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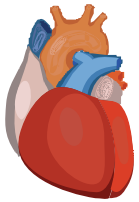


BREAKOUT SESSION #1

THE FUNDAMENTALS OF EXERCISING WITH T1D

Exercise Has Many Benefits for People with T1D

- Weight management 
- Reduced heart disease risk
 - Lower blood pressure
 - Lower bad cholesterol, raise good cholesterol
- Improved HbA1c and insulin sensitivity



- Psychological benefits
 - Improved sense of well-being
 - Improved self-esteem

- Reduced other complications

 – Eye

 – Kidney

There are Barriers to Exercise Among People with T1D – But They Can be Overcome!

Health and medical

- How blood glucose could be affected by activity
- Low blood sugars
- Complications (problems with eyes, feet, kidneys)
- Other non-diabetes-related health problems

Time, work, and lifestyle

- Demands on people with diabetes can be greater than for most people
- Demands in the home or caring for children or relatives
- Perceived lack of time

Others

- Low level of motivation to exercise
- Embarrassment or fear of failure
- Body image concerns
- Cost and access to facilities
- Weather

Factors that Contribute to Increased Lows During Exercise in T1D

	People <u>Without</u> Diabetes	People <u>With</u> Diabetes
Insulin	Don't make insulin during exercise	Can't turn off the insulin that has been injected (aka insulin on board)
Absorption and action of insulin	Insulin action is fast	Insulin action can take a while to start and remains longer (Too much insulin causes the muscles to take in more sugar from the blood leading to less sugar in the blood being available for the brain)
Counter-regulation	Working properly	Diabetes blunts counter-regulation (The body's natural defense against low blood sugar is not working in people with diabetes)
Liver sugar	Liver stores sugar properly	Reduced production of sugar in the liver

PHYSIOLOGY IN ACTION

A CASE-BASED LOOK AT T1D AND EXERCISE

KEY POINT #1

DIFFERENT FORMS OF EXERCISE HAVE
DIFFERENT EFFECTS

Intense Exercise Can Cause High Blood Sugars and May Increase Insulin Needs Afterwards

- Glucose is exclusive fuel used during intense exercise
- An intense sprint (10 second) can cause blood sugars to go up

Resistance Exercise Is a Good Way To Avoid Lows

- Resistance exercise (for example weight lifting) causes sugar levels to drop very little (over 40 minute time period)
- Aerobic exercise causes sugar levels to drop a lot (over 40 minute time period)
- Adding resistance training before aerobic activity can help minimize lows
 - Reduces declines in blood glucose
 - May reduce need for carbs during exercise
- Carry carbohydrates when exercising

Key Considerations for Managing Glucose Levels in Physically Active Patients with T1D

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 low blood sugar

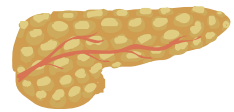
KEY POINT #2

PEOPLE MAINTAIN “NORMAL” GLUCOSE LEVELS
THROUGH PHYSIOLOGY

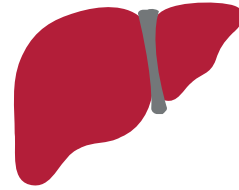
Without Diabetes: Physiologic Mechanisms Maintain Tight Glucose Levels During Exercise



