Managing the Adolescent Athlete with Type 1 Diabetes Mellitus

Martin B. Draznin, MD

KEYWORDS

• Diabetes • Hypoglycemia • Hyperglycemia
• Adolescent • Athlete • Management

Providing safe and successful diabetes management assistance and advice to an adolescent athlete is a challenging task. It should also be a very rewarding task. To make accurate and useful recommendations one must master required elements: key knowledge about the athlete, the sport, the team and coach, the effects of exercise on diabetes and of diabetes on the ability to exercise, and the resources that can be accessed or employed to support an adolescent athlete who has type 1 diabetes. This article points to sources of information that can be successfully employed by the physician and athlete, and illustrates the use of some of them. The reader is encouraged to access tables and charts of data from work that has been done by research centers; this article is designed to help the reader make effective use of that information. The physician who undertakes the management of an adolescent with diabetes should access and use the International Society for Pediatric and Adolescent Diabetes 2009 *Clinical practice consensus guidelines* (http://www.ispad.org)[1] as a framework within which each athlete's management should be individualized based on his or her unique needs and circumstances.

PREPARTICIPATION CONSIDERATIONS

The physician must get to know the athlete; aptitudes, attitudes, intelligence, intensity, and family variables may all come into play. It is also often necessary to ''get into the head'' of the athlete regarding rituals, such as lucky things done or worn, to bring success. It is useful to explore the youth's ideas about performance at different levels of blood glucose, attitudes about knowing blood glucose by how it feels versus testing with a blood glucose meter, and fears about hypoglycemia. Also, explore how and

Pediatric Endocrine Subspecialty Clinics, Michigan State University Kalamazoo Center for Medical Studies, Michigan State University College of Human Medicine, 1000 Oakland Drive, Kalamazoo, MI 49008, USA
E-mail address: draznin@kcms.msu.edu

Pediatr Clin N Am 57 (2010) 829–837
doi:10.1016/j.pcl.2010.02.003 **pediatric.theclinics.com**
0031-3955/10/$ – see front matter

when concentration or visualization is used to prepare for sports so that diabetes-related actions will be incorporated and reliably executed without the athlete feeling loss of ability to excel.

The next thing to know is the sport: the balance between aerobic and anaerobic exercise, how intensively the sport is played and practiced, the duration of the exercise, the risks of injury, and especially the risk for injury to self or others if distracted by hypoglycemia. These are only a few of the critical aspects of a sport. It is vital to understand the nature and intensity of the training and of the competition—and how those two aspects may affect the athlete in different ways—so that appropriate adjustments in management can be made.

One must know the teammates and the coach: their attitudes, abilities, methods, and willingness to assist in the diabetes management are critical to a successful plan for participation. This is included but not always emphasized in the scientific literature regarding athletes with diabetes. Where appropriate, and with permission of the athlete and family, direct contact with teammates and the coach may be very helpful.

Knowledge of the physiology of exercise, at least at a basic level, is needed in order to understand the changes in fuel use, blood sugar levels, or insulin effects.

Knowledge, both of the effects of diabetes complications on participation in the particular sport and of the risks of sports participation in the presence of complications is important.

Knowledge of the diabetes management resources that benefit the athlete is another key area. Necessary information includes: how insulin works, what delivery devices are used for the insulin, what monitoring devices are in use, which insulin administration protocols are being followed, what sources of carbohydrate are available to support exercise, or to treat hypoglycemia, who has access and knowledge of the use of emergency glucagon kits for severe episodes of hypoglycemia, and how to access support groups and information that the athlete can employ for improvement of the process.

Follow-up of the recommendations to assess how well they have worked during the sports season, is not an element of knowledge to be gained, but it is the only sure way to allow for necessary adjustments.

THE ATHLETE

Getting to know the athlete before the start of the season will give the best chance for making a plan that has the participation and buy-in of the adolescent. The preparticipation interview regarding diabetes management for sports is ideally part of routine diabetes care, and it certainly may be done in the primary care setting by a knowledgeable physician.

