

COMPLIMENTARY CE

Fundamentals of Exercise Physiology and T1D

Jointly Provided by



Developed in collaboration with



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INTRODUCTION TO PHYSICAL ACTIVITY AND T1D



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Many People with T1D Have Lower Levels of Physical Activity

Study	Study Type	% Study-Defined Low Levels of Physical Activity
DCCT	Retrospective analysis	19%
EURODIAB	Prospective cohort study	36%
FINNDIANE	Cross sectional	44%
DPV Database	Cross sectional	63%

Makura CB, et al. *BMC Endocr Disord.* 2013;13:37; Tielemans SM, et al. *Diabetologia.* 2013;56:82-91; Waden J, et al. *Diabetologia.* 2015;58:929-36; Bohn B, et al. *Diab Care.* 2015;38:1536-43.



3

ADA Aerobic Exercise Recommendations

- **Adults: 150 minutes/week** of moderate-to-vigorous physical activity (brisk walking or greater), with no more than 2 days off in a row plus strength training 2-3 x/week on nonconsecutive days. For younger and more physically fit individuals, shorter durations (75 min/week) of vigorous-intensity or interval training may be sufficient.
- **Youth: 60 minutes/day** of moderate-to-vigorous physical activity (420 min/week), including vigorous-intensity activities 3 or more days/week and strength-building activities (for muscle and bone) 3 or more days/week.

ADA. *Diabetes Care.* 2018;41(Suppl 1):S38-50.



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Benefits of Exercise in Diabetes

- Weight management, increased lean body mass
- Reduced cardiovascular risk factors
 - Lower blood pressure
 - Lower unfavorable and higher favorable lipids
- Improved HbA1c and insulin sensitivity
- Reductions in microvascular complications
 - Retinopathy
 - Microalbuminuria
- 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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Attitudes and Barriers to Exercise Among People with T1D Are Multifactorial

- Health and medical
 - How blood glucose could be affected by activity
 - Hypoglycemia
 - Complications due to diabetes
 - Other non-diabetes-related health problems
- Time, work, and lifestyle
 - Demands on their time is greater barrier than diabetes for most people
 - Demands in the home or caring for children or relatives
 - Erratic lifestyle—a perceived lack of time
- Social and personal
 - Lack of motivation to exercise
 - Embarrassment or fear of failure
 - Body image concerns
- Environmental
 - Access/cost of sports facilities
 - Weather

Lascar N, et al. *PLoS One*. 2014;9:e108019.



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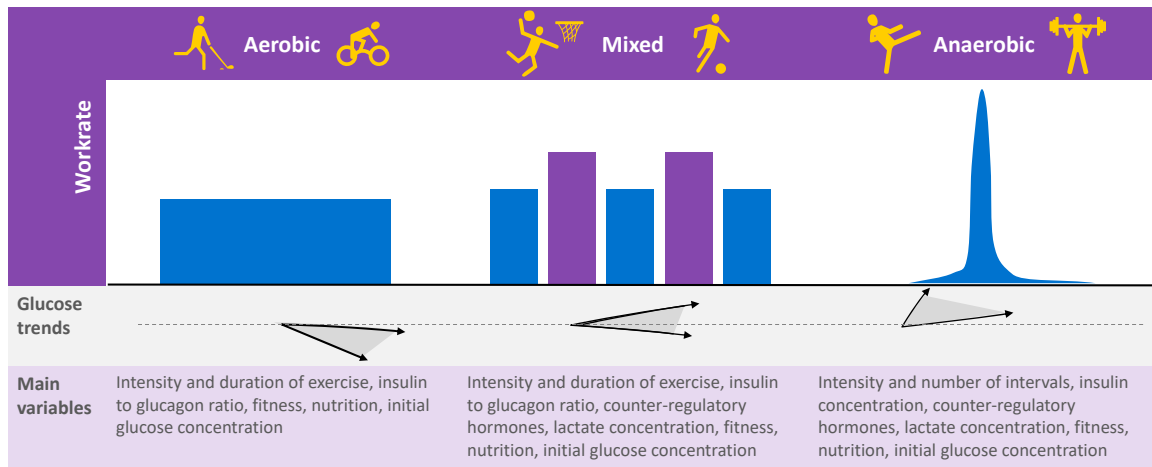
Factors that Contribute to Increased Hypoglycemia During Exercise in T1D

