Exercise and Pump Therapy

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Physical activity has significant effects on people with diabetes. Increased blood flow to exercising muscle is accompanied by an increase in insulin-stimulated as well as non-insulin-mediated glucose uptake (1). Concurrently, production of counterregulatory hormones (catecholamines, glucagon, cotrisol, growth hormone) may increase abruptly during certain forms of exercise. As a result, glucose levels may rise, fall or remain unchanged under different exercise conditions.

Although most studies have shown little impact upon HbA1c levels, the benefits of physical activity are far wider: weight control (2), functional capacity, reduced cardiovascular risk, and psychological well-being. For some insulin pump users, participation in physical activity is somewhat sporadic and related to leisure, chores or work/school demands. For others, daily exercise is a part of an overall training/conditioning program. With persistence, expert guidance, and the benefit of peer support via social media, a growing number of insulin pump users are reaching for the highest levels of performance in a variety of group and individual sports activities.

Diabetes, and certainly insulin pump use, should not limit one's ability to engage in virtually any form of physical activity. In fact, insulin pump use offers a number of unique advantages over injection therapy for the "athletic diabetic." This section is intended to address the challenges associated with physical activity and insulin pump use, and offer practical solutions.

Preventing Hypoglycemia

Most forms of low-to-moderate intensity physical activity will increase insulin sensitivity and accelerate muscle cells' uptake of glucose. In a metabolically well-managed patient, this can produce an undesired drop in the blood glucose level. Some pump users believe that suspending, or disconnecting from, the pump will prevent hypoglycemia. However, given the time-action profile of rapid-acting insulin analogs used in pumps, eliminating basal insulin during the activity will have minimal effect on the glucose level during the activity. The most effective ways to prevent exercise-induced hypoglycemia are to reduce bolus insulin, increase food, or a combination of both (3).

When physical activity is going to take place within 90 minutes after a meal, the best approach for preventing hypoglycemia is to reduce the mealtime bolus (4, 9). Since both aspects of the bolus (the part given for food and the part given to correct an elevated glucose) are made more potent by physical activity, both need to be reduced. To accomplish this, reduce the usual mealtime bolus (based on the premeal glucose level and anticipated carbohydrate intake) by a percentage. The more intense and prolonged the activity, the greater the bolus reduction.

Bolus Reduction ↘	**Short** Duration (20-40 minutes)	**Moderate** Duration (40-60 minutes)	**Long** Duration (>60 minutes)
Low intensity	-10%	-20%	-30%
Moderate intensity	-25%	-33%	-50%
High intensity	-33%	-50%	-67%

For example, if Ann plans a moderate-intensity 45 minute workout after breakfast, a 33% bolus reduction is likely in order. Her usual 6.0 unit dose is reduced to 4.0 units.

When exercise is going to be performed before or between meals, reducing the bolus at the previous meal would only serve to drive the pre-workout glucose level very high. A better approach would be to take the normal bolus at the previous meal, and then snack prior to exercising – preferably by consuming high-glycemic-index forms of carbohydrate such as cereal, crackers or a sports drink. (10)

The amount of the snack depends on the duration and intensity of the workout as well as the size of the individual. There is no way of knowing *exactly* how much will be needed, but the chart below should serve as a safe starting point.

	Carbohydrate Replacement Per 30 Minutes of Physical Activity				
	50 lbs (23 kg)	100 lbs (45 kg)	150 lbs (68 kg)	200 lbs (91 kg)	250 lbs (114kg)
Light Activity	3g	5g	8g	10g	12g
Moderate Activity	5g	8g	10g	12g	15g
Intense Activity	8g	12g	18g	24g	30g

For example, if Stan weighs about 150 lbs and is doing 90 minutes of intense yardwork, he should consume about 18g of carbohydrate before starting and every half hour. Of course, if his pre-activity glucose level is above or below target, the amount of the initial snack should be adjusted accordingly.

Basal adjustment for prolonged activities

When engaging in relatively short periods of exercise (90 minutes or less), basal insulin adjustments tend to have little bearing on glucose levels. In fact, even short-term cessation of basal insulin delivery during exercise can produce post-exercise hyperglycemia. (4) It typically takes several hours for changes in basal insulin to have a noticeable effect. For prolonged activities (lasting two hours or more), basal insulin adjustments can be helpful for reducing the amount/frequency of snacks and preventing hypoglycemia. In most cases, a good starting point is to reduce the rate of basal insulin delivery by 50% using the TEMPORARY BASAL RATE feature.