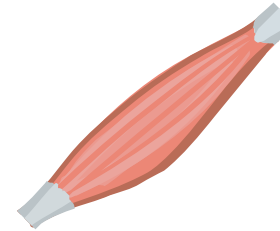
- Brain
 - Adrenaline: sugar up



- Pancreas
 - Insulin: sugar down
 - Glucagon: sugar up



- Liver (sugar stores):
 - Sugar released



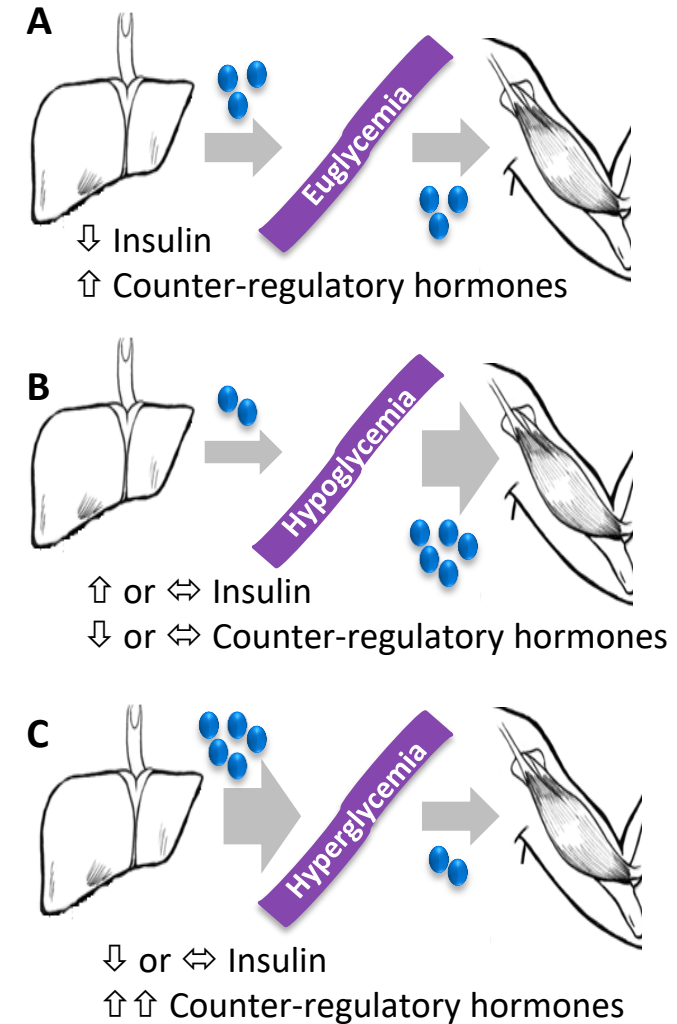
- Muscles
 - Stores sugar as well

KEY POINT #3

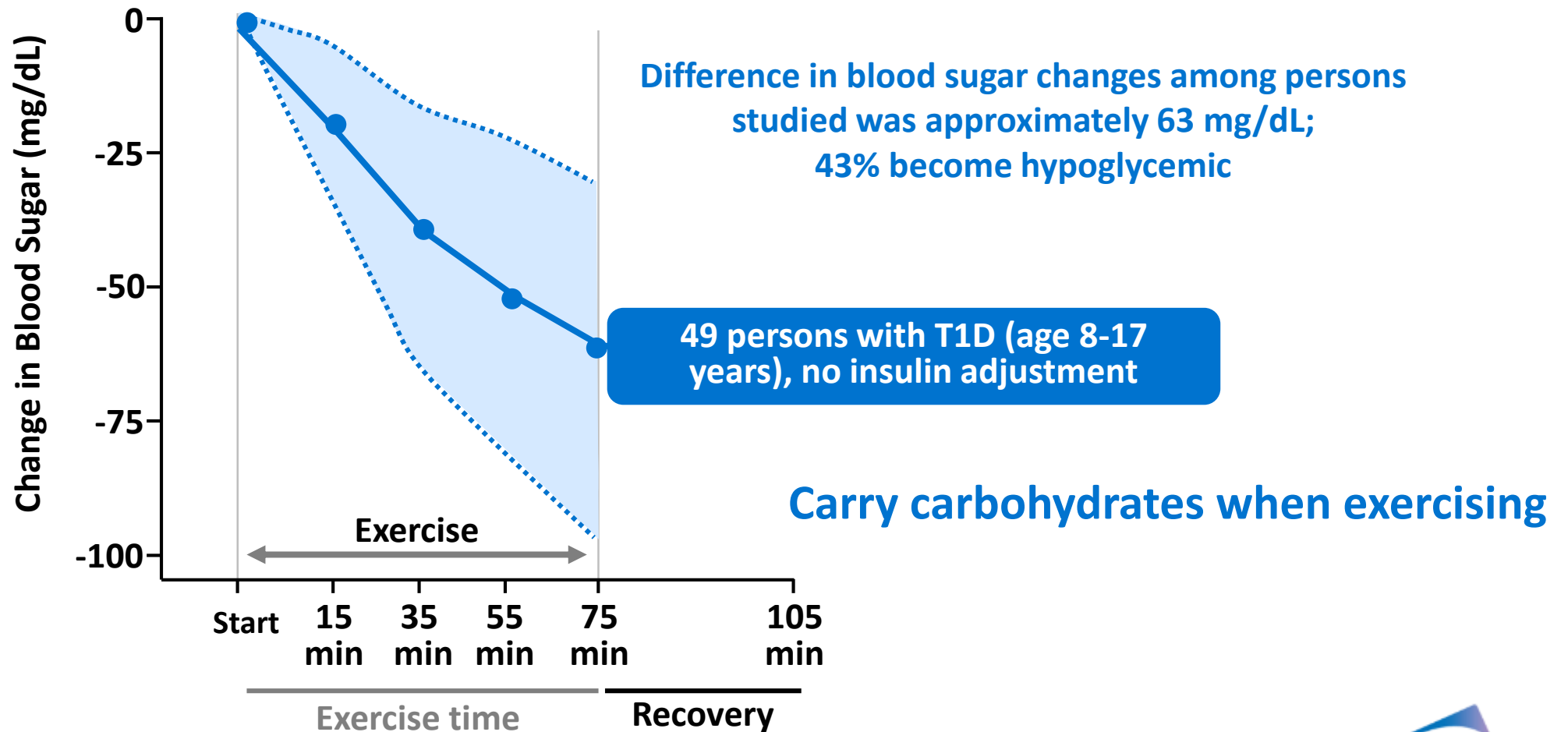
EXERCISE IN T1D LEADS TO GLUCOSE IMBALANCE DUE TO ALTERED PHYSIOLOGIC RESPONSES

Exercise in T1D Can Lead to Low or High Blood Sugar Levels

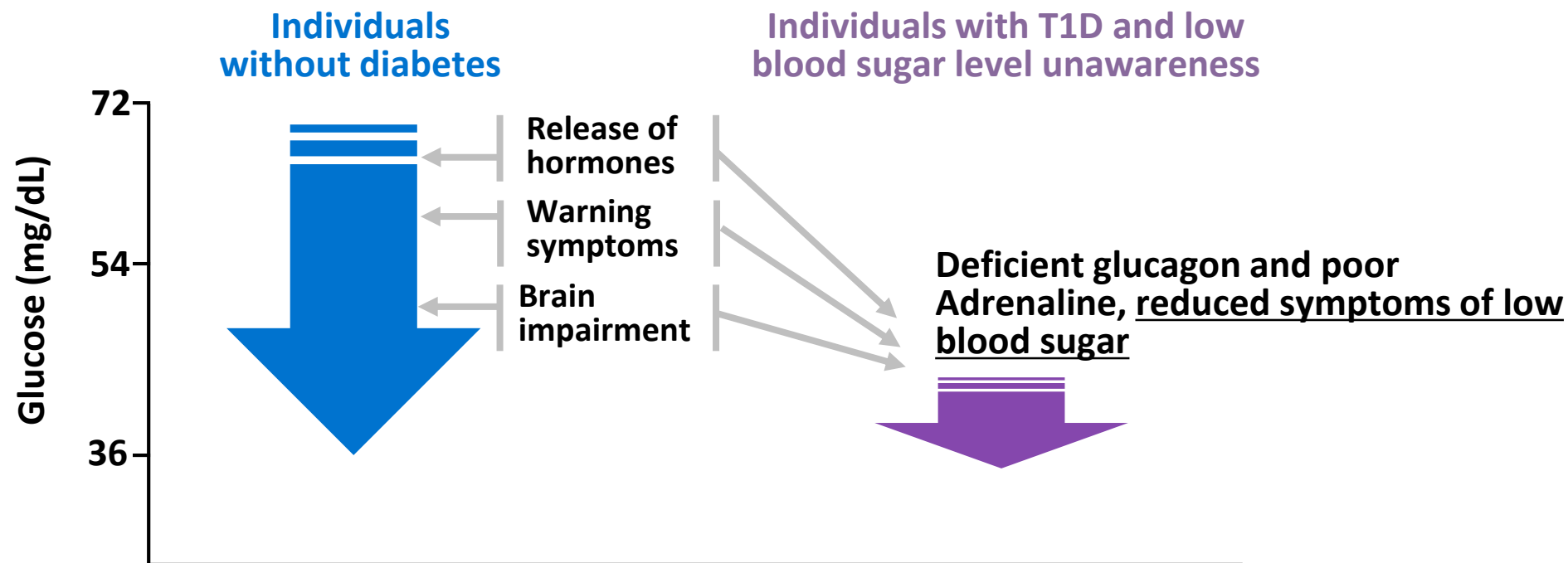
- During normal blood sugars
 - ↓ insulin
 - ↑ counter-regulation (hormones such as glucagon, growth hormone, cortisol, catecholamines)
- During Lows
 - Too much insulin on board
 - Broken counter-regulation
- During Highs
 - Too little insulin on board
 - ↑ counter-regulation (hormones including catecholamines, etc)
 - Anaerobic metabolism (lactate production)



