EXERCISE AND TYPE 1 DIABETES

Joseph Henske, MD, FACE
Department Chair
Endocrinology, Diabetes, and Metabolism
DuPage Medical Group
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JDRF PEAK
T1D Performance in Exercise and Knowledge

Exercise Has Many Benefits for People with T1D

- Weight management, increased lean body mass
- Reduced heart disease risk
  - Lower blood pressure
  - Lower LDL, higher HDL cholesterol
  - Improved HbA1c and insulin sensitivity
- Reductions in microvascular complications
  - Eyes, Kidneys, Nerves
- Psychological benefits
  - Improved sense of well-being
  - Improved self-esteem

ADA. *Diabetes Care*. 2018;41(Suppl 1):S38-50; Bohn B, et al. *Diab Care.* 2015;38:1536-43.

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There are No Limits

KEY POINT #1

DIFFERENT FORMS OF EXERCISE HAVE DIFFERENT EFFECTS

Blood Glucose Effects of Different Types of Exercise

	Aerobic	Mixed	Anaerobic
Main variables	Intensity and duration of exercise, insulin to glucagon ratio, fitness, nutrition, initial glucose concentration	Intensity and duration of exercise, insulin to glucagon ratio, counter-regulatory hormones, lactate concentration, fitness, nutrition, initial glucose concentration	Intensity and number of intervals, insulin concentration, counter-regulatory hormones, lactate concentration, fitness, nutrition, initial glucose concentration

Riddell M, et al. *Lancet Diab Endo*. 2017;5:377-90.

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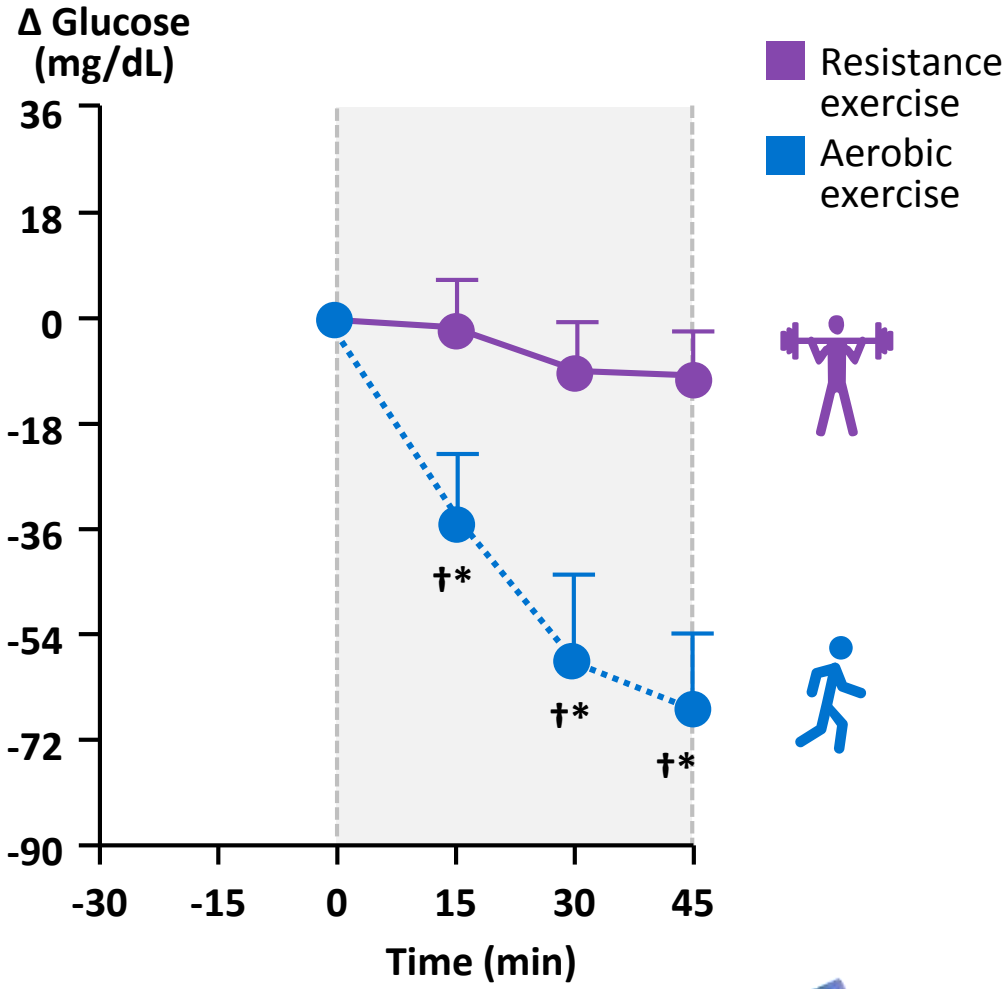
Resistance Exercise has Can Be a Good Way To Avoid Lows

- Adding resistance training before aerobic activity can help minimize lows
  - Reduces declines in glucose
  - May reduce need for carbs
- 10 second sprints during aerobic exercise can increase blood glucose as well



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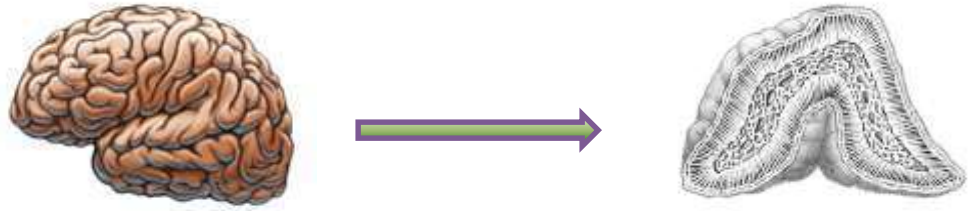
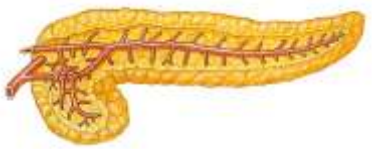
KEY POINT #2

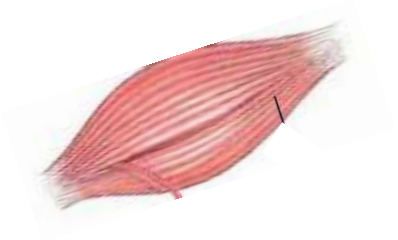
PEOPLE MAINTAIN “NORMAL” GLUCOSE LEVELS THROUGH PHYSIOLOGY

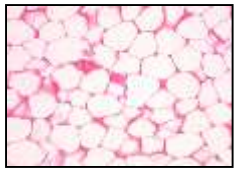
Normal Physiologic Mechanisms Maintain Tight Glucose Levels During Exercise

- Brain
  - Stimulates Adrenaline: sugar goes up
- Pancreas
  - Makes Glucagon – sugar goes up
  - Makes Insulin – sugar goes down
- Liver
  - Sugar released into circulation
- Muscles
  - Stores sugar for release, Burns glucose as fuel
- Fat
  - Stores sugar as well for release