- Absence of physiologic decrease in insulin secretion
- Increase in absorption of insulin from subcutaneous tissue
- Increase in rate of glucose transport into muscle
- Blunting of counter-regulatory hormone responses (especially with sleep)
- Diminished hepatic glucose production

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

KEY POINT #1
DIFFERENT FORMS OF EXERCISE HAVE
DIFFERENT PHYSIOLOGIC EFFECTS

Blood Glucose Effects of Different Types of Exercise

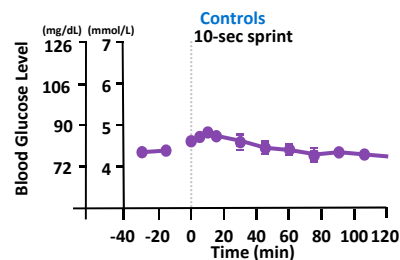


Riddell M, et al. *Lancet Diab Endo.* 2017;5:377-90.

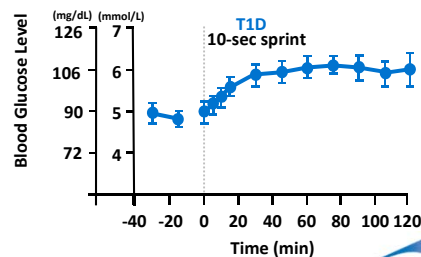
Intense Exercise Can Cause Hyperglycemia and May Increase Insulin Needs During Recovery

- Glucose is *exclusive* fuel used during intense exercise (>80% VO_2 max)
- Regulation of glucose production and utilization are different at higher versus lower exercise intensities

Insulin release is able to control glucose rise in controls



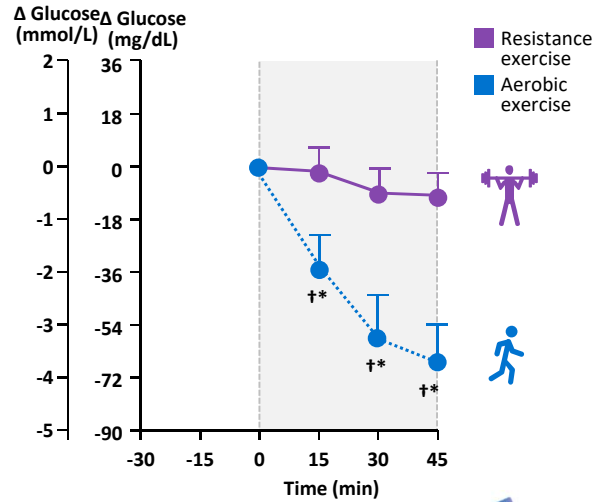
Without insulin administration, glucose rise is unchecked in T1D



Marliss EB, et al. *Diabetes.* 2002;51 Suppl 1:S271-83; Fahey AJ, et al. *J Clin Endocrinol Metab.* 2012;97:4193-200.

Resistance Exercise Presents an Opportunity for Protection Against Hypoglycemia

- Individuals who develop exercise-associated hypoglycemia may benefit by adding resistance training before aerobic activity
 - Attenuates declines in glucose
 - May lower reliance on glucose supplementation
- Individuals with exercise-associated hyperglycemia may benefit from adding aerobic exercise before resistance training



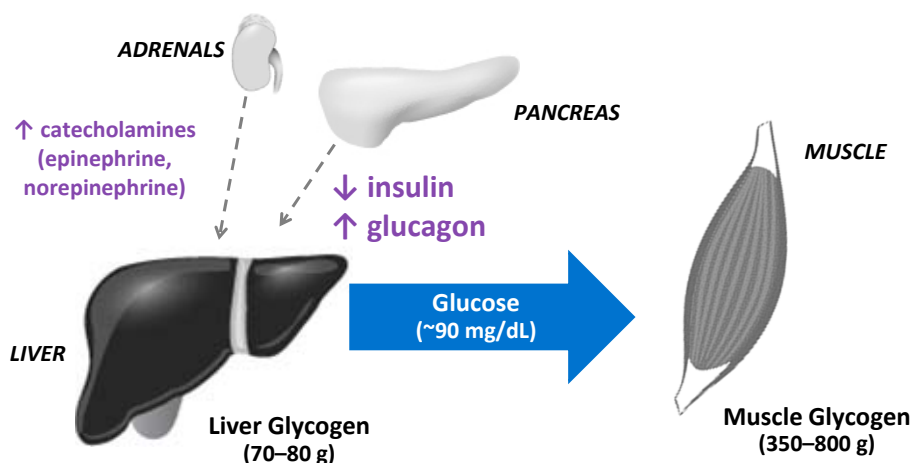
Yardley JE, et al. *Diabetes Care*. 2012;35:669-75.