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



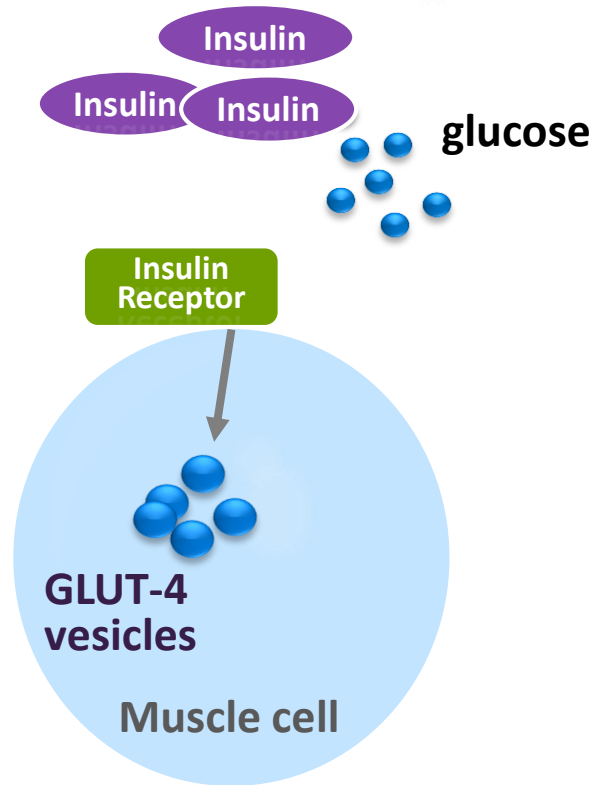
Symptoms of Lows May Be Blunted in T1D



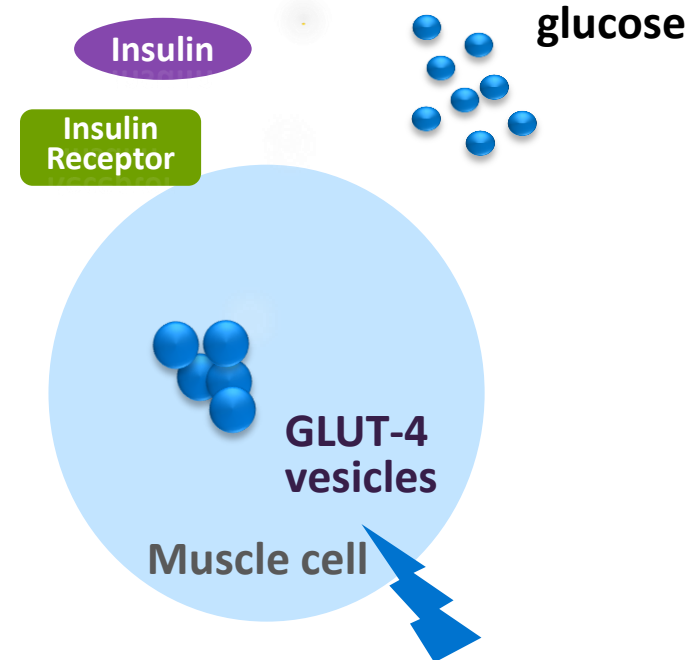
KEY POINT #4

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

Both Insulin and Muscle Contraction Increase Glucose Uptake into Muscles

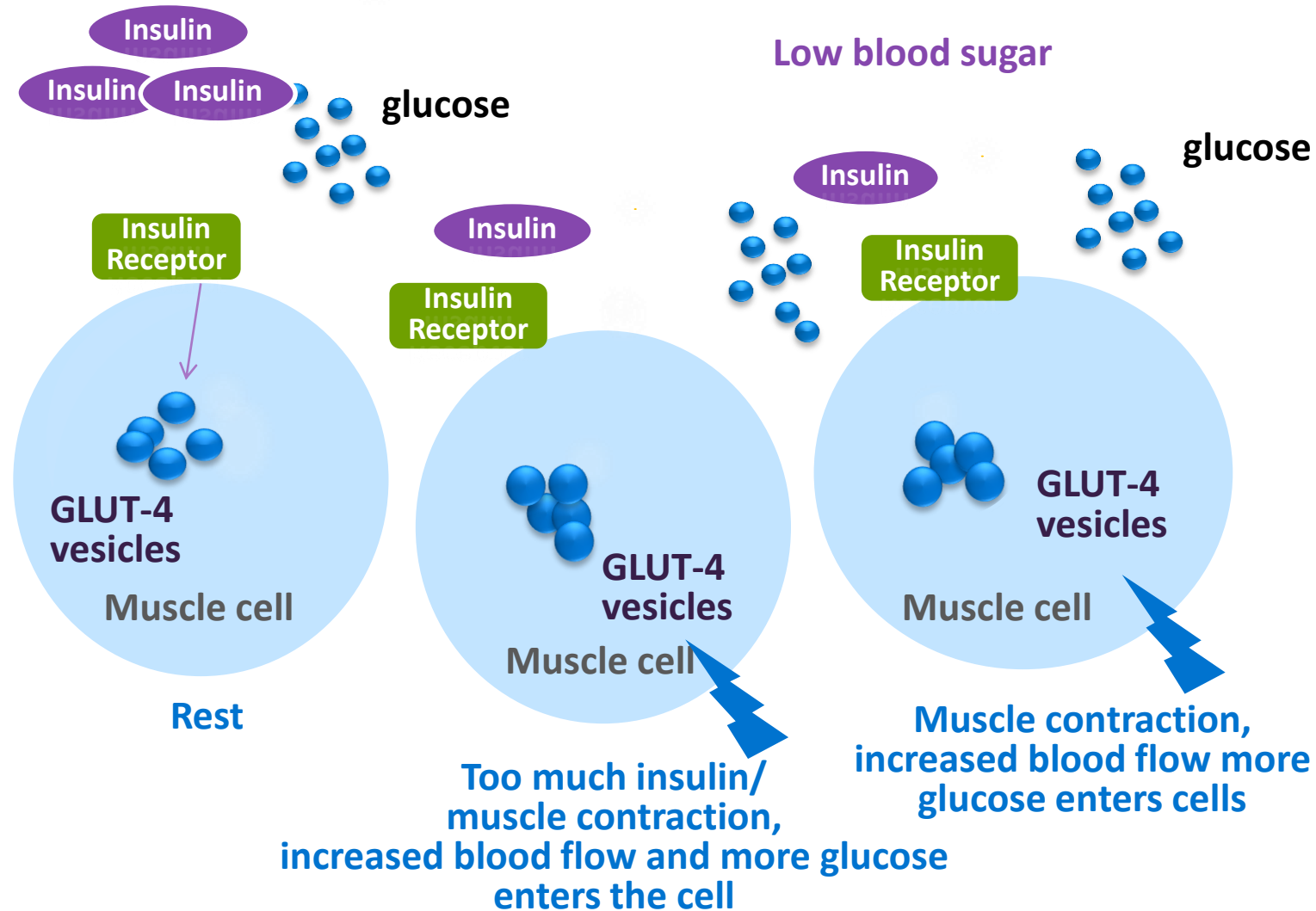


At rest insulin causes muscles cells to take glucose from the blood



Muscle contraction alone can cause glucose to enter the cell

Exercise: Both Insulin and Muscle Contraction Increase Glucose Uptake into Muscles– Increased Risk For Lows!



KEY POINT #5

COOLDOWN MINIMIZES INCREASE IN AFTER EXERCISE
HIGH BLOOD SUGARS

Cool Down Can Reduce High Blood Sugar Risk After Vigorous Exercise

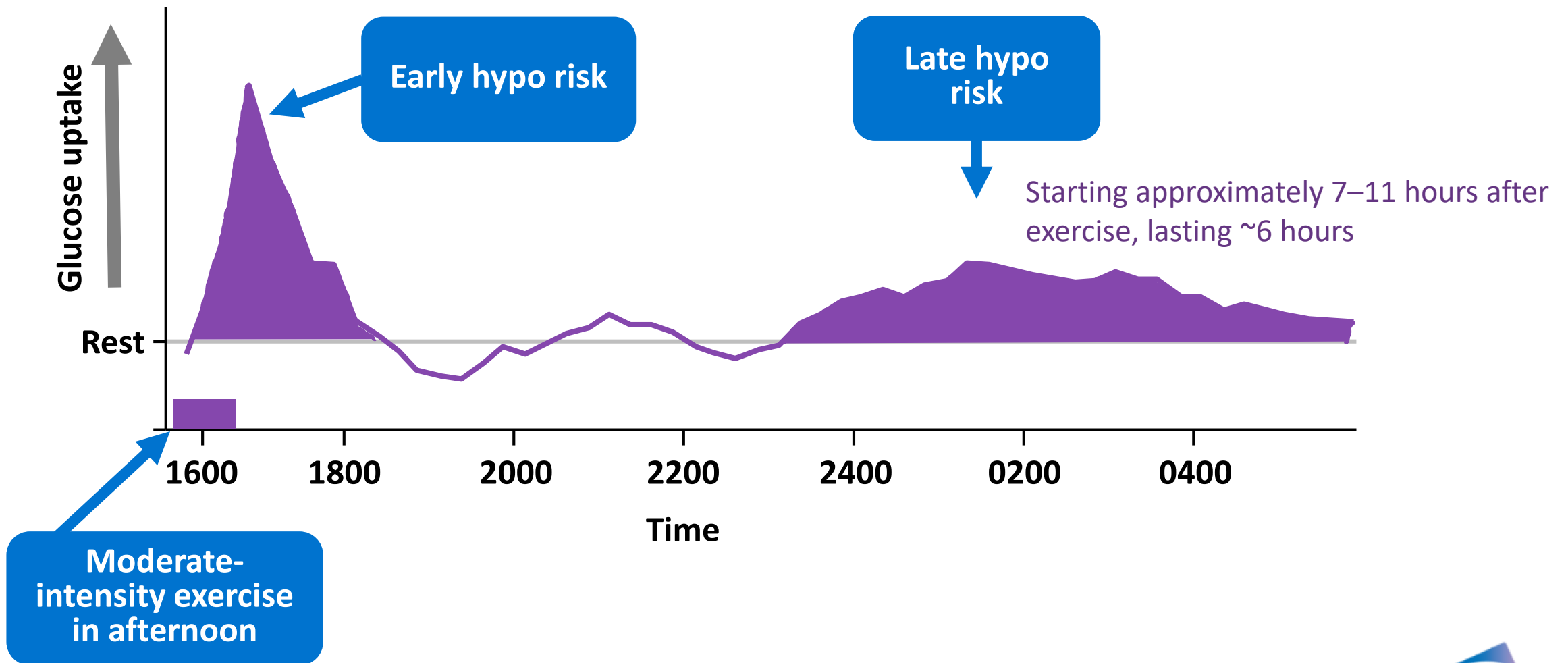
- Sitting after anaerobic activity can easily spike blood glucose
 - Due to low insulin, no muscle contraction
- High blood sugars shortly after exercise can be reduced by a 15-20 min passive cool down at a moderate intensity
- Monitoring of glucose is essential



KEY POINT #6

EXERCISE HAS BOTH IMMEDIATE AND DELAYED EFFECTS ON BLOOD SUGAR

After Exercising, Blood Sugars “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.