KEY POINT #3

EXERCISE IN T1D LEADS TO GLUCOSE IMBALANCE DUE TO ALTERED PHYSIOLOGIC RESPONSES

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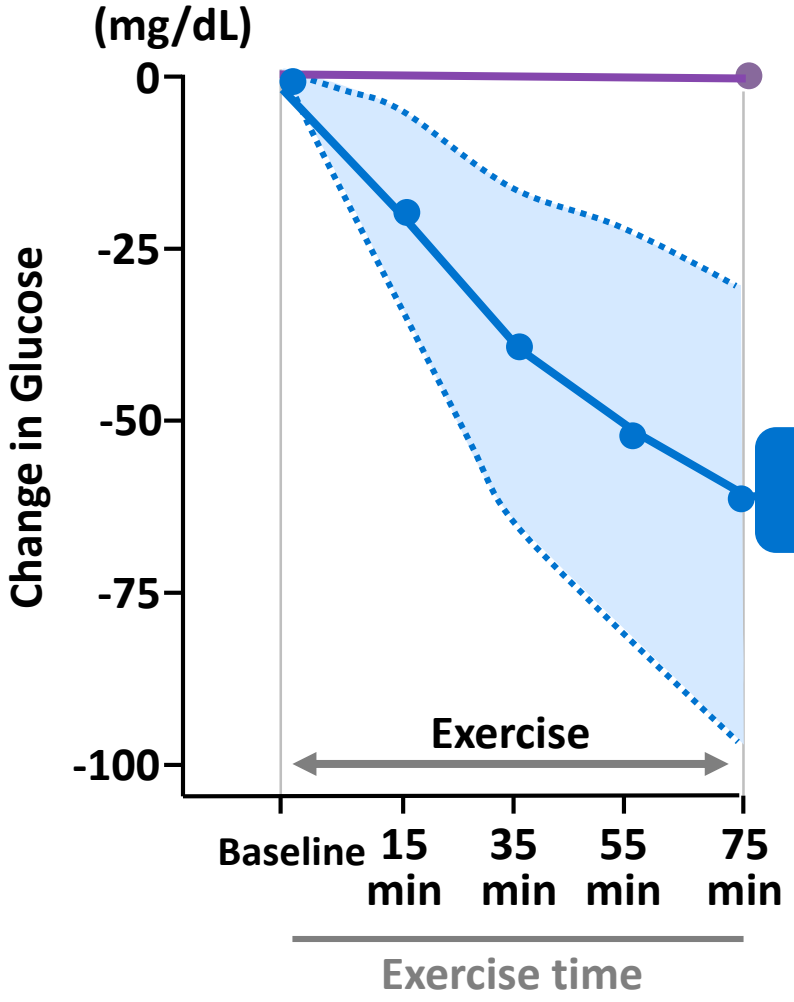
Factors that Contribute to Increased Lows During Exercise in T1D

- People with diabetes (PWD) can't turn off insulin that's already been dosed
- There is an increase in skin absorption of insulin from injection/pump site
- There is an increase in sugar use by muscles
- Exercise blunts counter-regulatory hormone responses
- Therefore there is diminished liver glucose production in PWD

Riddell M, et al. *Lancet Diab Metab*. 2017;5:377-90.

Aerobic Exercise Without Adjusting Insulin Can Cause Blood Sugars to Drop (at Variable Rates!) and May Cause Lows



T1D, age 8–17 years, n=49
75 min of intermittent aerobic exercise

T1D, no insulin adjustment

Δ=~ 63 mg/dL
43% become hypoglycemic

The Diabetes Research in Children Network (DirecNet) Study Group, et al. *Diabetes Care*. 2006;29:2200-4.

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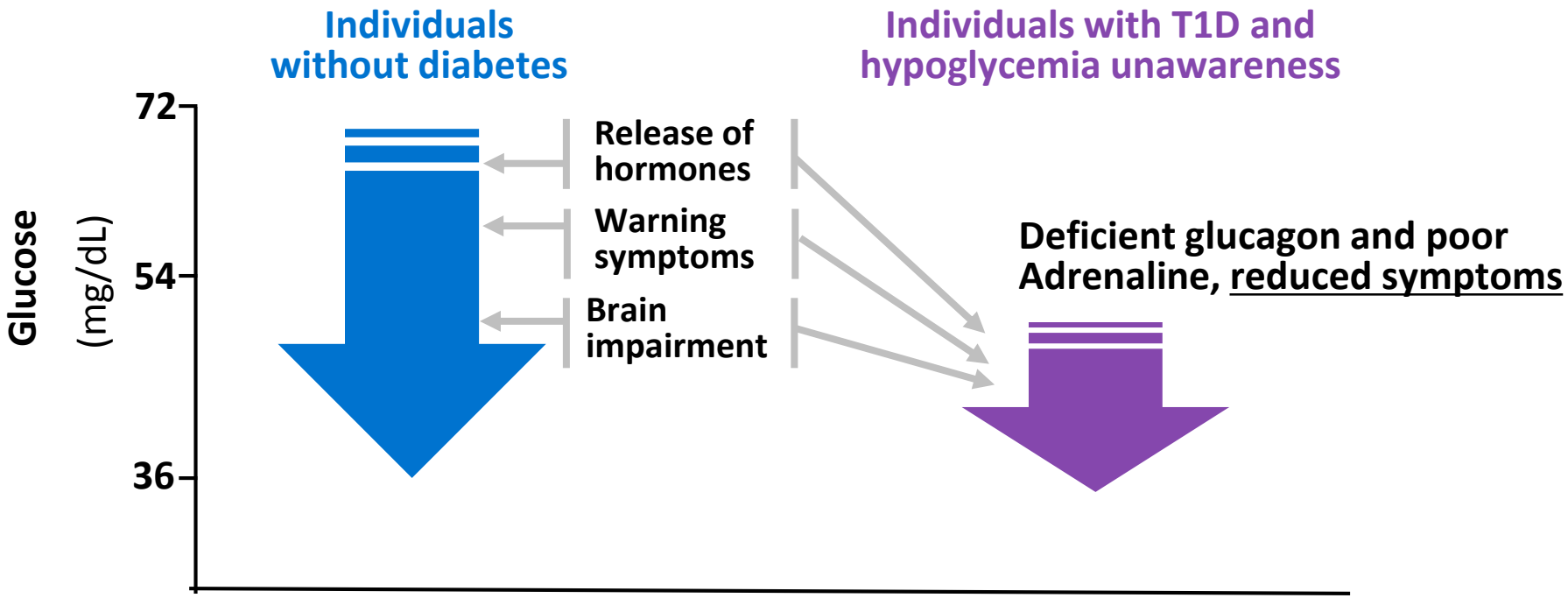
Symptoms of Lows May Be Blunted in T1D