To make the most of a temporary basal adjustment, it is best to start it one to two hours prior to the onset of prolonged physical activity. That way, when the activity begins, the level of basal insulin in the bloodstream will already be on the decline. It is best to end the temporary basal reduction shortly before the end of the activity so that the post-exercise insulin level returns to normal in a timely manner.

For example, if Karen plans to ride her bike a long distance, she sets a 50% temporary basal reduction 90 minutes before leaving. She also snacks periodically during her ride, but the amount and frequency of the snack is much less than if she had not reduced her basal rate. A few miles before returning home, she suspends her temp basal and returns to her normal settings.

Delayed Effects

Exhaustive forms of exercise, such as prolonged/intense aerobic activities and maximal strength training, deplete muscle glycogen stores and greatly increase muscle sensitivity to insulin (8). This combination can cause blood glucose to drop several hours after cessation of the activity – a phenomenon called *Delayed Onset Hypoglycemia*. (11)

Anyone who uses insulin can prevent a delayed fall in blood glucose by consuming slow-digesting (low-glycemic index) carbohydrates without compensatory insulin. However, by having the ability to temporarily reduce basal

insulin levels, insulin pump users are in a unique position to prevent delayed onset hypoglycemia. Once a pattern of delayed glucose-lowering is detected, patients can usually prevent further bouts of hypoglycemia through a modest 20-30% temporary basal insulin reduction. The adjustment should be made following the activity, and set for a duration that lasts until the glucose drop normally occurs.

For example, Glenn finds that his glucose level drops overnight after he plays full-court basketball during the day. To prevent this delayed drop, he sets a 25% basal decrease that runs from after basketball until the middle of the night.

Managing exercise-induced hyperglycemia

Glucose regulation involves a complex interaction between the factors that raise blood glucose (carbohydrates in the diet and counterregulatory hormones) and the factors that lower it (insulin and physical activity). Some forms of exercise induce a dramatic increase in stress hormones, resulting in an acute rise in blood glucose (5). Examples include:

- Weight lifting, particularly when the weight is high and reps are low
- Sports that involve intermittent "bursts" of activity such as softball, golf or martial arts
- Maximal sprints in events such as running, swimming and rowing
- Events where performance is being judged, such as gymnastics or figure skating
- Sports in which winning is the primary objective

For those who detect a consistent rise in their blood glucose during certain activities, the solution is to take extra insulin in preparation for the event. Because physical activity makes the body more sensitive to insulin, a reasonable pre-activity bolus is equal to 50% of the amount required to offset the expected rise, administered 30-60 minutes before exercising.

For example, if Jenny's glucose tends to rise 100 mg/dl (5.4 mmol/l) when she runs a 5k race and her sensitivity to insulin is 50 mg/dl (2.7 mmol/l), she would normally require a 2-unit bolus to offset the adrenaline-induced BG rise. Instead, she takes 1 unit an hour prior to the run and monitors her glucose level closely.

Another potential source of rising glucose during exercise is a lack of working insulin in the body. Because insulin pump users do not typically take long-acting insulin, any problem with insulin delivery, absorption or potency can result in insulinopenia in just a few hours. Without sufficient insulin to meet the body's basic metabolic needs, exercise will usually cause a rapid glucose rise and, potentially, progression toward DKA.

For this reason, pump users should check their blood (or urine, if a blood ketone meter is unavailable) for ketones whenever glucose levels are inexplicably elevated prior to exercise. Patients should be instructed to treat the hyperglycemia and ketones according to standard procedure (typically administering insulin via injection, hydrating, and changing the pump's infusion set) and postponing exercise until ketones have cleared and the glucose level returns to an acceptable range (6).

In the absence of ketones, it is not usually dangerous to exercise with a high glucose level. Performance may not be optimal, but the risk to the patient is minimal. The best option is to administer a bolus equal to half of the usual correction dose and hydrate adequately.