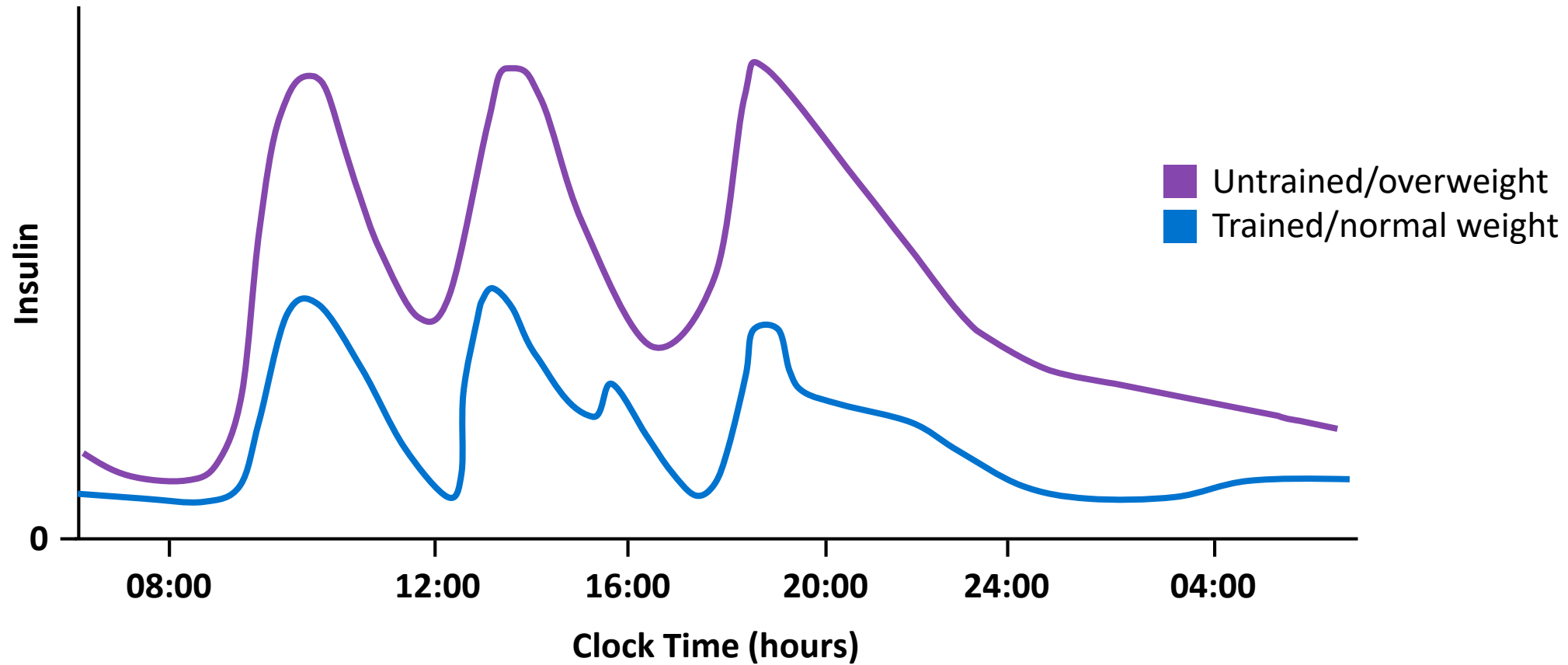
KEY POINT #7

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

- The more fit you are the more insulin sensitive you are
- Lower intensity exercise more fat is burned
- Higher intensity exercise more glucose and glycogen are burned
- Training increases fat burning and spares muscle and liver sugar stores

Training Increases Insulin Sensitivity and May Lower Insulin Requirements



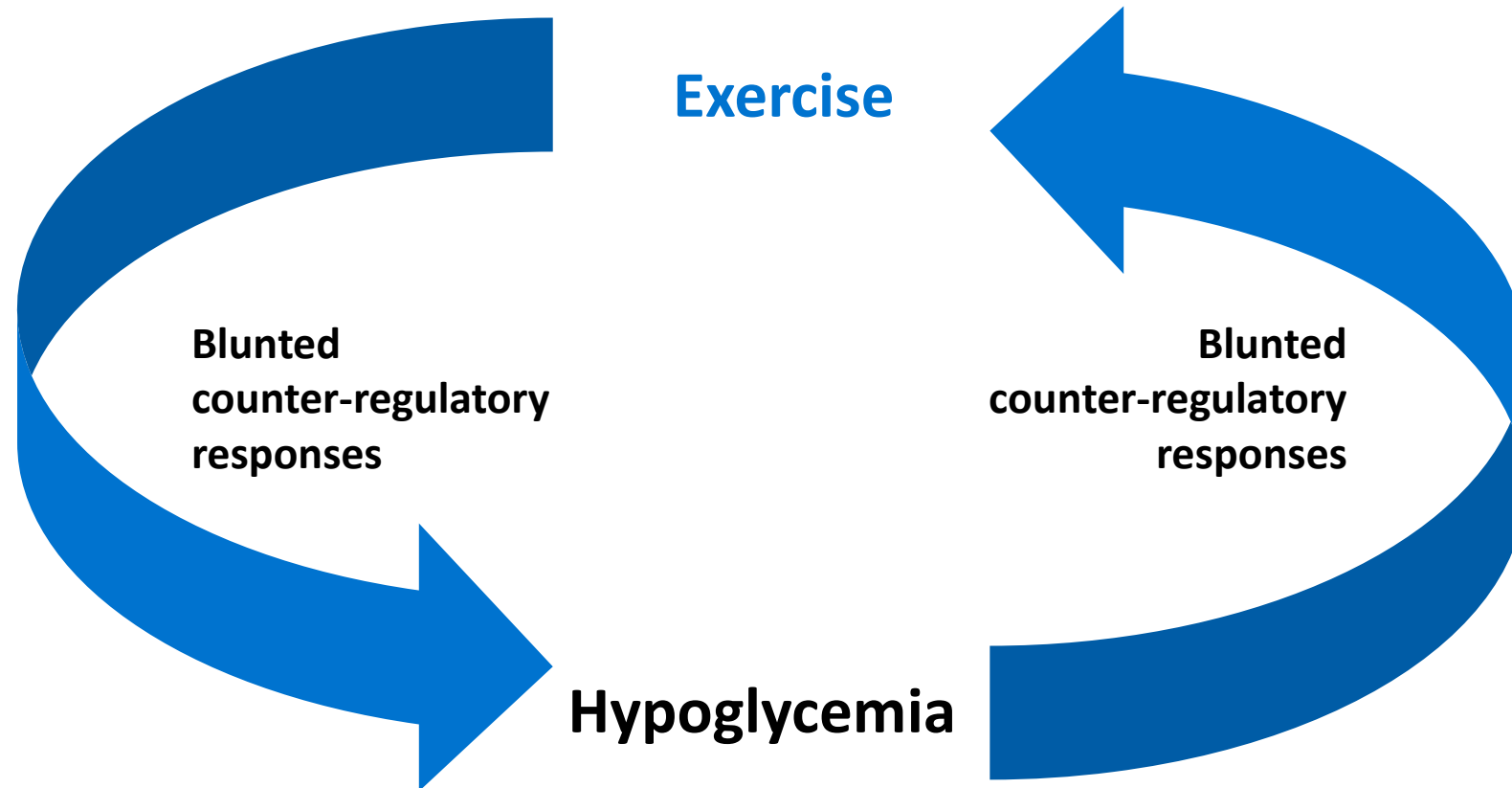
Schematic; derived from expert opinion.