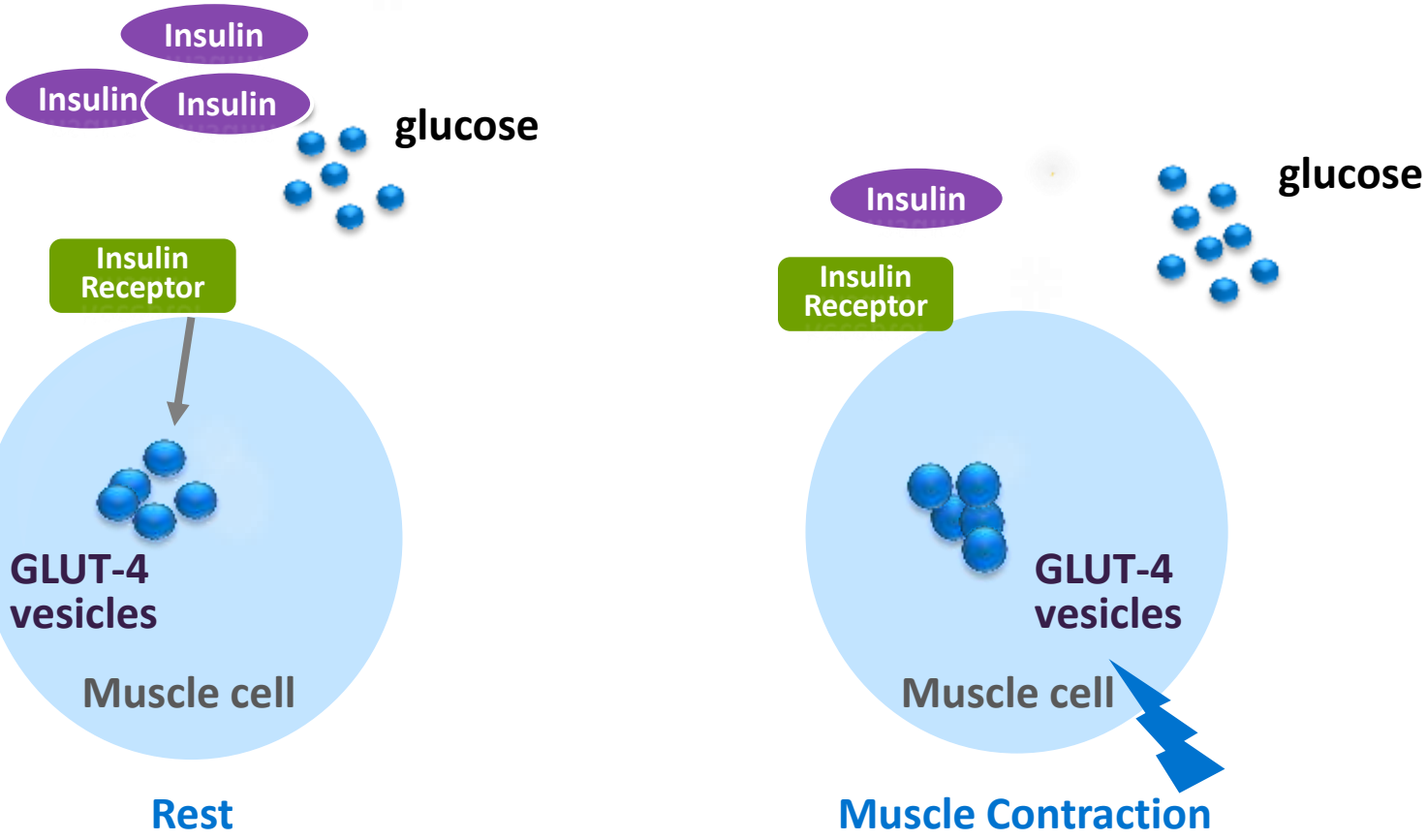


Martin-Timon I, et al. *World J Diabetes.* 2015;6:912-26.

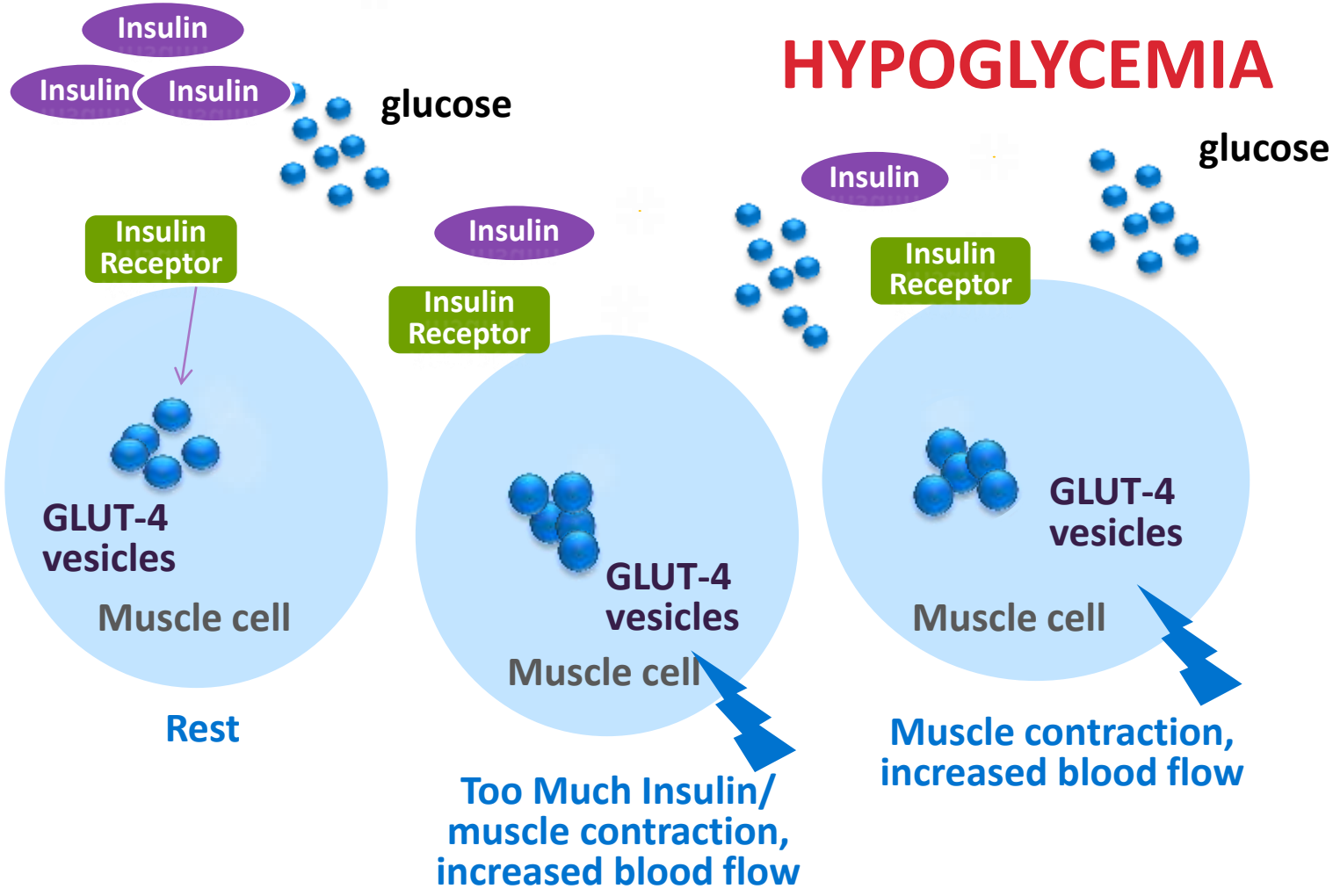
KEY POINT #4

BLOOD SUGARS CAN DROP DUE TO BOTH INSULIN ACTION AND MUSCLE CONTRACTION

Both Insulin and Muscle Contraction Increase Glucose Uptake into Muscles via Distinct Mechanisms



Both Insulin and Muscle Contraction Increase Glucose Uptake into Muscles via Distinct Mechanisms – Increased Risk For Lows!



KEY POINT #5

EXERCISE HAS BOTH IMMEDIATE AND DELAYED EFFECTS ON BLOOD GLUCOSE

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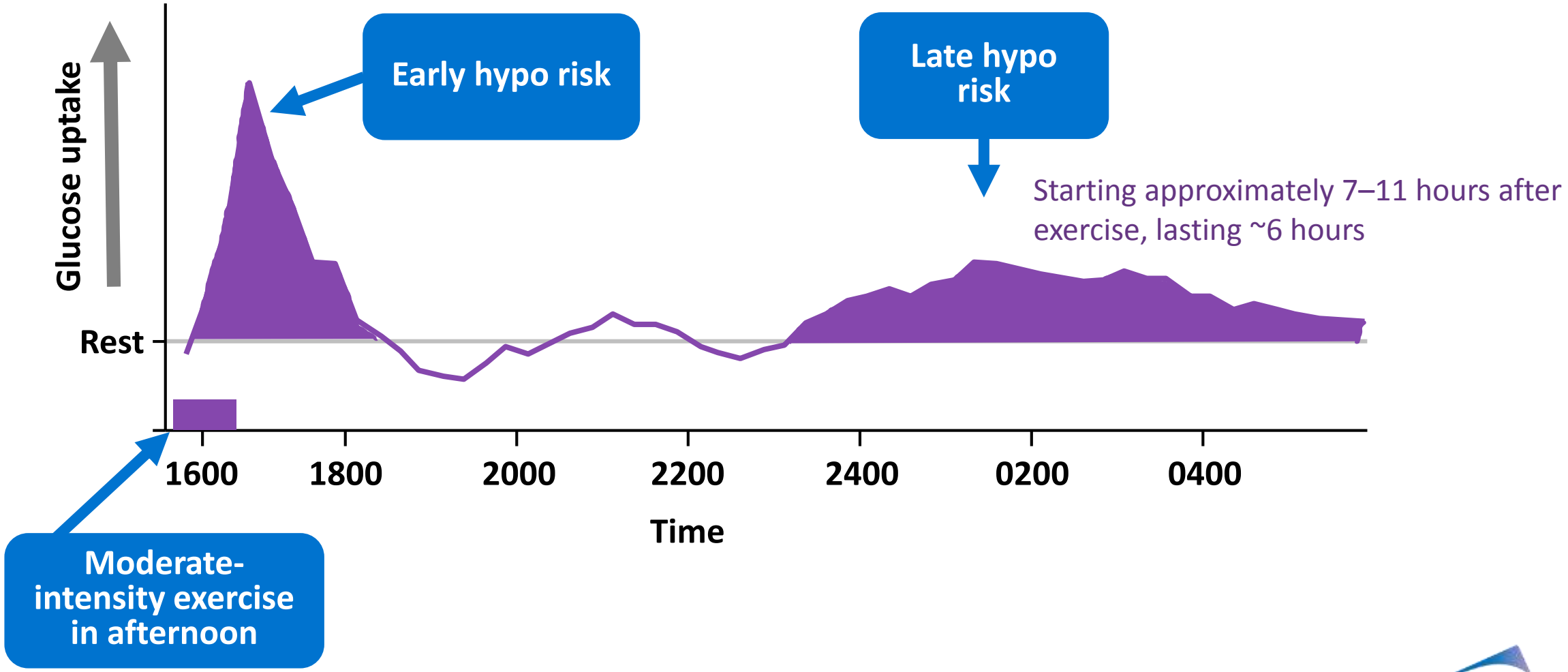
After Exercising, Blood Sugar "Burn" Remains High for Hours to Replenish Muscle Glycogen Stores (i.e. overnight)



Adapted from McMahon SK, et al. *J Clin Endocrinol Metabol*. 2007;92:963-8.