*Significant difference from baseline ($P < .05$) *Significant difference from resistance exercise ($P < .05$)

KEY POINT #2

PHYSIOLOGIC MECHANISMS MAINTAIN TIGHT GLUCOSE LEVELS DURING EXERCISE IN THE ABSENCE OF DIABETES

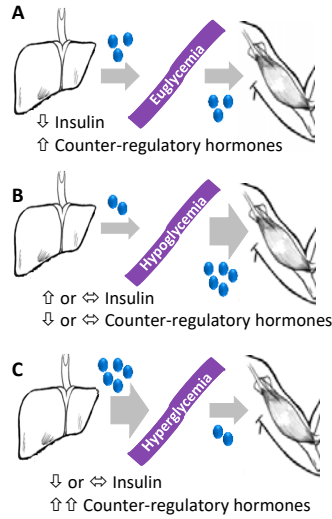
Physiologic Mechanisms Maintain Tight Glucose Levels During Exercise



KEY POINT #3
EXERCISE IN T1D LEADS TO GLUCOSE IMBALANCE DUE TO ALTERED PHYSIOLOGIC RESPONSES

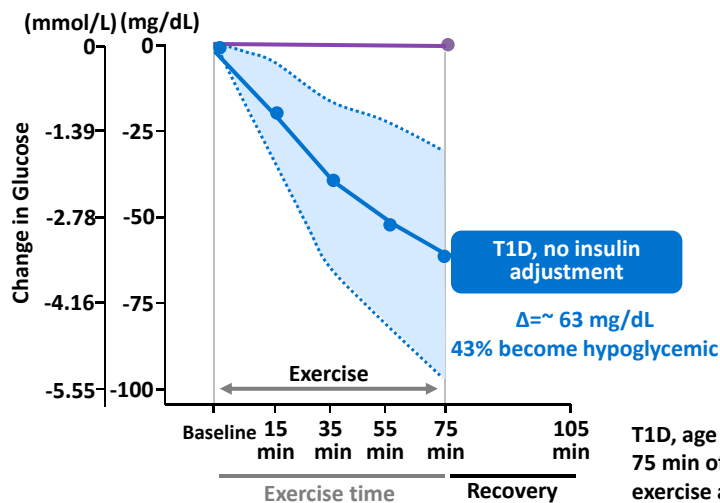
Exercise in T1D Can Lead to Hypo- or Hyperglycemia Because of Impaired Physiologic Response

- Euglycemia
 - ↓ insulin
 - ↑ counter-regulation (glucagon, growth hormone, cortisol, catecholamines)
- Hypoglycemia
 - Relative hyperinsulinemia
 - Impaired counter-regulation
- Hyperglycemia
 - Relative hypoinsulinemia
 - ↑ counter-regulation (catecholamines, etc)
 - Anaerobic metabolism (lactate production)



Chu L, et al. *Phys Sportsmed.* 2011;39:64-77.

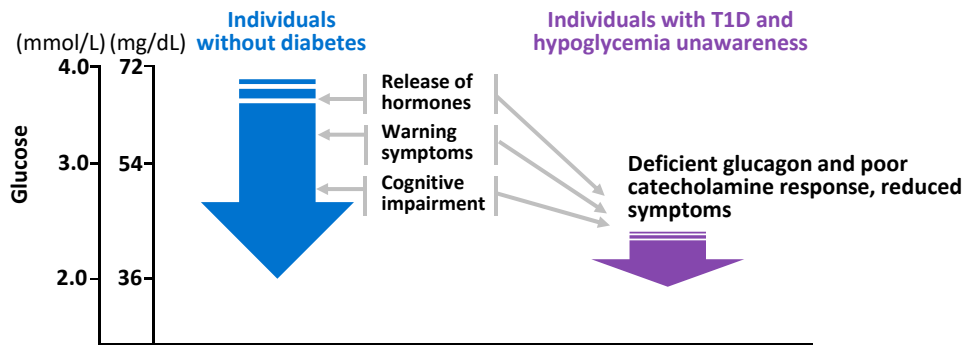
Aerobic Exercise Without Adjusting Insulin Promotes a Variable Drop in Glucose and May Cause Hypoglycemia