KEY POINT #8

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

Dangerous Cycle of Hypoglycemia and Exercise

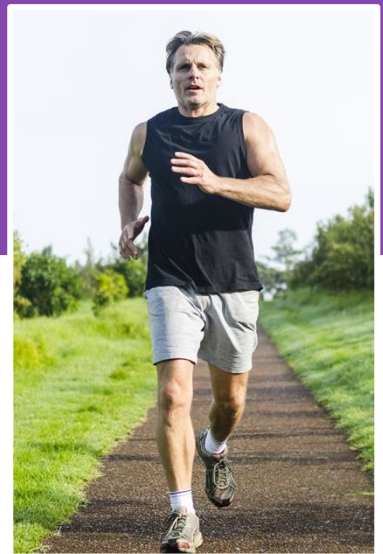
Repeated occurrence of post-exercise low blood sugar levels can lead to reduced counter-regulation, which in turn may increase risk of low blood sugar levels and hypoglycemic unawareness





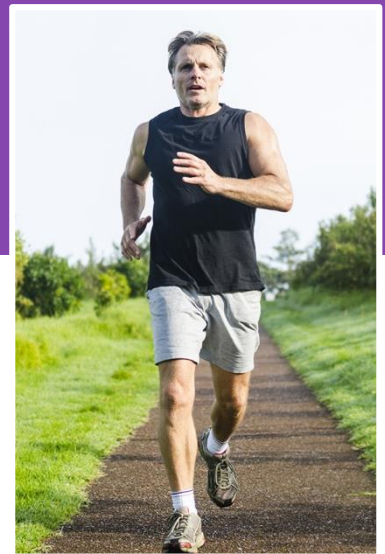
Andrew

- 45-year old man who has had T1D for 30 years
- HbA1c usually 7.0-7.5%
- No significant complications
- Current diabetes treatment:
 - Insulin pump and CGM
- Andrew wants to increase the intensity and frequency of his exercise
- Has had occasional low blood sugar with exercise, resolved with increases in carbohydrates





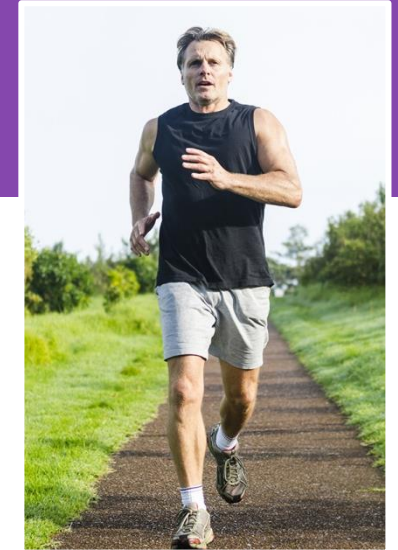
Andrew's Recent High Blood Sugar Experiences



- High blood sugar PRIOR to exercise
 - Ate a banana, energy bar and had coffee 1 hour before a run
 - Reduced insulin bolus by 50%
 - Blood sugars rose to 280 mg/dL
- High blood sugar DURING exercise
 - On race day (10K), reduced basal rate by approximately 50% 1 hour before race
 - 30 min before race blood sugar was lower than he'd like to start the race (110 mg/dL) so he had a banana
 - 10 min before race, blood sugar was still low, so he had 5 glucose tabs
 - Started the race at 250 mg/dL
- High blood sugar AFTER exercise
 - After a bike ride, blood sugar was 120 mg/dL
 - Pump was set at 50% of basal starting 90 min before the ride
 - Consumed 20g carbohydrate every 30 min during the 1 hour ride
 - After shower, blood sugars rose to 220 mg/dL



Recommendations for Managing High Blood Sugar Before Aerobic Exercise

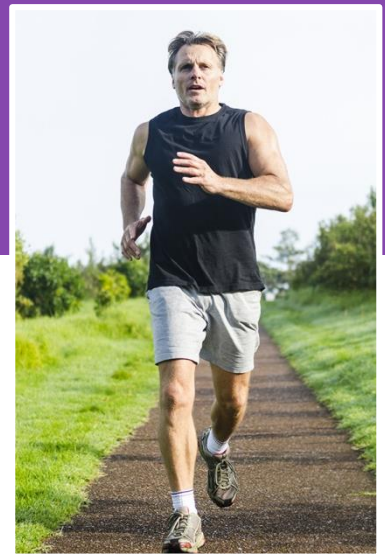


- Why does it happen?
 - Reducing insulin on board before exercise to avoid low blood sugar levels during workout is associated with increased risk of high blood sugar, especially when eating foods that contain carbohydrate
- How can you reduce risk?
 - Eat 3–4 hours before exercise or workout in fasting state
 - If meal is closer to workout, choose slowly digested carbohydrates
 - Insulin adjustments before short-duration (30 minutes or less) workouts should be in pre-meal insulin only (25% reduction) ; no change in basal insulin is needed



Andrew's Recent High Blood Sugar Experiences

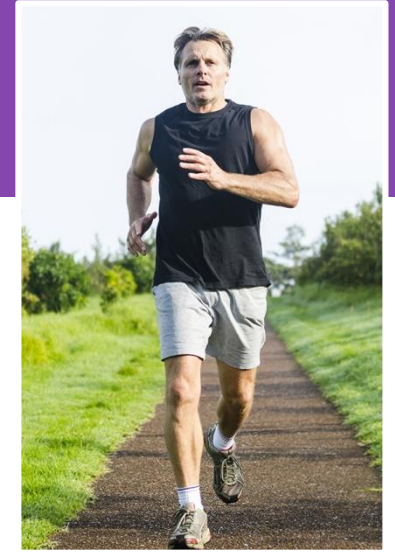
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Recommendations for Managing High Blood Sugar During Aerobic Exercise

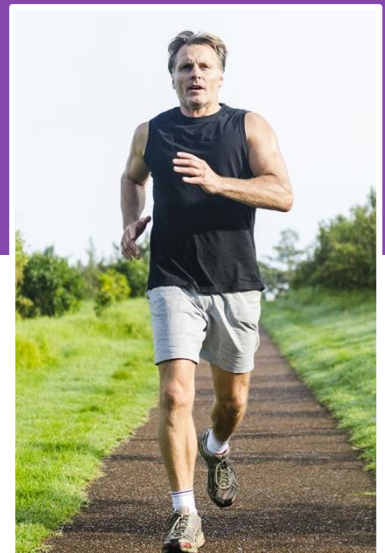
- Why does it happen?
 - Rapid-acting carbohydrate just before exercise
 - Anxiety about blood sugars
 - Excitement during the competition
 - Too great a reduction in basal insulin rate
- How can you reduce the risk?
 - Take 20 g carbohydrates before exercise if sugar is below target at start
 - Minimize basal insulin reduction
 - Meditation or visualization exercises may be helpful to reduce anxiety and therefore a high blood sugar level spike
 - Use insulin boluses via pump during long aerobic exercise carefully; 1 unit of insulin may be as effective as 2 units (or more) when you are at rest





Andrew's Recent High Blood Sugar Experiences

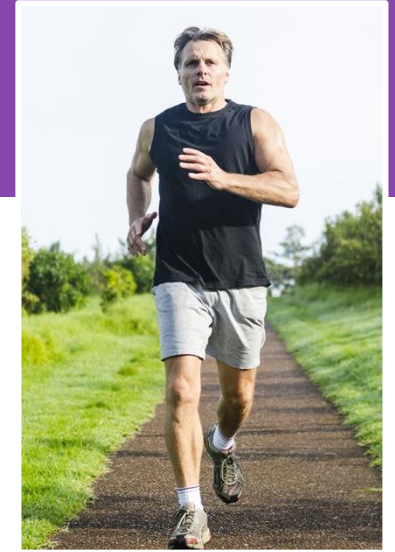
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 - After shower, blood sugars rose to 220 mg/dL