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KEY POINT #6

THE BODY ADJUSTS ITS SOURCE OF ENERGY AS INTENSITY OF EXERCISE AND OVERALL FITNESS CHANGE

The More Intense the Exercise, the More Glucose Is Burned as Fuel to Keep You Going

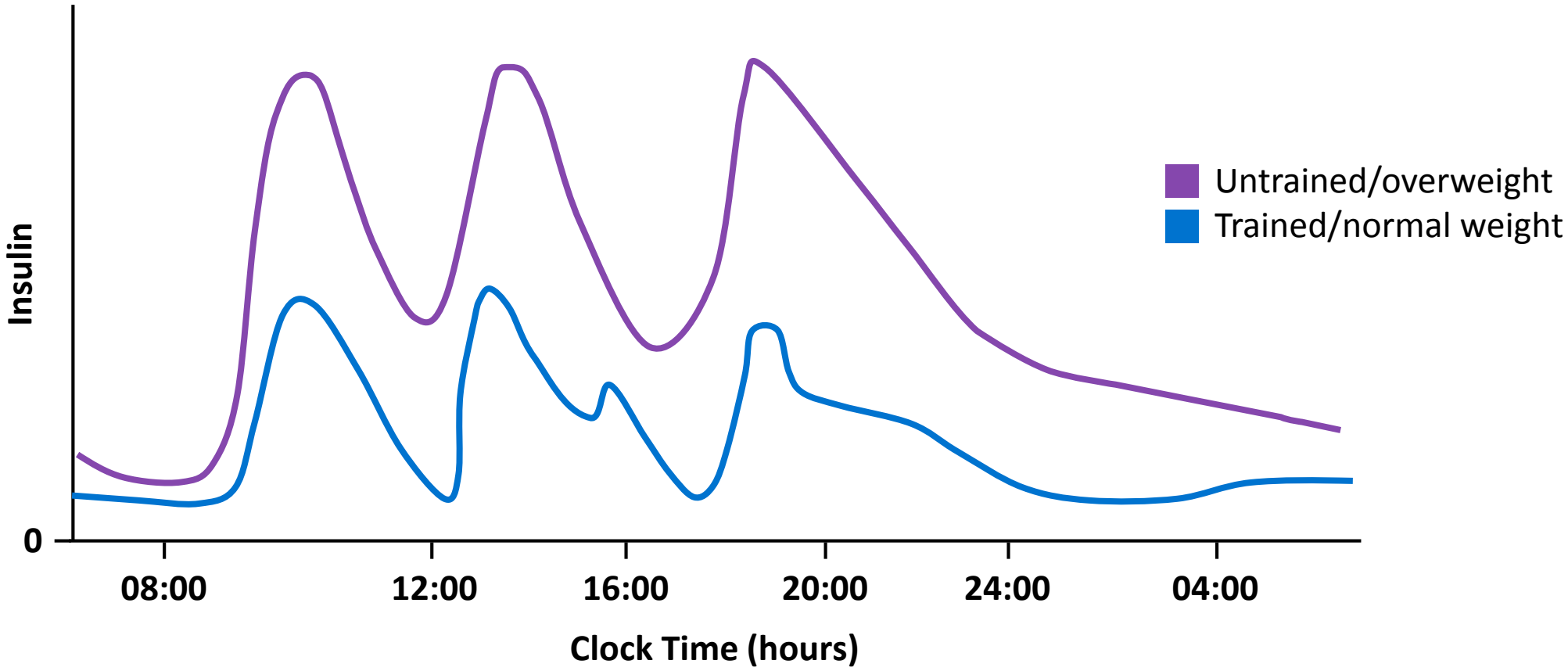
- Lower-intensity exercise
  - High lipid (fat) use
- Higher-intensity exercise
  - High muscle glycogen use
  - High plasma glucose use
- Training increases fat burning and spares muscle and liver sugar stores

Romijn JA, et la. *Am J Physiol.* 1993;265:E380-91; van loon LJ, et al. *J Physiol*. 2001;536:295-304.

KEY POINT #7

INSULIN SENSITIVITY INCREASES WITH FITNESS

Training Increases Insulin Sensitivity and May Lower Insulin Requirements



Schematic; derived from expert opinion.

KEY POINT #8

COOLDOWN MINIMIZES INCREASE AFTER-EXERCISE HIGH BLOOD SUGARS

Cool Down Can Reduce High Blood Sugar Risk After Vigorous Exercise

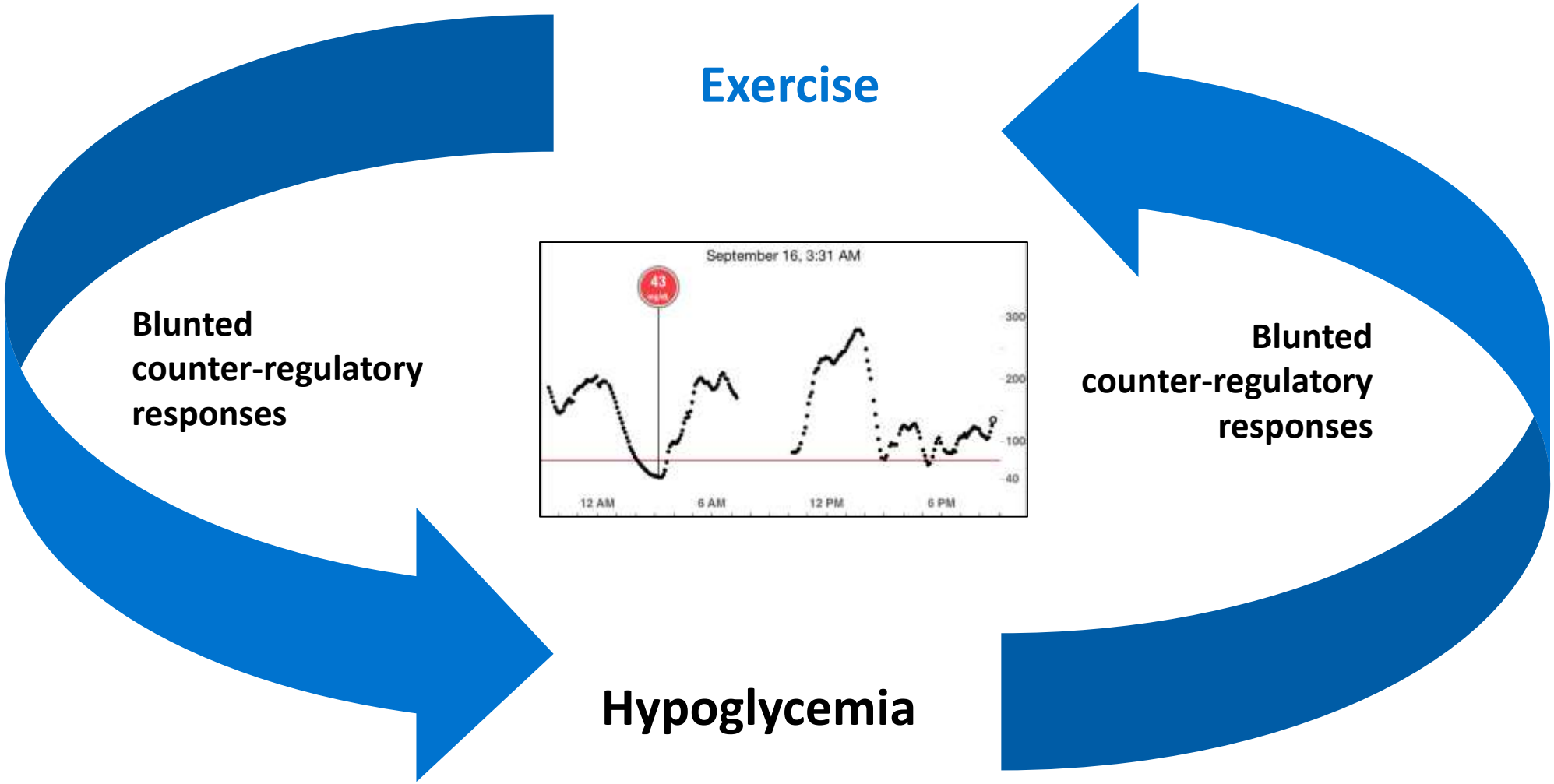
- Counter-regulatory hormones and high lactate levels may increase blood sugar levels after exercising
- High blood sugars shortly after exercise can be reduced by a prolonged passive cool down at a moderate intensity (ex. 15-20 min walking)
- Monitoring of glucose is essential

