The Impact of Insulin on Board for Safe Exercise With T1D

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INTRODUCTION

Guidelines recommend physical activity for individuals with type 1 diabetes (T1D), yet most youth and adults with the condition get less exercise than their peers without diabetes.[1] Studies have shown that fear of hypoglycemia is the primary obstacle, but a lack of basic knowledge about managing insulin dosing before, during, and after physical activity is also a contributing factor.[2,3]

Seeking More Information on Exercise Barriers?

A more in-depth discussion about barriers to physical activity and strategies to improve activity levels can be found at www.jdrf.org/peak. Visit the site and participate today!

An often overlooked factor that can play into these fears and knowledge gaps is "insulin on board," or IOB—insulin that is systemically active in the body from previous dosing.[4] IOB can contribute to exercise-related hypoglycemia and complicate decisions around glycemic management and physical activity.[5]

By understanding how IOB factors into optimal insulin management, individuals with T1D may be able to better avoid exercise-related blood glucose swings.[4] Avoiding these swings may, in turn, reduce fears about hypoglycemia, increase confidence related to adjusting insulin appropriately, and make physical activity feel less risky or complicated.

PHYSICAL ACTIVITY: EFFECTS ON INSULIN AND GLUCOSE HOMEOSTASIS

The type, intensity, and duration of physical activity each affects insulin sensitivity and glucose metabolism (Table 1).[6] Importantly, individual factors, such as fitness level, can also influence insulin sensitivity and glucose metabolism (eg, an active person with T1D will have an overall lower glucose level than a sedentary counterpart).[7]

TABLE 1. Effects of Different Exercise Types on Blood Glucose Levels

ACTIVITY	 **Aerobic exercise** (> 30 minutes)	**Resistance training**	 **High-intensity interval training**	 **Brief, intense anaerobic exercise**	 **Long-duration exercise**
EFFECTS	Generally decreases blood glucose, unless carbohydrates are consumed	Keeps blood glucose more stable; may modestly increase blood glucose	Attenuates the decrease in blood glucose seen with aerobic exercise	Typically increases blood glucose	Increases blood glucose utilization; may increase potential for hypoglycemia

IMPORTANT

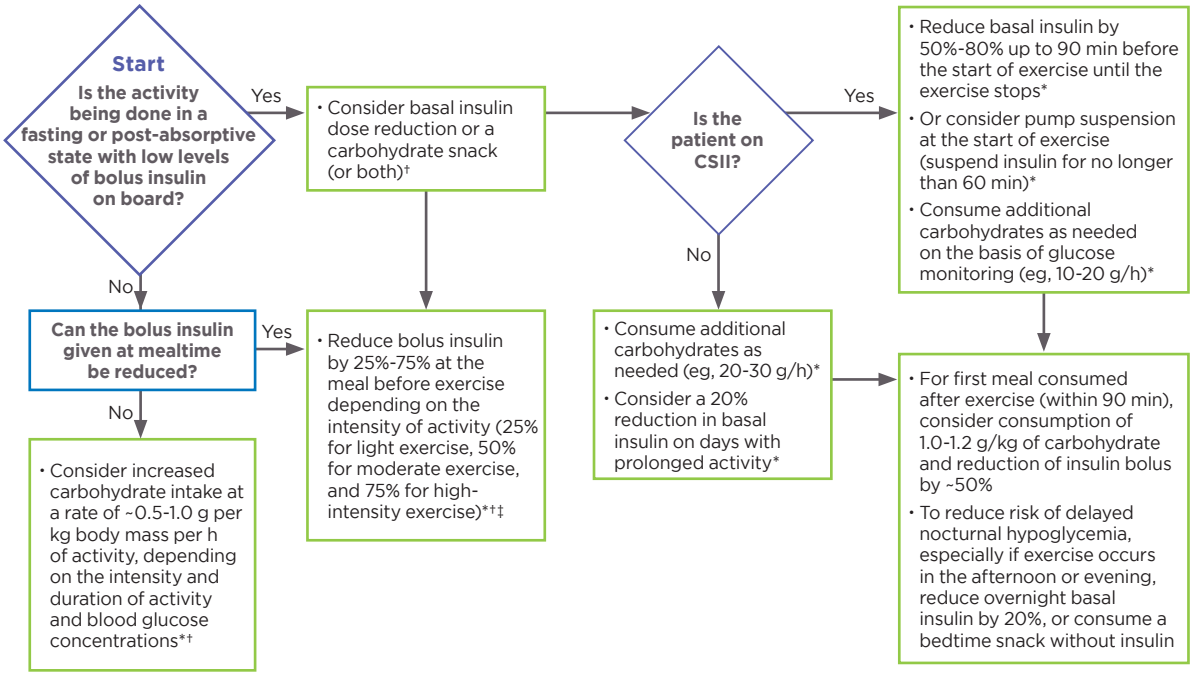
The successful management of blood glucose before, during, and after exercise requires ALL of the following:

- **Taking into consideration the type, duration, and intensity of exercise**
- **Weighing the impact of individual factors**
- **Monitoring glucose frequently**
- **Adjusting basal and bolus insulin dosing**
- **Adjusting carbohydrate intake before, during, and after exercise**

These factors are further complicated by the potential effects of IOB. In particular, the use of rapid-acting insulins—with peak actions at about 1 hour and durations of action of approximately 4 to 6 hours—frequently requires dosing adjustments to prevent exercise-related hypoglycemia.[6,8] Basal insulins have a relatively flat duration of 12 to 24 hours but may also require adjustments.[6,8]

Figure 1 is an algorithm that can be used as a general starting point for insulin adjustments in T1D for physical activity, but keep in mind that adjustments must be highly individualized—requirements may even vary from day to day in the same individual participating in the same physical activity because of pre-exercise meal composition, stress levels, and other variables.[6]

FIGURE 1. Algorithm for Insulin and Carbohydrate Adjustments for Exercise* in T1D



CSII = continuous subcutaneous insulin infusion.
*Algorithm is for use in persons with T1D who are performing aerobic or mixed anaerobic/aerobic exercise lasting longer than 30 minutes. Mixed anaerobic/aerobic activities may require less reduction in insulin or lower carbohydrate intake than recommended here.
†If both resistance and aerobic exercise are to be done, resistance exercise could be done first to help attenuate hypoglycemia.
‡In some situations, such as Nordic skiing, marathon running, or prolonged cycling and trekking, increased carbohydrate feeding rather than insulin dose reduction might help improve endurance performance in prolonged activities. In other situations, both bolus and basal insulin dose reductions might be needed to help restrict or reduce carbohydrate intake. Continuous glucose monitoring could be considered where patient or parent preference dictates, or in individuals with a history of nocturnal or severe hypoglycemia.
Reprinted with permission from Riddell MC, Gallen IW, Smart CE, et al. Exercise management in type 1 diabetes: a consensus statement. *Lancet Diabetes Endocrinol.* 2017;5(5):377-390.

IOB AND TECHNOLOGIES

Newer insulin pump technologies now incorporate IOB calculations that use various algorithms to estimate IOB, modify bolus dosing, and prevent "insulin stacking" (overlapping of rapid-acting insulin doses).[1,9] Theoretically, these take into account prior insulin dose and timing, absorption rates, insulin sensitivity, and correction factors.[1] Currently, only generalized corrections for exercise are included in bolus calculators and may inappropriately estimate the duration of bolus insulins.[1] Moreover, substantial training and clinical guidance are required for persons with T1D to select and adjust appropriate settings, alter bolus recommendations when necessary, and make decisions based on downloaded data.[9] Without this additional support, the user experience with insulin pump technologies often falls short of expectations.[10]

CGM: AN IMPORTANT TOOL FOR EXERCISE IN T1D

Continuous glucose monitoring (CGM) systems can measure glucose as often as every 5 minutes, alert users to glucose highs or lows, and provide information on glucose trends—information that can be useful in making exercise-related insulin dosing decisions.[11] Notably, several studies have found that CGM can help prevent hypoglycemia after exercise.[12,13] Existing CGM sensors are generally adequate for use during exercise.[6] However, readings during exercise can be affected by the lag time between the reading and rapidly changing blood glucose, potentially resulting in an overestimation of blood glucose when concentrations drop and an underestimation of blood glucose when levels rise.[1,6] Of note, combining a CGM system with insulin pump technology (ie, a closed-loop system) has been shown to reduce hypoglycemic events in T1D, but users frequently underuse the protective function of these devices in daily life, primarily because of alarm fatigue and inadequate education.[14]

WHAT THE FUTURE HOLDS

Tools for adjusting insulin dose based on predicted episodes of hypoglycemia do not yet exist; however, this is an active area of research. Variations in exercise type and intensity make predictions difficult, and studies have found conflicting results on the effects of insulin pump suspension or basal dose reduction before exercise.[5,15-17] Moreover, the differential effects of exercise type and intensity further complicate the development of reliable tools and algorithms.[15] However, algorithms designed to predict hypoglycemia during exercise in T1D are being developed and may soon be integrated into decision-support systems or automated artificial pancreas technologies.[18]

ADDITIONAL RESOURCES

We hope that you found this to be a helpful overview of the importance of considering IOB to avoid blood glucose swings and adjust insulin before, during, and after exercise. The following resources provide additional education on this topic:

- **www.jdrf.org/peak (online CME webinars on T1D and exercise)**
- **https://diabetes.ucsf.edu/sites/diabetes.ucsf.edu/files/Exercise%20Diabetes%20Final%20%20112309.pdf (recommendations from pediatric diabetes program at UCSF)**

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