Recommendations for Managing High Blood Sugar After Aerobic Exercise

- Why does it happen?
 - Persistent adrenaline hormones causing insulin resistance combined with a drop in muscle glucose uptake after exercise
 - Decreased basal rate or delayed glucose absorption from carbohydrate eaten during workout
- How can you minimize the risk?
 - Consider a conservative bolus of 50% of usual correction for post-workout hyperglycemia
 - Low-intensity cooldown of 10–15 minutes of walking would also reduce the spike in blood sugars



Summary

1. Different forms of exercise have different effects
2. People maintain normal blood sugar through physiology
3. Exercise in T1D can lead to glucose imbalance
4. Blood sugar can change due to both insulin action and muscle contraction
5. Cooldown minimizes increase in blood sugar after exercise
6. Exercise has both immediate and delayed effects on blood glucose
7. The body adjusts its source of energy as intensity of exercise and overall fitness change
8. Short term risk of low blood sugar levels during exercise is increased by recent hypoglycemia and recent exercise

BREAKOUT SESSION NUMBER 2

FUNDAMENTALS OF GLUCOSE AND INSULIN MANAGEMENT BEFORE, DURING, AND AFTER EXERCISE FOR PEOPLE WITH T1D

GLUCOSE AND INSULIN MANAGEMENT

A CASE-BASED LOOK AT T1D AND EXERCISE



Sara



- 18 year old woman who has had T1D for 15 years
- Current diabetes treatment:
 - Insulin pump
- Target blood glucose: 100 mg/dL during day, 120 mg/dL during nights
- HbA1c 8.1%
- Has struggled with her weight since mid-teen years, now considered obese
- Also struggles with mild anxiety and depression
- Interested in starting an exercise program for fitness, mental health, weight management, and glycemic control



Current Eating Patterns

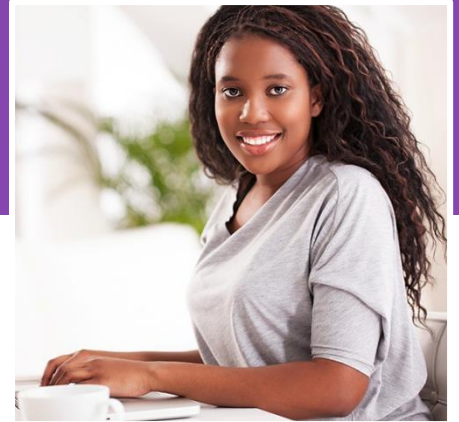
- Carbohydrate counting
- No dietary restrictions
- Often omits entering carbs into pump, mainly using experienced estimation
- Total calories 2300/day; 3 meals with 1 snack daily
 - Carbs: 178 g
 - Protein: 147 g
 - Fat: 108 g
- **Wants to lose weight:** her primary goal is to avoid college weight gain; she also wants to limit the need to treat low blood glucoses during exercise





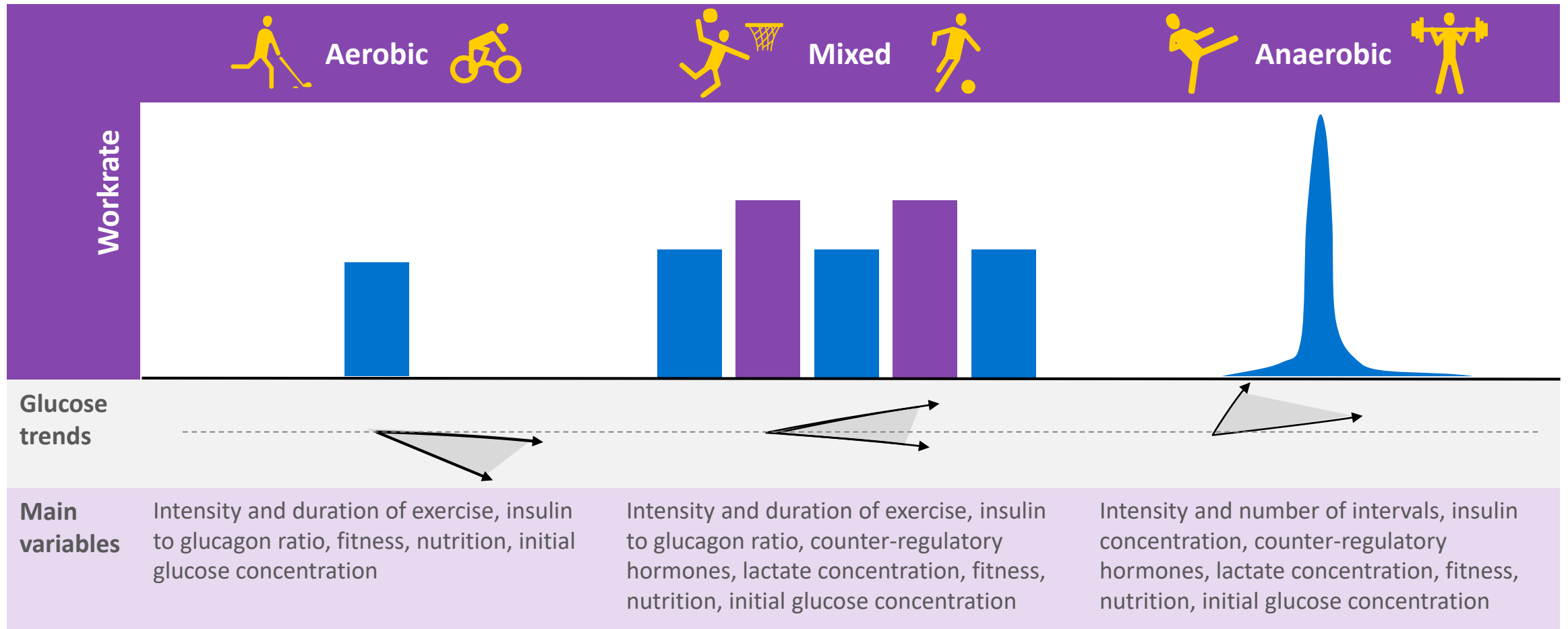
Current Exercise Plan

- Modest exercise, works with children at day camp
- Plans to go to college gym twice weekly to use the elliptical machine
- May try weight lifting, too
- Sara agrees to resume CGM use
- **So what happens to Sara when she starts exercising?**
- **How should Sara's insulin and nutrition be adjusted?**



KEY CONSIDERATIONS

Blood Glucose Effects of Different Types of Exercise



General Carbohydrate Recommendations Related to Exercise

- Carbohydrate is the major fuel source for exercise
- Requirements will vary widely
- **Carbohydrate may be needed during exercise for performance, low blood sugar prevention, or both**
- Distribution and timing of carbohydrate intake is important
- Consider including part of daily carbohydrate intake in the period 4–5 hours after exercise

Frequent Glucose Monitoring Is Critical During Exercise

- 1. The best way to avoid low blood sugar 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**