Modified from Exercise Physiology Energy, Nutrition, & Human Performance, 6e.
Editors: William D. McArdle, Frank I. Katch, Victor L. Katch.

KEY POINT #9

SHORT TERM RISK OF LOWS DURING EXERCISE IS INCREASED BY RECENT HYPOGLYCEMIA AND RECENT EXERCISE

Dangerous Cycle of Hypoglycemia and Exercise



Ertl AC, Davis SN. Diabetes Metab Res Rev. 2004 Mar-Apr;20(2):124-30.

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Summary

1. Different forms of exercise have different effects
2. Physiologic mechanisms maintain tight blood sugar levels during exercise in people without diabetes
3. Exercise in T1D leads to blood sugar imbalance due to altered physiology
4. Blood sugar uptake is high due to both insulin action and muscle contraction
5. Exercise has both immediate and delayed effects on blood sugar
6. The body adjusts its source of energy as intensity of exercise and overall fitness change
7. Insulin sensitivity increases with fitness
8. Cooldown minimizes increase in blood glucose levels after exercise
9. Short term risk of hypoglycemia during exercise is increased by recent hypoglycemia and recent exercise

GLUCOSE AND INSULIN MANAGEMENT

A CASE-BASED LOOK: MANAGING BLOOD SUGARS BEFORE, DURING, AND AFTER EXERCISE

Sara

- 18 year old, has had T1D for 15 years
- Uses an insulin pump
- HbA1c 8.1%
- Has struggled with her weight
- Daily calorie intake is approximately 2300 calories
- Exercise:
  - Wants to start with 3-4 days per week
  - Plans to use elliptical, also some weight lifting
- Exercise goals:
  - Weight loss, improved mental health, fitness, glucose control

- How should she adjust her insulin before, during, and after exercise?
- How will she be able to lose weight?

5 Factors to Consider

1. Type of exercise
2. Duration and intensity of exercise
3. Timing of exercise in relation to time of day and food intake
4. Insulin on board
5. Impact of previous exercise and previous hypoglycemia

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Frequent Glucose Monitoring Is Critical During Exercise

1. **The best way to avoid hypoglycemia is to regularly monitor/check glucose level before, during, and after exercise**
2. **People with T1D should not exercise if their glucose meter (or CGM) and strips are not readily available**

Riddell M, et al. *Lancet Diab Endo*. 2017;5:377-90.

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BEFORE EXERCISE

Bolus Insulin Dose Adjustment Before Aerobic Exercise

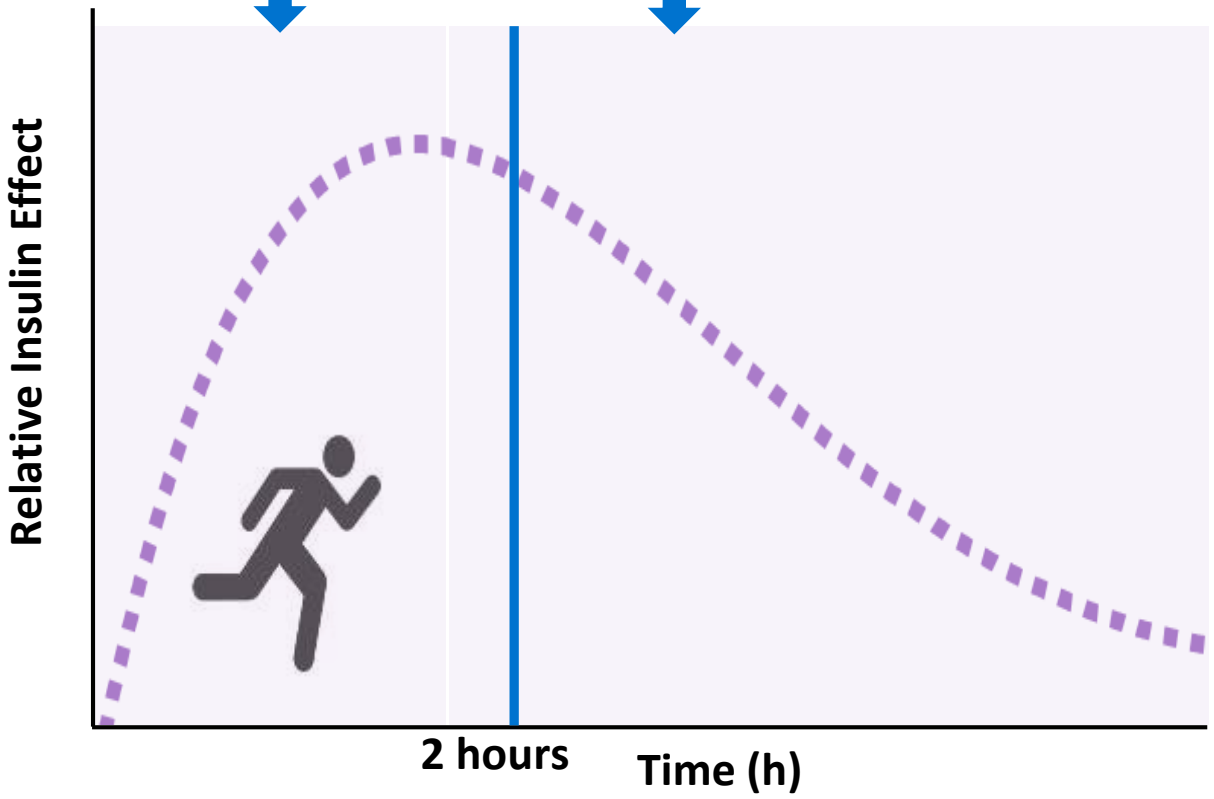
	Recommendations
Consider the amount of insulin on board!!	**This is the most important recommendation! The key to exercising successfully is matching the amount of insulin on board to the exercise and carb intake**
Exercise ≤ 2 hours after bolus insulin dose	▪ Reduce pre-exercise insulin dose by 25–75%
Exercise > 2 hours after bolus insulin dose	▪ Possibly no insulin adjustment (otherwise will run very high after meal) ▪ If blood glucose is running low, must consume carbohydrate

Mauvais-Jarvis F, et al. *Diabetes Care.* 2003;26:1316-7; Hernandez JM, et al. *Med Sci Sports Exerc.* 2000;32:904-10; Rabasa-Lhoret R, et al. *Diabetes Care.* 2001;24:625-30; West, et al. *Diabetic Med.* 2009;26:60; DirecNet Study Group, et al. *Diabetes Care.* 2006;29:2200-4.