T1D, age 8–17 years, n=49
 75 min of intermittent aerobic
 exercise at $\sim 60\% \text{ VO}_2 \text{ max}$

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

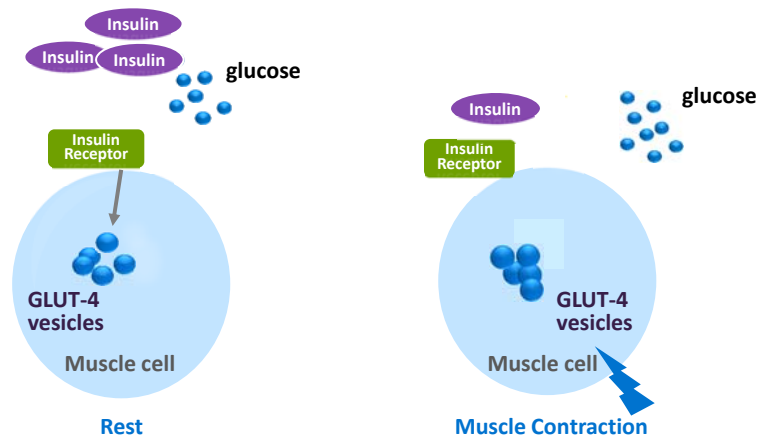
Symptoms of Hypoglycemia May Be Blunted in T1D



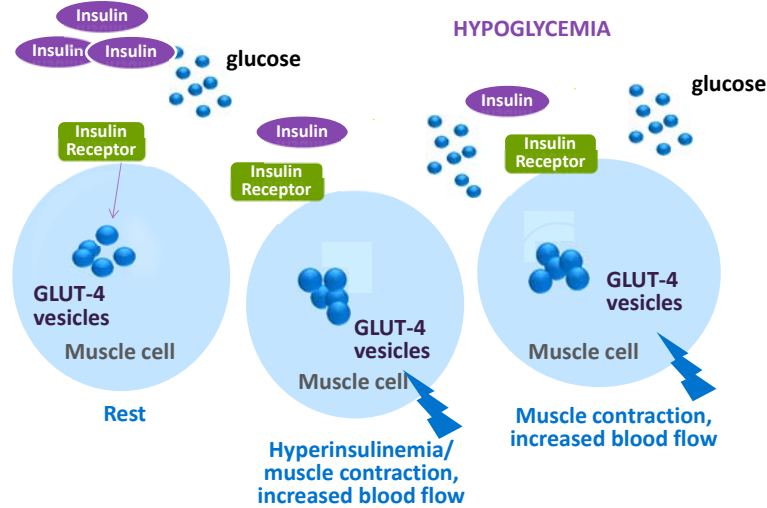
Martin-Timon I, et al. *World J Diabetes*. 2015;6:912-26.