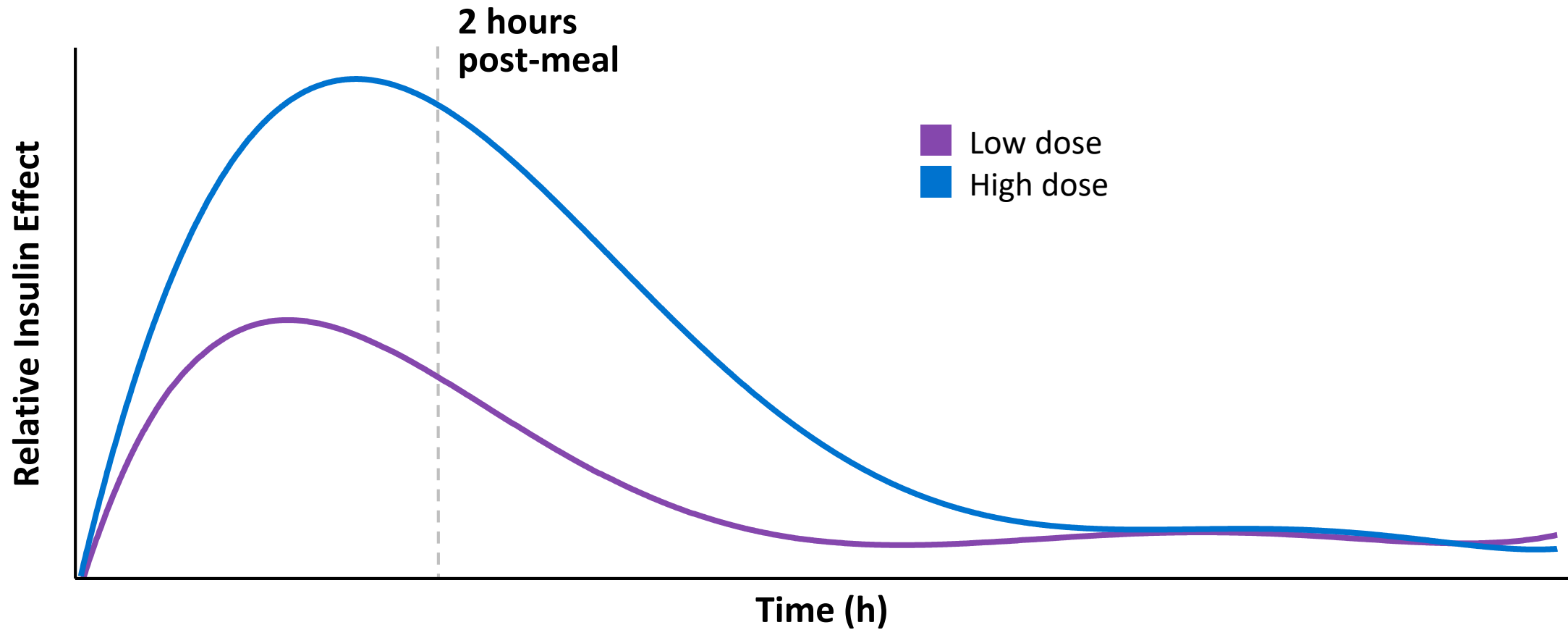
BEFORE EXERCISE

Bolus Insulin Dose Adjustment Before Aerobic Exercise

	Recommendations
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 or less from last bolus insulin dose	Reduce pre-exercise insulin dose by 25–75% and consume carbohydrate with a low glycemic index at mealtime
Exercise more than 2 hours from last bolus insulin dose	If blood glucose is running low, must consume carbohydrate

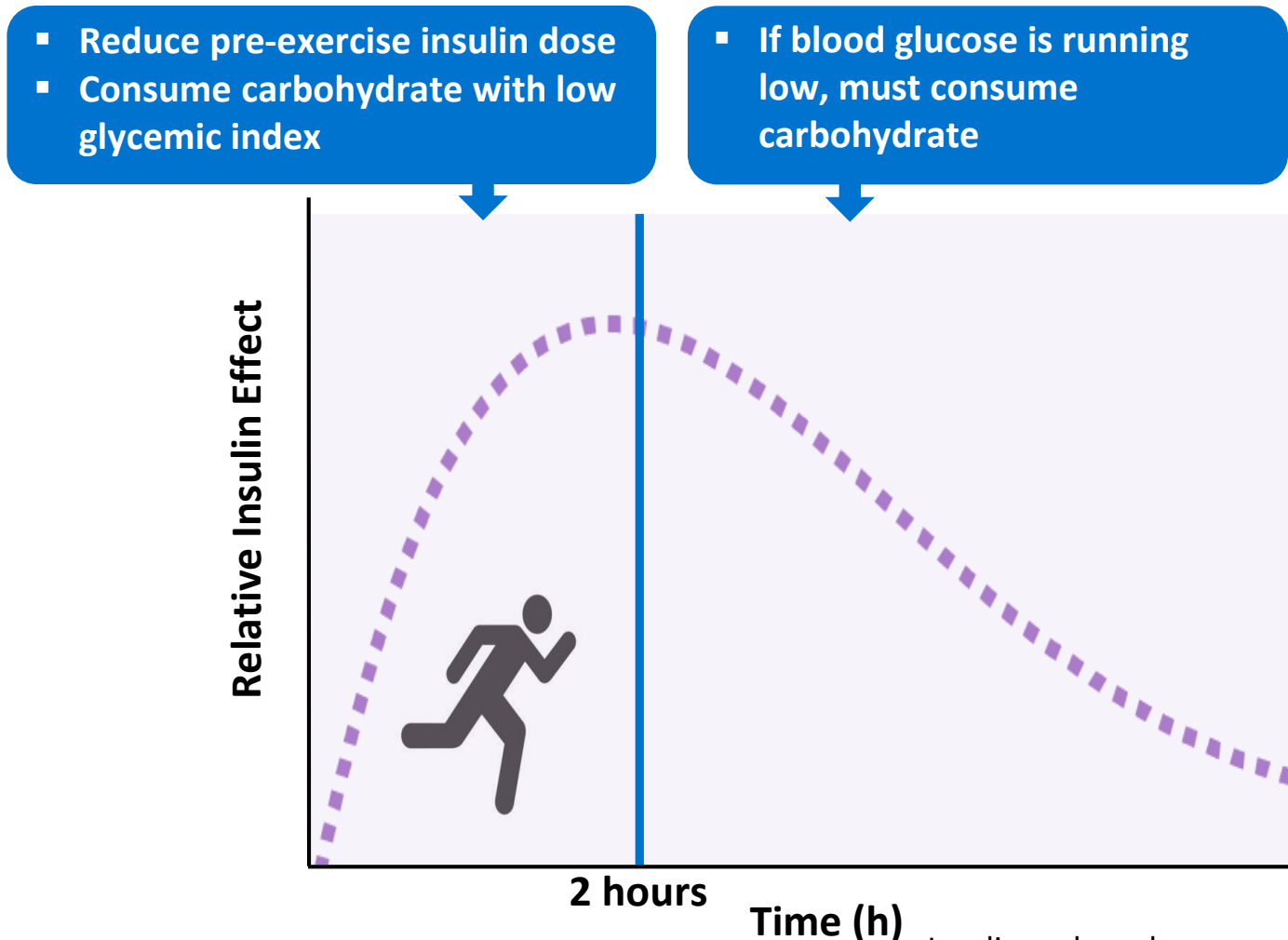
Mauvais-Jarvis F, et al. *Diabetes Care*. 2003;26:1316-7; Hernandez JM, et al. *Med Sci Sports Exerc*. 2000;32:904-10; Rabasa-Lhoret R, et al. *Diabetes Care*. 2001;24:625-30; West, et al. *Diabetic Med*. 2009;26:60; DirecNet Study Group, et al. *Diabetes Care*. 2006;29:2200-4.

