Exercise and T1D: New Technologies to Overcome Barriers

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INTRODUCTION

For individuals with type 1 diabetes (T1D), regular physical activity enhances psychological well-being, helps maintain a healthy body mass index and cardiovascular fitness, decreases total daily insulin needs, and improves the ability to achieve hemoglobin A1c (HbA1c), blood pressure, and blood lipid targets.[1] However, physical activity—especially in those with T1D—can have profound and not always predictable effects on blood glucose (BG) levels that make exercising safely a challenge and that may impair athletic performance.[1] Fortunately, recent technological advances, such as insulin pumps, devices for continuous glucose monitoring (CGM), closed loop/"hybrid closed loop (HCL)" systems, and wearable electronic fitness devices, are helping make glucose control easier to achieve.[2,3]

INSULIN PUMPS

For physically active individuals, continuous subcutaneous insulin infusion (CSII) via an insulin pump has been shown to provide important advantages over multiple daily injections (MDI), including greater flexibility in both bolus and basal insulin delivery.[1,4,5] This can also enhance glucose control during and after exercise.[1,4,5] To limit the risk of hypoglycemia in these time periods, pre-exercise bolus insulin (given to cover meals) can be reduced, delayed, or delivered over an extended length of time.[2] Similarly, basal insulin administered by a pump can be reduced or suspended before, during, and after exercise to account for individual glucose level and exercise type/intensity.[2]

Despite having these important advantages for glucose control, CSII can present several challenges related to physical activity:

- The pump may need to be disconnected when participating in contact/high-impact activities like wrestling, certain team sports, such as football or basketball, or activities requiring apparel that creates logistical barriers, such as gymnastics or ballet[1,6]
- Unless it is waterproof, the pump may need to be disconnected for water activities, such as swimming, boating, and diving[1,7]
- Excessive perspiration may be problematic, as it can loosen the adhesive that attaches the pump or infusion device to the body[8]
- Exercising in excessive heat may result in spoilage of the insulin within the pump and tubing (though not probable)[8]

Endocrine Society Recommendations for Using CSII in T1D

- CSII is recommended over analog-based basal-bolus MDI in those with T1D who have not achieved their HbA1c goals, but only if the patient and/or caregivers are able and willing to use the device
- In patients with T1D who have achieved HbA1c goals, CSII is recommended if severe hypoglycemia or glucose variability remains challenging, but only if the patient and caregivers are able and willing to use the device
- CSII is also recommended in patients with T1D who require increased insulin delivery flexibility and who are capable of using the device

Difficulty participating in sports is one of the most common reasons for insulin pump discontinuation, and young individuals may be self-conscious about wearing the devices.[9] Clinicians should be prepared to help children, adolescents, and caregivers navigate these barriers.[9] In particular, referral to a certified diabetes educator specializing in pump therapy training can help address common problems.[2,10]

CONTINUOUS GLUCOSE MONITORING

Because of the highly variable effects of exercise on BG, individuals with T1D must monitor their glucose levels before, during, and after physical activity.[1] Only then can appropriate adjustments to bolus and basal insulin doses be determined.[1]

Conventional "finger-stick" devices that measure capillary BG have evolved to be accurate and portable and require only a minimal blood sample.[2,6,11] However, they remain point-in-time values and fail to provide trending information, necessitating frequent checks throughout the day with lancets and reagent strips (6 to 10 times/day in those with T1D).[2,3] Unfortunately, most individuals with T1D (almost two-thirds) do not perform sufficient daily self-monitoring of blood glucose (SMBG).[12] Many find it to be inconvenient, especially when it requires an interruption in exercise.[6] Furthermore, the discreet readings obtained from conventional devices can offer only a limited perspective on the daily fluctuations in glucose levels, particularly during physical activity.[2,13]

Recommendations for Use of CGM in T1D

Endocrine Society

- Real-time CGM devices are recommended for adults with T1D and HbA1c levels above target and in adults with well-controlled T1D
- Individuals must be willing and able to use the CGM device on a daily basis

American Diabetes Association

- CGM should be considered in all children and adolescents with T1D
- Good adherence to the use of the device is key to experiencing the benefits of CGM

Continuous glucose monitoring (CGM) devices that measure interstitial glucose values have been available since 2006, but are now increasingly being used in the routine care of children and adolescents with T1D.[3] CGM has a number of advantages over conventional BG monitoring devices. It can:

- Provide real-time measurement of interstitial glucose concentrations as often as every 5 minutes (up to 288 readings per day), which can help patients and providers better assess glycemic response to exercise and optimize insulin dosages and carbohydrate intake throughout the day[2,14,15]
- Provide valuable data on trends for the user (ie, is glucose rising or falling, and at what rate?) to help prevent or treat low blood sugar levels sooner[6,14]
- Alert the user of potentially dangerous high or low glucose levels before they occur[1,6,14]
- Have a positive effect on HbA1c levels in those using CSII or MDI[3]
- Decrease fears about exercise and hypoglycemia

CGM offers several additional advantages for people with T1D who are physically active or who wish to engage in exercise, including:

- Alerting the wearer to rapid declines in glucose levels that may occur during physical activity via alarms and rate-of-change arrows on the device display[13,14,16]
- Providing early detection of nocturnal post-exercise hypoglycemia for those who exercise in the afternoon or evening[13]
- Lessening the burden of manual SMBG during sports to allow for more continuous and independent participation—an especially important consideration for children and adolescents[6,13]
- Data analysis software that allows users and their clinicians to detect sport-specific glucose patterns[3,10,17]

Of note, the accuracy of CGM devices has increased substantially since their development in the early 2000s.[16,18] Older devices had a relatively high degree of inaccuracy and failure rates, but with advances in sensor technology, the mean absolute relative differences between CGM readings and Yellow Springs instrument (YSi) laboratory values can be as low as 9% to 14%.[16] Importantly, studies confirm that CGM systems appear to be able to adequately track acute changes in glucose concentrations that occur during different intensities and types of exercise.[11,14]

Accuracy may, however, be affected by the lag time between interstitial glucose levels and blood glucose levels that are often rapidly changing during exercise.[11,16] In these circumstances, glucose levels may be overestimated when concentrations are dropping or underestimated when they are rising.[1]

Clinicians should be aware of the following key factors regarding CGM and convey them to their patients who are using or considering this technology:

- For CGMs to be effective, device data must be applied in real-time to adjust insulin dosages and carbohydrate intake; for some CGMs, a blood glucose reading is necessary when changing insulin or carbohydrate intake[16,19]

- Proper CGM performance requires that a number of maintenance tasks be performed according to manufacturer specifications, including calibrating the device, changing the sensor, and charging the transmitter and receiver[10,14]
- Patients and their clinicians must be aware of "alarm fatigue"—a situation in which users fail to respond to an alarm or discontinue the use of the device when CGM sensors repeatedly generate alerts; setting alert thresholds at appropriate (but meaningful) levels and changing the alert style (tone or vibrate) can help[14,19]

HYBRID CLOSED LOOP SYSTEMS

HCL systems integrate CGM devices with insulin pumps and an algorithm control system to regulate basal insulin delivery.[7,20] User intervention is still required for bolus dosing and adjusting for physical activity.[3,7,20] The most recent American Diabetes Association position statement on T1D in children and adolescents recommends that the use of automated insulin delivery systems be considered in this patient population.[3]

American Diabetes Association Recommendations for the Use of Closed Loop Systems in T1D

- Automated insulin delivery systems (or HCL devices) should be considered in pediatric patients with T1D
- These systems appear to reduce hypoglycemia and improve glycemic control

Studies suggest that HCL systems are associated with an increased percentage of time spent in the target BG range and a lower risk of hypoglycemia after exercise compared with open-loop systems (ie, those relying fully on user input).[4,21] This is primarily due to the HCL system's ability to automatically reduce basal insulin delivery in the event of a glucose decline during or following rigorous exercise.[4] Current research is aimed at creating algorithms for artificial pancreas systems that more accurately mimic endogenous insulin responses to physical activity.[2]

IMPORTANT

Current HCL systems allow the user to temporarily raise the glucose "set point" (the value that the algorithm targets) in anticipation of physical activity.[22,23] Although an adjustment of this type can help reduce the risk of hypoglycemia during exercise, many users report the need to raise the set point 1 to 2 hours before the onset of planned physical activity.[22,23] Users should be advised that use of an elevated set point may not preclude the need for additional carbohydrate before and during exercise (please note that ingesting carbohydrate before exercise may cause a rise in glucose and subsequent insulin delivered by the pump, and may therefore lower glucose during exercise), particularly when participating in activities of a prolonged or strenuous nature.[22,24]

Bi-hormonal systems—those involving the delivery of both insulin and its antagonist glucagon—are currently under investigation and may eventually provide more physiologic responses and better BG control compared with insulin alone.[14]

OTHER HEALTH AND FITNESS DEVICES

A variety of wearable health and fitness devices and smartphone apps are available to help individuals make better decisions about physical activity. These include accelerometers, blood pressure and heart rate sensors, and diabetes management tools.[17,25] Information from activity sensors has the potential to be incorporated into HCL and full artificial pancreas algorithms to automate the delivery of insulin.[25] Such sensors could also potentially be added to closed loop systems to detect heart rate, temperature, perspiration, movement, and other parameters and improve functionality during exercise.[21] Additionally, patients with T1D and their clinicians can use the information from these trackers to better understand how activity affects their individual BG levels.[25] Many of these devices can directly transmit important information to software used to display data from pump/CGM systems.[17,25]

ADDITIONAL RESOURCES

We hope you found this information to be a helpful summary of how new technologies are making exercise safer and easier for patients with T1D. For additional information on this topic, please visit the following sources:

- The Endocrine Society: Diabetes technology guideline (https://academic.oup.com/jcem/article/101/11/3922/2764917)
- Diabetes Forecast: Consumer Guide, 2018 (www.diabetesforecast.org/landing-pages/lp-consumer-guide.html)

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