Taking Additional Carbs Can Offset Insulin On Board

- Reduce pre-exercise insulin dose
- Consume carbohydrate with low glycemic index

- If blood glucose is running low, must consume carbohydrate



Nosek L, et al. *Diabetes Obes Metab.* 2013;15:77-83; Riddell M, et al. *Lancet Diab Endo*. 2017;5:377-90.

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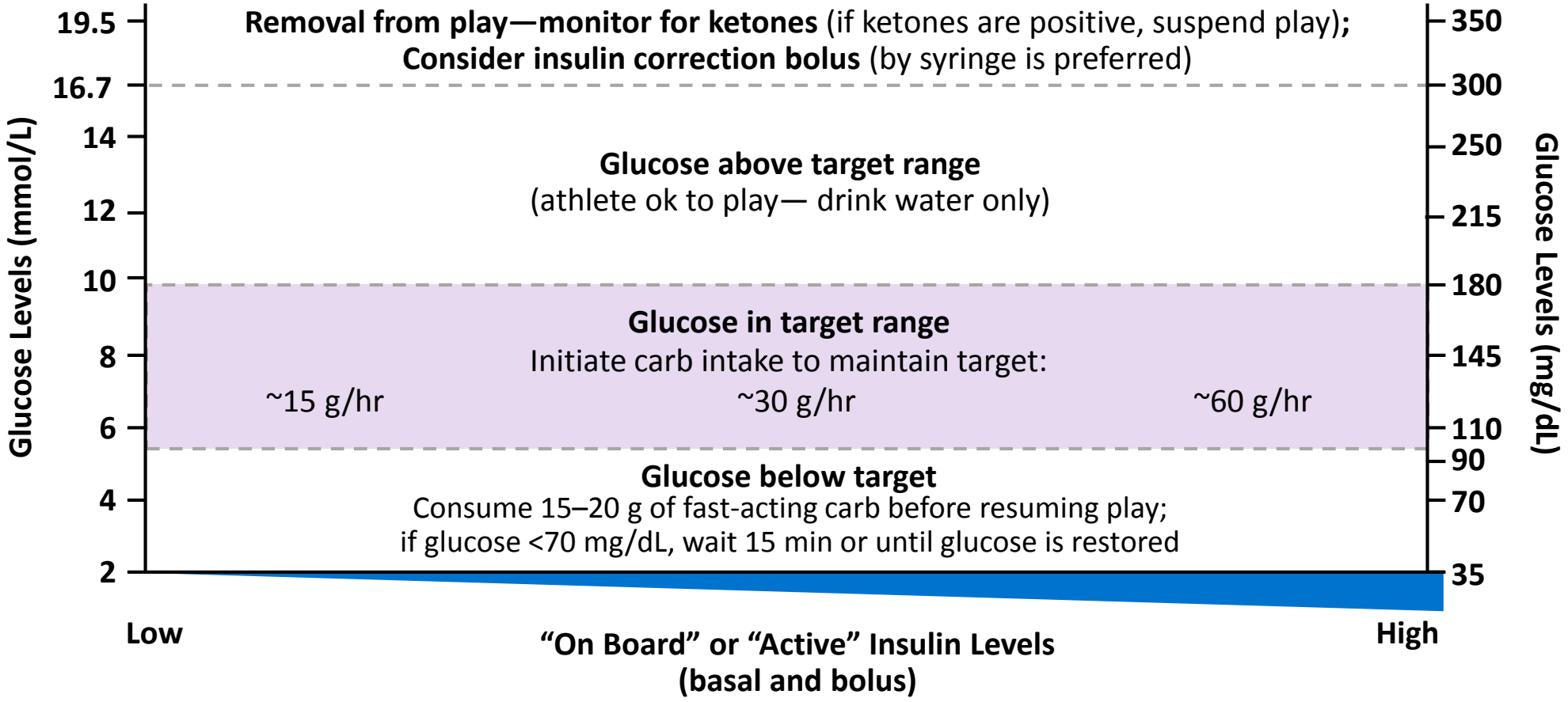
T1D Athlete Protocol



Riddell M, et al. *Lancet Diab Endo*. 2017;5:377-90.

Adjusting Basal Insulin

- **Basal** insulin provides background insulin that the body needs even in the fasted state (overnight and between meals) and for exercise
- Basal insulin, delivered either by pump or long-acting insulin analog, generally reaches a steady, stable level
- Therefore, in preparation for exercise, basal insulin needs to be reduced **in advance** of planned exercise

Expert opinion.

Basal Insulin

- **Basal** insulin delivered by pump needs to be reduced about 90 minutes before exercise to reduce circulating insulin levels for exercise
- Changes to **basal** insulin delivered by injection needs to be individualized due to differences in long-acting analogs; some can be reduced in the morning of the planned exercise
- Following exercise, **basal** insulin can be reduced in the evening or at bedtime to reduce risk of nocturnal hypoglycemia

Expert opinion.

Basal Insulin Dose Adjustment Before Aerobic Exercise

Patients on MDI

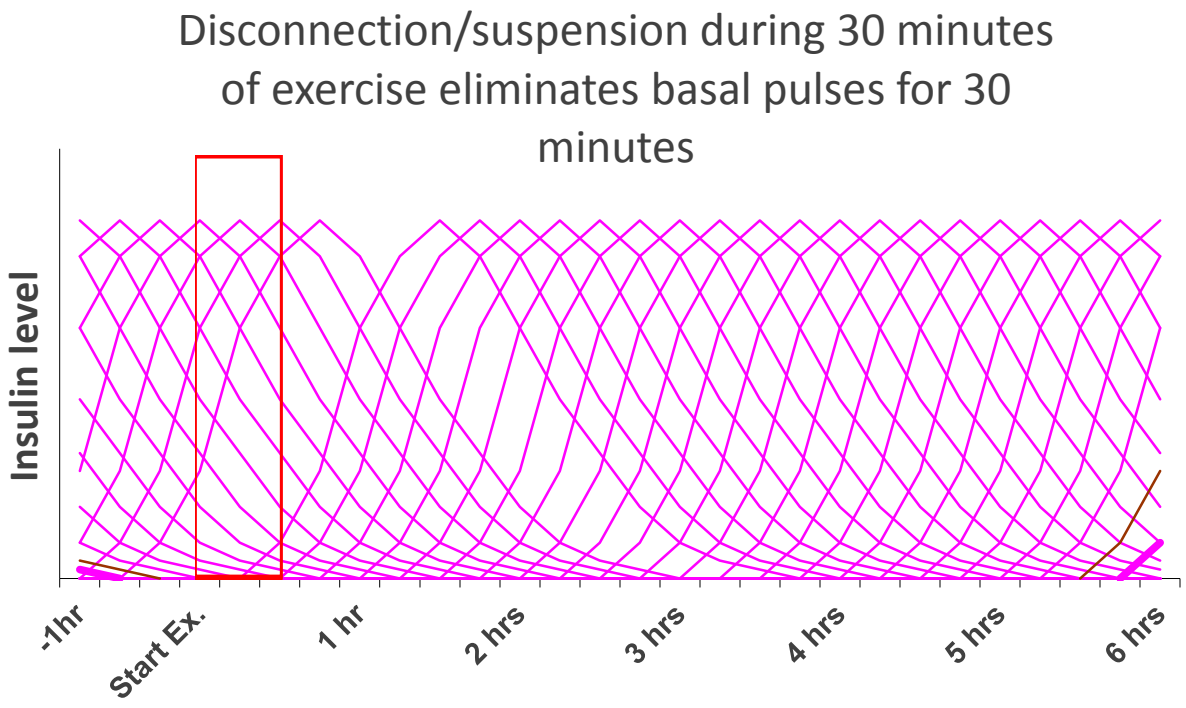
- Basal insulin dose adjustment is not routinely recommended
- If on twice daily basal, one could consider reducing one or both of the basal doses by 20%

Patients on Insulin Pumps

- Basal insulin dose reduction of 50–80% may be useful for exercise over 45–60 minutes
- Dose could be reduced up to 90 minutes before exercise

Riddell M, et al. *Lancet Diab Endo*. 2017;5:377-90.