Higher doses of insulin have a bigger impact on blood sugar levels



With higher insulin doses, circulating insulin levels will be higher for longer

Taking Additional Carbs Can Offset Insulin On Board



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

Basal Insulin

Background insulin -- even in the fasted state (overnight and between meals) and for exercise	Changes to basal insulin delivered by injection need to be individualized due to differences in long-acting analogs
Delivered either by pump or long-acting insulin analog; reaches a steady, stable level	After exercise, basal insulin can be reduced in the evening or at bedtime to reduce risk of nocturnal hypoglycemia
In preparation for exercise, basal insulin needs to be reduced in advance of planned exercise	

Basal Insulin Dose Adjustment Before Aerobic Exercise

Patients on Multiple Daily Insulin Injections

- Basal insulin dose adjustment is not routinely recommended
- If on BID 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



Nutrition Before Exercise

	1–4 Hours	Within 10–15 Minutes
Carbohydrate	A meal based on low-fat, low-GI carbohydrate 0.5–2 g/lb body weight	Depending on blood glucose level, insulin on board and activity type
Protein	Include 20–30 g low-fat, high-quality protein (eg, lean meat, fish, milk, yogurt)	Not required
Fluid	2–5 mL/lb body weight in the 2–4 hours before exercise	Between 5 to 10 ounces fluid depending on age/sex/environment

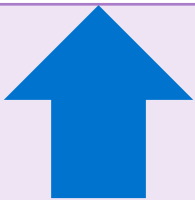
Recommendations Based on Starting Blood Glucose

Blood Glucose Concentrations	Recommendation
<90 mg/dL	<ul style="list-style-type: none">▪ Ingest 10–20 g of glucose before exercise▪ Delay exercise until blood glucose >90 mg/dL
90–124 mg/dL	<ul style="list-style-type: none">▪ Ingest 10 g of glucose▪ Exercise can be started, anaerobic and high-intensity interval training may be started without carbohydrates
125–180 mg/dL	<ul style="list-style-type: none">▪ Aerobic exercise can be started▪ Anaerobic exercise and high-intensity interval training may be started, but levels may rise
181–270 mg/dL	<ul style="list-style-type: none">▪ Aerobic exercise can be started▪ Anaerobic exercise can be started, but glucose concentrations may rise
>270 mg/dL	<ul style="list-style-type: none">▪ 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

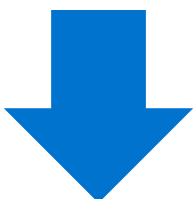
DURING EXERCISE

Carbohydrate Needs Vary Based on Many Factors

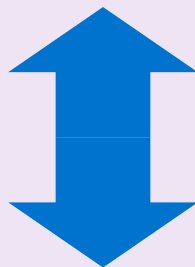
Carbohydrate Need Factors



- Blood glucose below 90 mg/dL
- Aerobic exercise
- New sport/unfamiliar activity





- Anaerobic exercise
- Short duration
- Exercise without insulin on board
- Insulin dose reduced (adjusted) with meal before exercise



- Competition

Nutrition Needs During Exercise

	30 mins	30–60 mins	>60 mins
Carbohydrates 	<ul style="list-style-type: none"> Not needed unless blood glucose dropping 	<ul style="list-style-type: none"> May be needed if very strenuous activity or no insulin adjustment 	<ul style="list-style-type: none"> May be needed for fuel 30–60 g/h (0.5–1 g/kg body weight for child) For ultraendurance (>3 hr) Up to 90 g/h; consider high-GI choices
Fluid 	<ul style="list-style-type: none"> Water should be adequate for hydration 	<ul style="list-style-type: none"> Drink appropriate amount* of fluids to replace sweat losses so that total body fluid deficit is <2% body weight 	<ul style="list-style-type: none"> May benefit from use of sports drinks

* 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.

Water or Sports Drink During Exercise?

Water

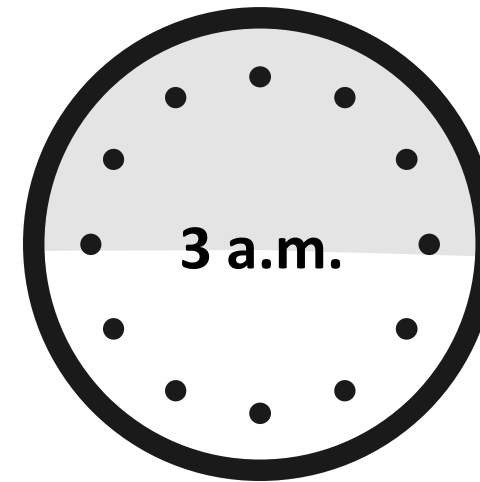
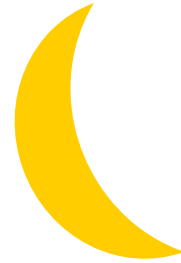
- Most commonly used
- Minimal side effects
- Adequate for shorter events (<60 mins)

Sports Drinks

- Beneficial for longer events (>60–90 mins)
- Sodium: 230–690 mg/1000 mL
- Be careful not to over-consume

AFTER EXERCISE

Basal Insulin Dose Adjustment After Exercise: Multiple Daily Insulin Injections vs Insulin Via Pump



Multiple Daily Insulin Injections

- Reduce nighttime dose by 20%
- Increase carbohydrate consumption to prevent low blood sugar overnight
- Check blood glucose during the night

Insulin Pump

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



Nutrition After Moderate-to-Intense Exercise

Carbohydrate

- Aim for approximately 0.5 g of carbohydrate per pound of body weight 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 low blood sugar risk and enhance glycogen synthesis

Fluid

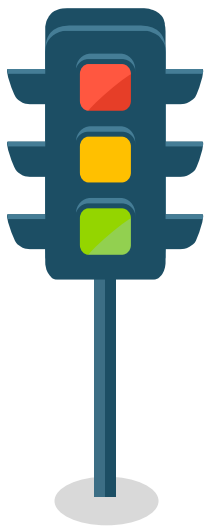
- Drink fluids after exercise with food to maximize rehydration

OTHER CAVEATS

Some Therapies Will Require Additional Considerations

- Insulin adjustments may be more challenging for patients using hybrid closed-loop pumps or ultra-long-acting basal insulins
- There are differences in absorption times for various insulin preparations (inhaled, faster acting, etc.)
- Impact of new and coming therapies (such as SGLT inhibitors) for T1D on glycemic control during exercise are largely unknown

SPECIAL CONSIDERATIONS



Supplements Require Caution and Some Should Be Avoided

Sports Foods

- Useful when active and impractical to consume everyday foods
- Sports drinks
- Sports gels
- Liquid meals
- Whey protein
- Sports bars
- Electrolyte replacement

Medical/ Nutritional Supplements

- Used to treat clinical issues
- Iron supplements
- Calcium supplements
- Multivitamins
- Vitamin D
- Probiotics

Performance Supplements

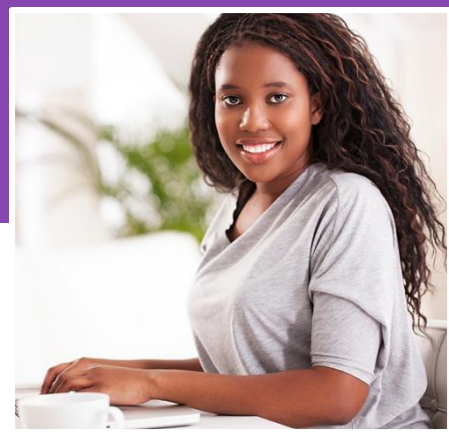
- Caffeine
- B-alanine
- Bicarbonate
- Beetroot juice
- Creatine

GLUCOSE AND INSULIN MANAGEMENT CASE WRAP UP



- Fear of low blood sugar with exercise leads Sara to start exercise with high blood sugar levels
- Sara also wants to avoid carbs with exercise as she hopes to lose weight
- Consistent use of CGM may help manage worries about low blood

- sugar with exercise
- It's important to be aware of CGM alert settings, including low, high, and trend alerts
- Review of past CGM patterns is important to see trends





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 low blood sugar
 - Reduce basal rate by

20% for 4–6 hours at bedtime to avoid overnight low blood sugar



Eating Plan Recommendations



- Continue carbohydrate counting
- Aim for 1800–2000 calories per day; eat 3 meals and 1 snack each day, shooting for the following ratios:
 - Carbohydrates: 50% of calories
 - Protein: 20% of calories
 - Fat: 30% of calories
- Before and after exercise snacks should be a 2:1 ratio of carbs-to-protein

Key Considerations for Balancing Glucose Control and Exercise

- Talk to your healthcare team about your goals for exercise
- Things to consider when planning exercise and insulin changes are:
 - Exercise type, duration, intensity, and time of day
- Timing of exercise and meals is important
- Consider insulin “on board” (active insulin) at exercise time
- Think about the impact of previous exercise and/or low blood sugar levels when planning exercise
- How insulin is taken (pump versus injections) will change how blood sugar is managed with exercise
- Know your glucose targets and talk to your healthcare team about best tools for monitoring and treating