Important factors include the type of diabetes management currently employed by the athlete; types of insulin and delivery devices; and how well the management is working, eg, glycohemoglobin level, number of severe episodes of hypoglycemia, or any ill effects on growth from the diabetes. To make useful adjustments in insulin dosing or carbohydrate intake, the athlete or his or her support team must be willing and able to make the kinds of calculations needed. These include carbohydrate counting, knowing the insulin-to-carbohydrate ratio for food coverage and the insulin dose for excessively high blood glucose, and tracking the blood glucose trends before, during, and after training and competition by frequent monitoring of capillary blood glucose levels. We use the slogan ‘‘just test it.’’

When the athlete is a highly intelligent and curious individual, reinvention of management ideas may occur between office visits. One basketball player in our clinic

discovered that the effect of the short-acting insulin analog given soon before eating did not persist long enough to adequately cover his evening meal—he had previously needed to wait 45 minutes after using regular insulin before eating to get good effect. He hit upon using 50% of each type of insulin so that he had no waiting and regained excellent control. This kind of discovery humbles and gladdens diabetes doctors!

THE FAMILY AND THE ATHLETIC STAFF

The family plays a vital, if not always front-seat role, in diabetes care of an adolescent. Involve family members in the planning because they, along with the adolescent, are the primary contacts for educating the coaching staff about the needs of the adolescent to safely participate. Discussion about the appropriate blood glucose-level strategy is a central part of the preparticipation interview. Ideas that a high blood sugar at the start of exercise will lead to a better performance are probably not correct.[2] Using out-of-range starting glucose levels to protect against hypoglycemia does not seem successful in youth seen in this clinic. It is also important that the athlete test real-time capillary blood glucose levels during the exercise, counting on how it feels to recognize hypoglycemia is not always accurate and can be dangerous.

Defining roles for the athlete, family and coaching staff should be decided early in the season: who will have the fast-acting source of carbohydrate, whether there will be a glucagon kit and who will know how and when to give it, and where the testing supplies will be kept and when they may be used. Validation of worries about hypoglycemia and developing a plan with the athlete to help avoid it will build the trust needed to keep the athlete on track with blood sugars. The fear of hypoglycemia is a major impediment to improving blood glucose control. To not recognize that, and thus miss the opportunity to help minimize risks while maintaining good control of levels, is to ask for hyperglycemia as the pre-exercise condition.

THE SPORT

Different sports have their own effects on diabetes management. Moderate aerobic exercise is associated with hypoglycemia while bursts of anaerobic exercise may actually raise blood glucose.[3] The very helpful tables of carbohydrate use and ''exercise exchanges'' (minutes of exercise requiring 15 g of carbohydrate based on size and type of exercise) from the work of Riddell and Bar-or[4] can be found in the *Handbook of exercise in diabetes*, and their table of exercise exchanges can be found online in the International Society for Pediatric and Adolescent Diabetes (ISPAD) Clinical Practice Consensus Guideline for 2009 entitled *Exercise in children and adolescents with diabetes*.[5] Recognize that these, like all other numeric calculations for diabetes care, are starting points, they are only approximations of the truth, which is to be found by testing levels when the individual athlete is exercising. It is only by monitoring the outcomes that they can be validated and adjustments made to fit an individual.

There is also a need to be certain that information regarding the effect of training and practice, as differentiated from the effect of competition, be kept in mind. Many sports have much longer practice times than game participation times in order to promote endurance, yet the athletes often ''leave it all on the field'' during a game. The role of exercise duration and the role of exercise intensity need to be assessed. One question to ask is: How much is practice biased toward aerobics and conditioning and how much is a game like repetitive sprints?