<u>Elevated BG Prior to Exercise</u>

If Explainable:

- Hydrate
- Administer 50% of usual correction bolus

If Unexplainable, Check for ketones

If ketones negative (≤15 mg/dl in urine sample; ≤.5 mmol/l in blood sample):

- Hydrate
- Administer 50% of usual correction bolus
- OK to exercise

If ketones positive:

- Hydrate
- Administer full correction bolus
- Do not exercise

Extended disconnection (> 90 minutes) from a pump can also cause a rise in the glucose level during or immediately following exercise. Many pump users choose to temporarily disconnect from the pump during sports that involve rough contact, jarring movements or exposure to water. Doing so for less than 90 minutes rarely presents a problem; it is not usually necessary to "replace" any of the missed basal insulin. However, for longer periods of disconnection, the patient should be instructed to reconnect hourly and administer a bolus equal to 50% of the ususal basal rate.

For example, Debbie prefers to disconnect from her pump while swimming and playing at the beach. Given that her usual basal rate is .6 units/hr, she reconnects hourly, delivers a bolus of .3 units, and then promptly disconnects.

When prolonged or intense activities preclude hourly reconnection to the pump, an *untethered program* may be utilized. This involves injecting a small dose of long-acting basal insulin in the morning and utilizing a secondary/reduced basal program on the pump for the next 24 hours. This approach allows for safe disconnection for extended periods of time, particularly during the daytime hours when the basal rate is usually at its lowest.

Infusion Set Practices

For every insulin pump user, the choice of infusion set should be matched to the individual. Patients who participate in high-impact sports activities should be advised to use a flexible plastic cannula in order to prevent potential discomfort and injury at the infusion site. Angled infusion sets are preferred for most lean athletes, as the angled orientation reduces the chances of penetrating or poking the underlying muscle wall. The clear window on the angled sets allow rapid detection of site irritation and bleeding, and the longer cannulae on the angled sets are less likely to pull out of the skin accidentally compared to shorter cannulae that are inserted in a perpendicular fashion.

Some patients have difficulty keeping their pump infusion set in place when exercising. Perspiration and rapid movements can cause the set to come loose or cause irritation below the skin. One of the best strategies for avoiding these types of problems is to wear the set on the buttocks, where there is ample subcutaneous fat, the skin does not move/stretch excessively, perspiration is minimal, and there is typically a tight garment covering the site.

Some athletes also find it helpful to place an adhesive dressing such as IV-3000 (Smith & Newphew) or Tegaderm (3M) over the infusion set. Cutting a hole in the center of the dressing before placing it over the set allows access to the usual connect/disconnect mechanism (for those who use a set that disconnects at the infusion site). If adhesion problems persist, Mastisol (Ferndale Labs) applied around the point of insertion prior to set placement provides excellent results. One other potential solution, particularly for those who perspire excessively, is Hypercare (Stratus Pharmaceuticals) -- a prescription-only antiperspirant containing a high concentration of aluminum chloride (20%). Applying Hypercare the night before inserting an infusion set works well for most patients. Many also report significantly less site itching, redness and irritation when the skin does not perspire.

Wearing the Pump During Exercise

Insulin pumps are made to withstand a considerable amount of impact. The majority of experienced pump users have found that insulin pumps do not interfere with most forms of sports activities. A number of excellent options exist for wearing the pump during exercise. If the standard clip will not hold the pump in place well enough, or if extra stability or protection are sought, a variety of pump accessories are available. The *SportPak (*Unique Pump Accessories) and *Zipps* (Pump Wear Inc) hold the pump tightly around the waist with an elastic waist strap. Spandex belts with pump-sized pockets that fit securely around the arm, thigh or calf are also available.

For waterproofing pumps that are not already water-tight, pumpers can use the AquaPac (AquaPac International Ltd). This clear flexible case allows the pump to be programmed while inside, and features a pass-through port for the pump tubing. Of course, this is not necessary with waterproof pumps and "patch"-type pumps.

Occasionally, exercise may take place under extreme conditions. High ambient temperature during exercise can not only lead to set adhesion problems; it can also contribute to insulin breakdown (7). Cold temperatures are not usually an issue as long as the pump is worn close to the body, but heat can lead to denaturing of insulin and hyperglycemia. When exercising at temperatures above 86°F, patients should be advised to shield their pump and tubing from direct sunlight. With prolonged exposure to warm temperatures, it may be necessary to change the pump reservoir and tubing more frequently than usual. If exposure to high temperatures is unavoidable, use of a Frio pump wallet (Frio Ltd) is an effective way to avoid insulin spoilage.

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