on the heart and vasculature.
- *Hypertension.* Exercise training helps lower chronic high blood pressure. Moderate-intensity aerobic exercise is generally recommended for those people with elevations in blood pressure. Weight

training can also be done as long as the focus is on low-weight, high-repetition training that would cause less dramatic increases in blood pressure than heavy weightlifting. High-intensity (near maximal effort), isometric exercises, and the Valsalva maneuver should be avoided due to their ability to cause extreme increases in systolic and diastolic blood pressures.

Guidelines for Type 2 Diabetes

In type 2 diabetes, blood sugars can be controlled with diet and exercise alone, at least initially. Oral hypoglycemic agents and other diabetic medications are used when blood sugars begin to no longer be controlled with this regimen. Weight loss often improves blood sugar control as well. Exercise is a vital component in the prevention and management of type II diabetes when used in conjunction with diet, oral medication, and insulin therapies. If insulin is used for type 2 diabetes treatment, the guidelines given for type 1 apply.

The potential benefits of exercise for people with diabetes are enormous. To make exercise safe and effective for all, some general guidelines apply as well as some safety precautions. Many of these guidelines will need to be fine tuned as the athlete becomes more familiar with their own metabolism, limitations and knowledge of the disease.

About the author

Conrad Earnest, PhD, FACSM is the Director of Nutrition and Human Performance Research at the world famous Cooper Institute. His areas of research interest include nutritional ergogenic aids for sport performance and health, as well as factors influencing cycling performance. He currently works collaboratively with the iBanesto.com professional cycling team of Spain, is a fellow of the American College of Sports Medicine, and holds an Elite Coaching License from USA Cycling.

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Table 3: Recommendations for increasing carbohydrate before cycling based on blood sugar levels. All values represent *grams* of CHO.

		Blood sugar before exericise (mg/dL)			
Duration (Minutes)	**Intensity**	**<100**	**100-150**	**150-200**	**>200**
15	Low	0-5	none	none	none
	Moderate	5-10	0-10	0-5	none
	High	0-15	0-15	0-10	0-5
30	Low	5-10	0-10	none	none
	Moderate	10-25	10-20	5-15	0-10
	High	15-35	15-30	10-25	10-25
45	Low	5-15	5-10	0-5	none
	Moderate	15-35	10-30	5-20	0-10
	High	20-40	20-35	15-30	10-25
60	Low	10-15	10-15	5-10	0-5
	Moderate	20-50	15-40	10-30	5-15
	High	30-45	25-40	20-35	15-30
90	Low	15-20	10-20	5-15	0-10
	Moderate	0-60	25-50	20-35	10-20
	High	45-70	40-60	30-50	25-40
120	Low	15-30	15-25	10-20	5-15
	Moderate	40-80	35-70	30-50	15-30
	High	60-90	50-80	40-70	30-60
180	Low	30-45	25-40	20-30	10-20
	Moderate	60-120	50-100	40-80	25-45
	High	90-135	75-100	60-105	45-90

Modified from Colberg S. The Diabetic Athlete. Champaign: Human Kinetics; 2001.

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