In addition, depending on the sport, some of the most intensely pleasurable experiences are related to level of skill, such as a perfectly executed golf or tennis swing, a weightless-feeling basketball during a well-executed hook shot, or the sensation of

the ''sweet spot'' of the bat crushing the baseball with no shock to the hands. Clear-headed concentration is needed both to attain those skills and to enjoy them. ''Practice does not make perfect, perfect practice makes perfect'' is not just a slogan, it is the core of motor memory training and well-controlled levels of blood glucose will facilitate this process. Risk of injury during episodes of hypoglycemia is a serious matter in sports with rapid movements; sports in which collisions routinely occur; and in sports such as climbing, scuba diving, and swimming, in which diminished attention could lead to a catastrophic event. The primary safety concern is avoidance of unrecognized hypoglycemia.

Additionally, in activities where an injured or incapacitated partner might risk the health or life of the other partner, such as technical climbing, mountaineering, or scuba diving, there is also a moral imperative to minimize the risk of hypoglycemia. Gradual acclimatization to these sports should be recommended with much attention to the effect on blood glucose so that appropriate adjustments in management can be made. For example, it did not seem necessary to stop mountaineers with diabetes from climbing Mt Everest or Denali because they were capable climbers. Helping them to keep their diabetes safe was the needed intervention.[6] World-class athletes with diabetes have earned Olympic Gold Medals and been professional athletes for decades, even with the older more cumbersome diabetes management systems.[7] One vignette regarding practice and competition comes to mind from our clinic. A very competitive sprint swimmer with diabetes had miserable experiences and slowing times when swimming 500-yard races in practice. We even went so far as to test him for the overtraining phenomenon, which is a transient hypopituitary state that is the equivalent of the oligomenorrhea seen in some intensely training female endurance athletes. In spite of his complaints about the 500-yard races, his times in the 50-yard races were quite good; in fact, he obtained a high ranking in the state and he felt well when sprinting. He elected to tolerate the ''misery'' of endurance training as he was in no danger and he had a successful year.

TEAMMATES AND COACH

Teammates and coaches are usually managed by the athlete and family. When an athlete is valuable to a team, or when the coach is a parent of the athlete with diabetes, the clinic may be able to interact directly, with permission of the athlete and family of course. One young woman distance runner's coach was willing and able to attend diabetes clinic with her on a few occasions. After discussions with the diabetes-care team about how exercise may affect diabetes, she and the athlete together made the necessary adjustments to carbohydrate-intake schedules for successful, safe training and a successful season. It is equally important that all athletes with diabetes, even those less ''valuable'' to the team, be given every opportunity to participate that a teammate without diabetes would have. Remedial education by consultation with coaches may be indicated when the athlete is restricted by the prejudices or fears of others rather than by ability and effort.

EXERCISE PHYSIOLOGY

Numerous comprehensive articles and chapters related to diabetes and exercise have described the effects of exercise on fuel metabolism in persons with diabetes.[8–10]

The initiation of exercise elicits hormonal signals to release fuels. Glucose from liver glycogen; use of the glucose stored as glycogen in muscle, leading to generation of lactic acid that is then cycled through the liver to make new glucose; mobilization of

fatty acids, especially in fit endurance athletes; and gluconeogenesis from amino acids all may be set in motion.

The nondiabetic individual has near instantaneous insulin modulation to keep blood glucose levels within normal range during exercise; the athlete with diabetes relies on the release of insulin from subcutaneous depots, the increased exposure of insulin to receptors on muscle cells as blood flow increases, and some element of non–insulin-induced muscle uptake. The lack of a closed-loop system can result in hyperglycemia during the initial exercise, hypoglycemia later on as the level of injected insulin can not respond to a falling level of glucose, and excess generation of ketone bodies if available insulin is insufficient to modulate use of fat for energy. In spite of the lack of automatic and easy regulation, young athletes can often manage very well.

More recently detailed attention has been paid to the effects of having diabetes to slightly lower exercise capacity.[11] However, the take-home message from observing athletes in sports activity is that, whereas there are real differences of laboratory-tested performance between athletes who do and do not have diabetes; these differences do not seem to be reflected in the everyday world outside the laboratories. In other words, athletes who have diabetes may be as capable, and feel nearly as well while exercising as if they did not have it, at least until or unless they have complications of diabetes that may limit them in other ways.