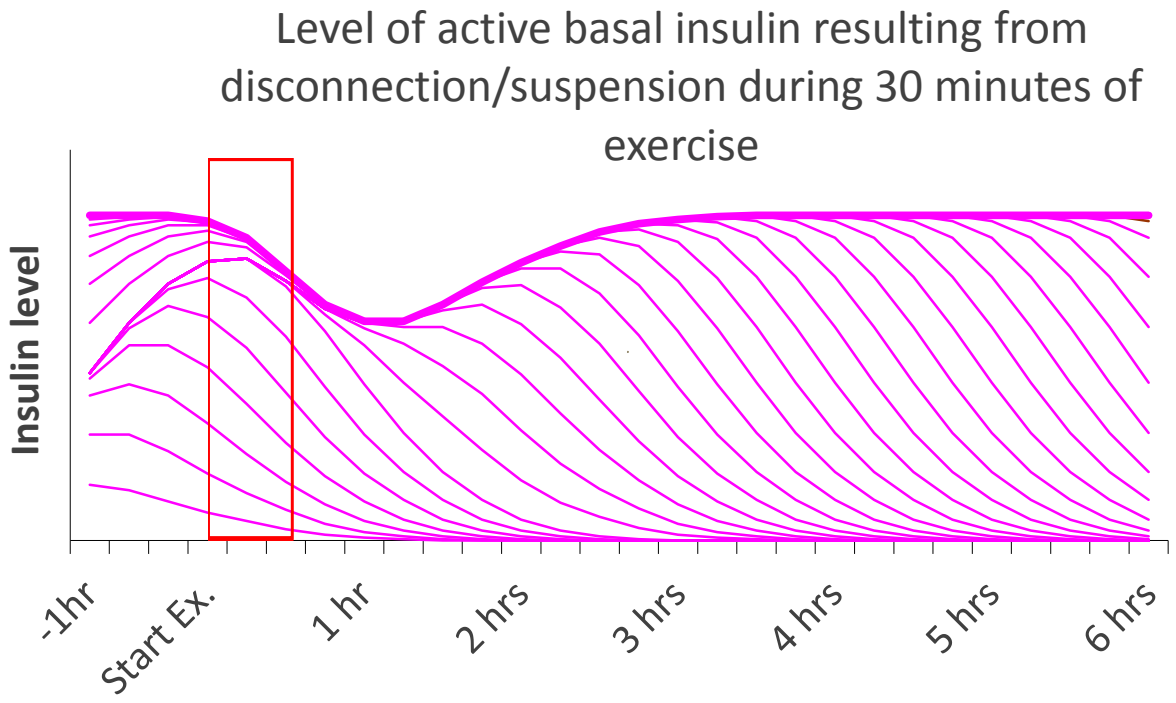
Effect of pump disconnection on basal insulin levels



Ex, exercise

Scheiner, G: Schematic representation of basal insulin delivery, based on pharmacokinetics of rapid insulin analogs.

Effect of pump disconnection on basal insulin levels



Disconnection during a short exercise session has minimal effect on insulin levels

Scheiner, G: Schematic representation of basal insulin delivery, based on pharmacokinetics of rapid insulin analogs.

Nutrition Before Exercise

	1–4 Hours	Within 10–15 Minutes
Carbohydrate	A meal based on low-fat, lower blood sugar impacting carbohydrate	Depending on blood sugar level, insulin on board and activity type
Protein	Include low-fat, high-quality protein (eg, lean meat, fish, milk, yogurt)	Not required
Fluid	5–10 mL/kg body weight in the 2–4 hours before exercise	Between 150–300 mL fluid depending on age/sex/environment

Thomas DT, et al. *J Acad Nutr Diet.* 2016;116:501-28; Burke LM, et al. *J Sports Sci.* 2011;29 Suppl 1:S17-S27; Coyle EF. *J Sports Sci*. 2004;22:39-55; Phillips SM. *Sports Med.* 2014;44 Suppl 2:149-53; Phillips SM, et al. *Int J Sport Nutr Exerc Metab.* 2007;17:S58; Riddell M, et al. *Lancet Diab Endo*. 2017;5:377-90.

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Recommendations Based on Starting Blood Glucose

Blood Sugar Concentrations	Recommendation
<90 mg/dL	▪ Ingest 10–20 g of glucose before exercise ▪ Delay exercise until blood glucose >90 mg/dL
90–124 mg/dL	▪ Ingest 10 g of glucose ▪ Exercise can be started, anaerobic and high-intensity interval training may be started without CHO
125–180 mg/dL	▪ Aerobic exercise can be started ▪ Anaerobic exercise and high-intensity interval training may be started, but levels may rise
181–270 mg/dL	▪ Aerobic exercise can be started ▪ Anaerobic exercise can be started, but glucose concentrations may rise
>270 mg/dL	▪ Check blood ketones and perform low-intensity exercise if ketones are not elevated, small corrective dose of insulin may be needed ▪ If modestly elevated (0.6–1.4 mmol/L), exercise should be restricted to a light intensity for only a brief duration (<30 min), small corrective dose of insulin may be needed ▪ If blood ketones are ≥1.5 mmol/L, exercise is contraindicated and corrective insulin dose should be given

Riddell M, et al. *Lancet Diab Endo*. 2017;5:377-90.

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Avoiding HYPERglycemia before exercise

- Cutting down insulin too much in advance may result in high blood glucose

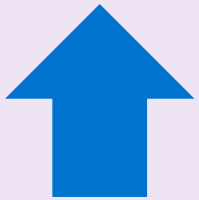
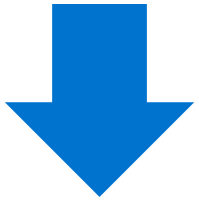
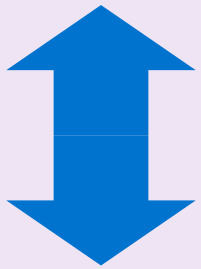
Recommendations:

- Eat pre-workout meal 3-4 hours before
- If eating close to workout time and reducing or skipping insulin, choose lower glycemic index or slower digested carbs

Riddell M, et al. *Lancet Diab Endo*. 2017;5:377-90.

DURING EXERCISE

Carbohydrate Needs Vary Based on Many Factors

Carbohydrate Need	Factors
	▪ Aerobic exercise ▪ Longer duration ▪ More insulin on board/no prior adjustment
	▪ Anaerobic exercise ▪ Short duration ▪ Exercise without insulin on board ▪ Insulin dose reduced (adjusted) with meal before exercise
	▪ Competition ▪ New sport/unfamiliar activity

Riddell M, et al. *Lancet Diab Endo*. 2017;5:377-90.