IMPLICATIONS OF DIABETES COMPLICATIONS

Hypoglycemia and Ketoacidosis

The main acute complications are hypoglycemia and ketoacidosis. Ketoacidosis may be engendered by exercise, whereas ketoacidosis that exists before exercise usually leaves sufferers feeling too ill to play. Antecedent hypoglycemia has long been known to blunt counterregulatory response to subsequent hypoglycemia. It also blunts the response to exercise.[12] This information should be shared with the athlete, so that much more attention is paid to checking blood glucose levels after there has been a significant low.

Ocular Changes

Long-term complications are not seen as early in the course of the diabetes during the current era of striving for tight metabolic control. It is still necessary to screen for them as they can have profound effects on participation in sports. Ocular changes have become less frequent during childhood and adolescence owing to improved care plans and patient success in adhering to them. It is rare to see proliferative retinopathy in youth. Nonproliferative retinopathy can be a risk factor during sudden impacts or breath-holding during extreme exertion such as weight lifting, which can lead to rapid increase of blood pressure and rupture of microaneurysms.

Neuropathy

Peripheral neuropathy is likewise uncommon in children and adolescents with diabetes. The risks would be due to clumsiness from lack of proper sensation in the feet. Autonomic neuropathy leading to loss of cardiac responsiveness, that is, low beat-to-beat variability of the heart rate while at rest and slow adaptation to change in posture or activity, may lead to syncope. This is not seen much in adolescents.

Other

Poorly controlled hypertension can be a problem, sapping performance and being exacerbated by exertion. Renal compromise would mostly be manifested early on

by hypertension. Advanced renal disease is much less common with modern care of adolescents. Whereas associated autoimmune conditions are not complications of diabetes, in that they cannot be prevented by excellent diabetes care, hypothyroidism impairs performance, celiac disease could impair ability to be very active, and the uncommon occurrence of Addison's disease or of pernicious anemia in youth with diabetes would also make exercise difficult or hazardous.

DIABETES MANAGEMENT FOR THE ATHLETE

Modern diabetes management systems have made it possible to prolong healthy life in children and youth with diabetes who can and will master their use.[1,13] They are also much more flexible, allowing for safe participation in sports and exercise. It must be acknowledged that there were superb athletes who had nothing more flexible for diabetes regulation than the difficult, cumbersome, and inflexible care systems from early years and they succeeded anyway.

Insulin and Insulin Regimens

Modern insulin has identical amino acid sequence and activity compared with the human molecule. The amino acid sequences can also be deliberately altered to allow specific action profiles to enhance effectiveness. Its concentration in the vial pen or pump is high and uniform so that the discomfort of injections is minimal. There are only miniscule amounts of impurities and their action from day to day is reproducible. Even the need to suspend insoluble intermediate acting forms and to mix insulin from two vials in one syringe has nearly disappeared in pediatric diabetes practices in United States.

Many, if not most, children and adolescents with diabetes now use what are called basal-bolus insulin regimens using a long-acting analog by injection or short-acting insulin delivered by an insulin pump at continuous low levels to provide basal, or foundation, insulin to prevent ketogenesis and provide needed insulin during fasting. Injections of short acting insulin or pump bolus infusions are used to cover the carbohydrate part of meals, and to correct high levels of blood glucose. Insulin is available in vials to be injected by syringe, in prefilled pen devices used with disposable needles for quick and precise dosing, and via insulin pumps. There are possibly as many protocols to setup and adjust these systems as there are diabetes clinics!

What makes intensive management of diabetes work for patients is the ability to quickly, and with some precision, measure blood glucose levels at appropriate times with the monitoring devices needing only tiny drops of blood. Fortunately, the discomfort level has become much less with the modern devices. There are also continuous monitoring devices that record or report the level of glucose in subcutaneous tissue fluids to assist in understanding how well insulin-dosing matches the needs of the patient. It is not clear that these can be used during strenuous exercise due to mechanical considerations or loss of the signal, but, if they could, they would provide helpful data.