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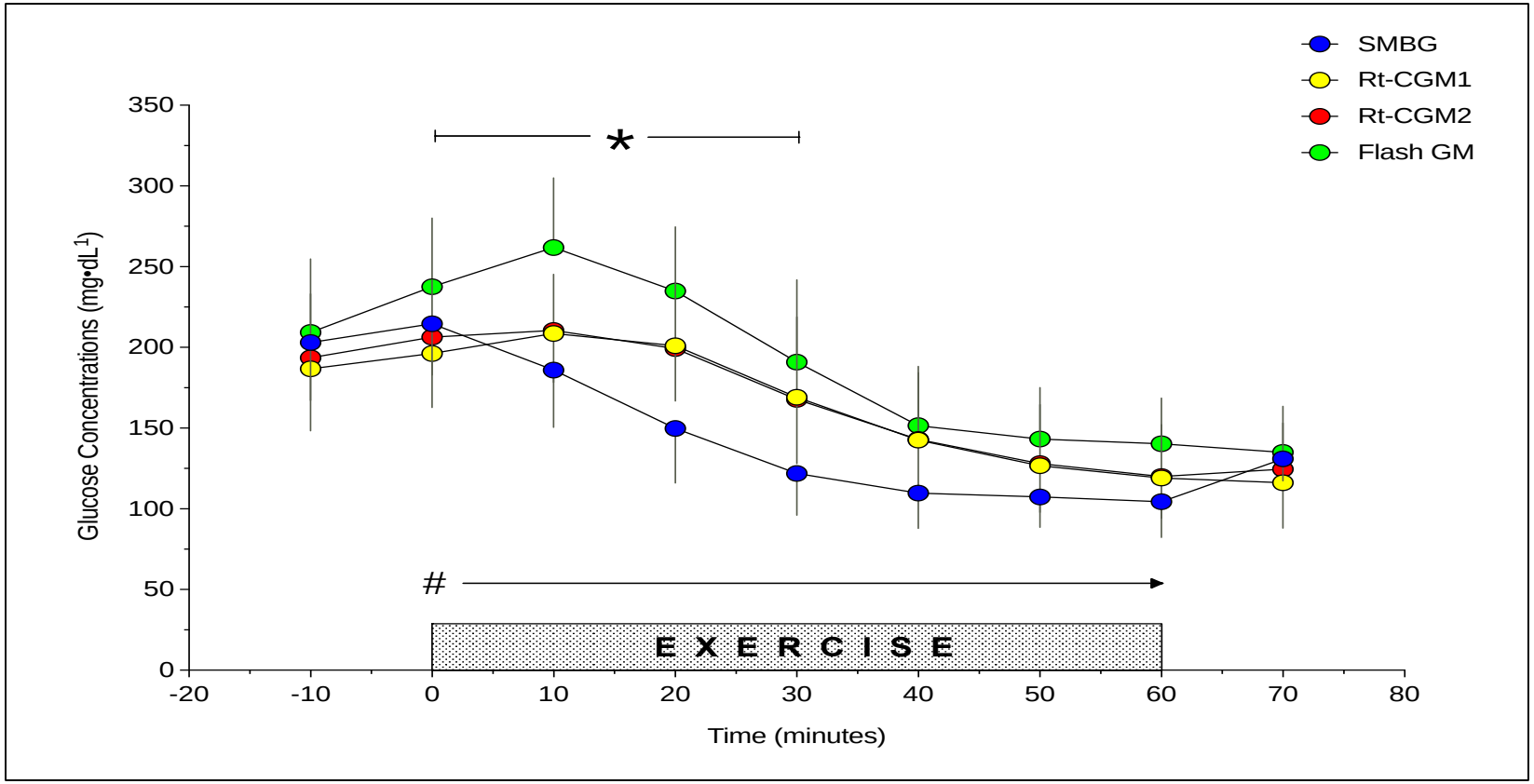
Comparing the Accuracy of CGM vs Fingerstick Glucose During Exercise

- 1 hour run
- 3 sensors: DEXCOM G5, Medtronic 670g, and FreeStyle Libre CGM
- All sensors can overestimate blood glucose during periods of rapid decline



Zaharieva, D. Henske, J. Journal of Diabetes Science and Technology 2019

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Nutrition Needs During Exercise

	30 mins	30–60 mins	>60 mins
Carbohydrates (drink/gel)	• Not needed unless blood sugar dropping	• May be needed if very strenuous activity or no insulin adjustment	• May be needed for fuel • 30–60 g/h (0.5–1 g/kg for a child) • For ultraendurance (>3 hr) up to 90 g/h; consider choices with more significant blood sugar impact
Fluid	• Water should be adequate for hydration	• Drink appropriate amount* of fluids to replace sweat losses so that total body fluid deficit is <2% BW	• May benefit from use of sports drinks (exercise >60 minutes)

* Depends on exercise intensity, duration, fitness, heat acclimatization, altitude, and environment (eg, humidity)

Thomas DT, et al. *J Acad Nutr Diet.* 2016;116:501-28.

Avoiding HYPERglycemia
During Aerobic Exercise

- Hyperglycemia <u>during</u> exercise is usually due to:
  - rapid-acting carbohydrate just before exercise
  - anxiety about blood sugars
  - adrenaline during the competition
  - too much decrease in basal insulin rate

- Recommendations:
  - ingest 20 g carbohydrate if blood sugars are below target before exercise
  - use CGM to monitor changes
  - reduce competition-related anxiety with meditation or visualization
  - use extra caution with insulin boluses during exercise

AFTER EXERCISE

Basal Insulin Dose Adjustment After Exercise: MDI vs Insulin Via Pump

MDI

- Consider basal adjustment
- Encourage increased carbohydrate consumption to prevent nocturnal hypoglycemia
- Check blood sugar during the night

Pump

- Reduce insulin dose by 20% for up to 6 hours (eg, 9 p.m. to 3 a.m.)
- Encourage increased carbohydrate consumption
- Check blood sugar during the night

Riddell M, et al. *Lancet Diab Endo*. 2017;5:377-90.

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Nutrition After Moderate-to-Intense Exercise

Carbohydrate

- Aim for 1 g/kg body weight carbohydrate eaten within 1–2 hours after exercise to replenish glycogen stores

Protein

- Protein should be consumed within 30-60 minutes of training for optimal muscle protein synthesis
- Addition of 15–25 g protein to a meal along with carbohydrate can help to reduce hypoglycemia risk and enhance glycogen synthesis

Fluid

- Drink fluids post exercise with food to maximize rehydration

Thomas DT, et al. *J Acad Nutr Diet.* 2016;116:501-28.

Managing HYPERglycemia
After Aerobic Exercise

- Hyperglycemia after exercise is usually due to:
  - persistent adrenaline combined with decreased glucose needs from muscle
  - delayed glucose absorption from carbohydrate used during exercise
  - decreased basal insulin rate
- Recommendations
  - Because insulin sensitivity is still increased, consider a conservative bolus of 50% of usual correction at first
  - low-intensity cooldown of 10-15 minutes of walking

OTHER CAVEATS AND CONSIDERATIONS

Some Situations Require Additional Considerations

- Insulin adjustments may be more complex for those using hybrid closed-loop pumps or ultra-long-acting basal insulins
- Consider differences in absorption times for various insulin preparations (inhaled, faster acting, etc.)
- Impact of emerging therapies for T1D such as SGLT2 inhibitors on glycemic control during exercise are largely unknown

GLUCOSE AND INSULIN MANAGEMENT
CASE WRAP UP

Exercise Recommendations

- For planned 30 minutes of elliptical at gym:
  - Decrease pump basal rate by 50% 1 hour before, during, and 1 hour after exercise
  - Reduce carbohydrate bolus by 50% for meals and correction doses within 2 hours of planned exercise—both before and after—to limit the need for extra carbohydrates to prevent hypoglycemia while working on weight management and glycemia
- Reduce basal rate 20% x 4–6 hours at bedtime after exercise in the afternoon to avoid nocturnal hypoglycemia

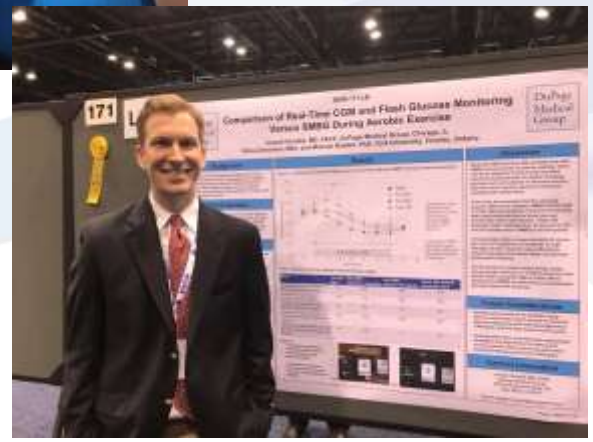
Eating Plan Recommendations

- Continue carbohydrate counting
- Aim for modest calorie restriction of 1800–2000/day; eat 3 meals and 1 snack each day:
  - Carbohydrates: 50% of calories
  - Protein: 20% of calories
  - Fat: 30% of calories

Summary of Considerations for Balancing Blood Sugar Control and Exercise

- You and your doctor should discuss your individual goals for exercise
- Type, duration, and intensity of exercise play a significant role in management
- Timing of exercise and meals is important
- Assess insulin “on board” (active insulin) at exercise time
- Consider the impact of previous exercise and/or hypoglycemia
- Delivery modality is an important factor in management
- Patients and their healthcare team should discuss glucose targets, trends, and available tools to measure

Thank you for you participation and attention!



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