Carbohydrates for Hypoglycemia

Rapidly absorbed sources of carbohydrate to treat hypoglycemia include 4 g or 5 g glucose tablets. "Take 4 or 3 for routine hypoglycemia, retest in 15 minutes, and repeat until under control" is the "rule of 15" used to treat low blood glucose with less risk of an overshoot. Athletes often take these tablets by the handful to keep up. Other sources of glucose include hard candies, cake icing in tubes, glucose gels, sport drinks (although it takes 250 mL of a 6% drink to provide 15 g), and soft drinks (a few ounces is enough but the carbonation may be problematic).

Modulation of Insulin Delivery for Exercise

How could or should the insulin delivery be altered to accommodate exercise? In growing children and adolescents, especially during the adolescent growth spurt, reducing insulin should be reserved for times when increased oral intake of carbohydrates cannot maintain safe blood glucose levels. Pediatricians tend to be in favor of increasing pre-exercise food intake to prevent hypoglycemia in exercising children and adolescents with diabetes; reducing insulin is a second step. To start, insulin in the basal-bolus systems is usually divided between 50% for basal needs and 50% for carbohydrate coverage. It is then adjusted based on blood glucose readings. It may be useful to lower the basal insulin.

One may also decrease pre-exercise meal coverage with short-acting insulin, but must be aware that the increased availability of fuels in the circulation may lead to hyperglycemia and ketogenesis if the meal insulin is lowered too much. Also, vexatious is what to do when postexercise blood glucose is high. Should one fully correct the high level as if no exercise had occurred, or perhaps only a half correction is enough? With an insulin pump, one can change one or more of the basal rates, have an entirely different set of rates and ratios for exercise versus nonexercise days, or even disconnect the pump for up to two hours to avoid hypoglycemia during exercise.

A useful insulin dose-alteration scheme devised by an internist with diabetes[14] employs a lowered basal pump rate for exercise intensive days; he uses 25% but that amount can be adjusted for the individual athlete. The key difference of his system from just having a different basal rate is that insulin glargine is then given to replace the ''missing'' 75% of the basal dose when the pump rate is lowered. This prevents the blood glucose from rising too much during nonexercise intervals. It also leaves insulin in the circulation when the pump is disconnected for more than two hours, but it is at a lower level than the usual pump delivery would yield, which prevents hypoglycemia during exercise. This has worked well for athletes from our clinic who have used it. For many types of sports, insulin pumps should be removed to avoid damage to the pump, or because the pump is not waterproof, this scheme works well. In the athletes using an older scheme of insulin dosing with an intermediate insulin, the pre-exercise dose may need to be reduced and short-acting insulin used to control high readings or the postexercise dose of intermediate-acting insulin may need to be reduced also to prevent late-onset hypoglycemia.

Glucagon

For extremely dangerous episodes of hypoglycemia in which the athlete is unconscious or confused to the extent that oral administration of glucose tablets or anything else would risk aspiration, glucagon should be injected directly into a large muscle such as the deltoid, or quadriceps femoris. The dose of glucagon should have been calculated in advance and the family must instruct whoever will administer it if it not a family member. Usually 1 mg for body weights above 100 lb will suffice, and 0.5 mg if the athlete is smaller. When the blood glucose level is raised enough to restore a more conscious athlete, oral feedings will probably be needed as well.

RESOURCES

Where should the athlete, family, and physician obtain information about adjustments in diabetes management to allow safe exercising, practicing, and competing? The ISPAD *Clinical Practice Consensus Guideline*,[5] available at http://www.ispad.org, is highly recommended. On the Internet, http://www.childrenwithdiabetes.org is a very

helpful and practical consumer-driven Web site. Also, http://www.desa.org is the Web site of an organization of committed athletes with diabetes, mostly adults. A British Web site, http://www.runsweet.com, has a number of commentaries on many different sports, again by adult athletes and based more on personal experiences than scientific studies. All of these Web sites provide thought-provoking insights that physicians would do well to access when working with today's web-savvy athlete. Physicians need to know where they get their independent information and what it is likely to best help them. Web sites such as the ones listed are very valuable, there may be some that are less so, or even dangerous.

SUMMARY

The essence of successful diabetes management depends on assessment of outcome so that necessary adjustments in the regimen can be made. No perfect process exists that can be applied to diabetes care in a "fire-and-forget" manner. Intensive diabetes management will not succeed without multiple capillary blood glucose measurements at strategic times to allow for course corrections, to avoid hyperglycemia and long-term complications on the one hand and severe hypoglycemia on the other. Similarly, the recommendations that physicians make to athletes with diabetes must be validated by the athletes' outcome testing and awareness. If the clinic and the athlete are able to communicate during the season without need for office visits, or if the plan is comprehensive enough to include recommendations for adjustments, a safe season should be the reward. Constant attention to details, agility in making adjustments to match needs, and focus on the outcome are helpful for diabetes management and are not different from the kinds of actions needed by athletes to progress in their sport. Physicians should emphasize those similarities for their patients' benefit! The energy, focus, and drive that make it possible to be a successful athlete ought to be harnessed to make diabetes management successful also.

REFERENCES

1. ISPAD Clinical practice consensus guidelines 2009 compendium. Available at: http://www.ispad.org. Accessed February 6, 2010.
2. Stettler C, Jenni S, Allemann S, et al. Exercise capacity in subjects with type 1 diabetes mellitus in eu- and hyperglycaemia. Diabetes Metab Rev 2006;22(4): 300–6.
3. Bussau VA, Jones TW, Ferreira LD, et al. The 10-s maximal sprint. A novel approach to counter an exercise-mediated fall in glycemia in individuals with type 1 diabetes. Diabetes Care 2006;29(3):601–6.
4. Riddell MC, Bar-or O. Children and adolescents. In: Ruderman N, Devlin JT, Schneider SH, et al, editors. Handbook of exercise in diabetes. Alexandria (Egypt): American Diabetes Association; 2002. p. 547–66.
5. Robertson K, Adolfsson P, Riddell M, et al. Exercise in children and adolescents with diabetes. Pediatr Diabetes 2009;10(Suppl 12):154–68 In: Hanas R, Donaghue K, Klingnsmith G, et al, editors. ISPAD Clinical practice consensus guidelines 2009 compendium. Available at: http://www.ispad.org. Accessed February 6, 2010.
6. Mountaineering stories. Available at: http://www.runsweet.com. Accessed February 6, 2010.
7. Rowing and swimming. Available at: http://www.runsweet.com. Accessed February 6, 2010.

8. Riddell MC, Iscoe KE. Physical activity, sport, and pediatric diabetes. Pediatr Diabetes 2006;7:60–70.
9. Oetliker JS, Alleman S, Ith M, et al. Fuel metabolism during exercise in euglycemia and hyperglycemia in patients with type 1 diabetes mellitus—a prospective single-blinded randomized crossover trial. Diabetologia 2008;51(8):1457–65.
10. Rosa JS, Glassetti PR. Altered molecular adaptation to exercise in children with type1 diabetes: beyond hypoglycemia. Pediatr Diabetes 2009;10:213–36.
11. Komatsu WR, Gabbay MA, Castro ML, et al. Aerobic exercise capacity in normal adolescents and those with type 1 diabetes mellitus. Pediatr Diabetes 2005;6(3): 145–9.
12. Davis ST, Galassetti P, Wasserman DH, et al. Effects of antecedent hypoglycemia on subsequent counterregulatory responses to exercise. Diabetes 2000;49: 73–81.
13. Kamboj MK, Draznin MB. Diabetes mellitus. In: Patel DR, Greydanus DE, Baker RJ, editors. Pediatric practice: sports medicine. New York (NY): McGraw-Hill; 2009. p. 157–66.
14. Edelman S. The un-tethered regimen. Available at: http://www.childrenwithdiabetes.org. Accessed February 6, 2010.