KEY POINT #4
GLUCOSE UPTAKE IS HIGH DUE TO BOTH INSULIN ACTION AND MUSCLE CONTRACTION

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

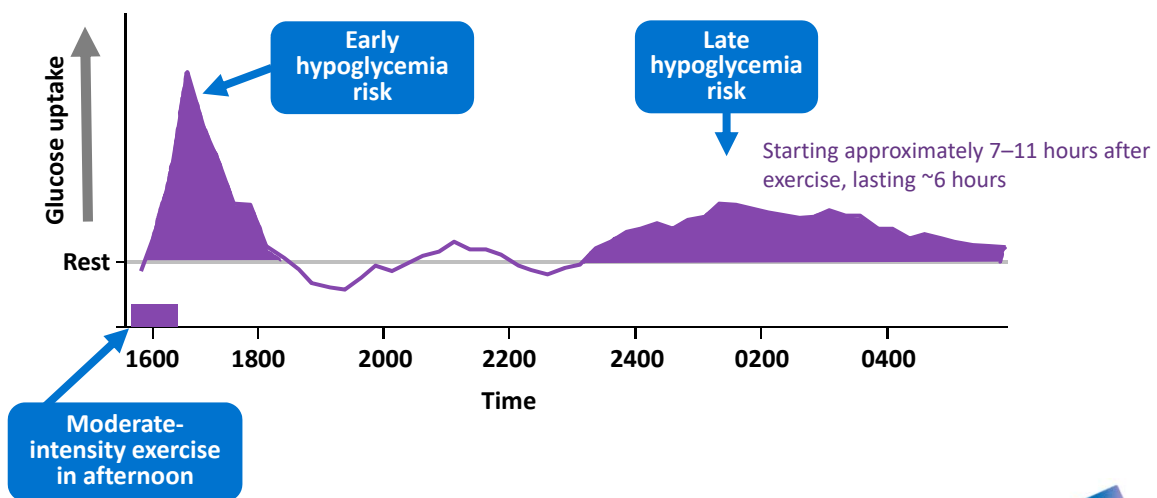


Both Available Insulin and Muscle Contraction Increase Glucose Uptake into Skeletal Muscle via Distinct Mechanisms



KEY POINT #5
EXERCISE HAS BOTH IMMEDIATE AND DELAYED
EFFECTS ON BLOOD GLUCOSE

Post-Exercise Glucose Uptake Remains Elevated
for Hours to Replenish Muscle Glycogen Stores



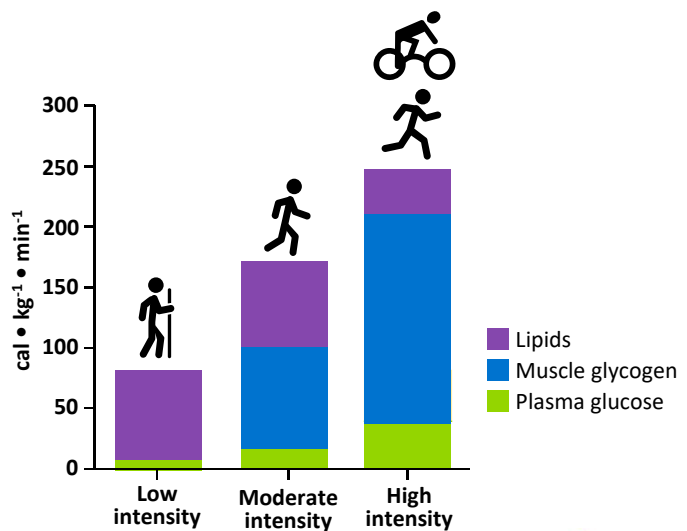
Adapted from McMahon SK, et al. *J Clin Endocrinol Metabol.* 2007;92:963-8.

KEY POINT #6

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

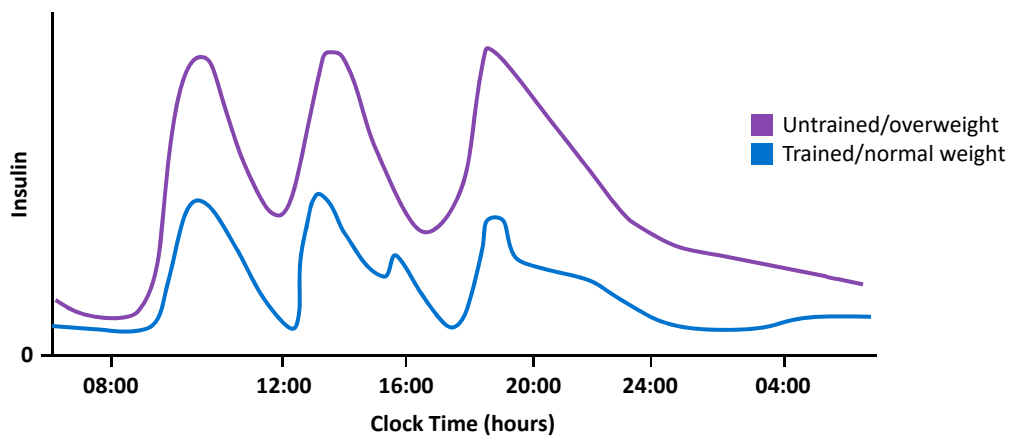
Fuel Utilization: Muscle Glycogen Demand Increases with Intensity

- Lower-intensity exercise
 - High lipid (fat) use
- Higher-intensity exercise
 - High muscle glycogen use
 - High plasma glucose use



KEY POINT #7
INSULIN SENSITIVITY INCREASES WITH FITNESS

**Training Increases Insulin Sensitivity and
May Lower Exogenous Insulin Requirements**



Schematic; derived from expert opinion.

KEY POINT #8

COOLDOWN MINIMIZES INCREASE IN GLUCOSE LEVELS DUE TO MULTIPLE MECHANISMS

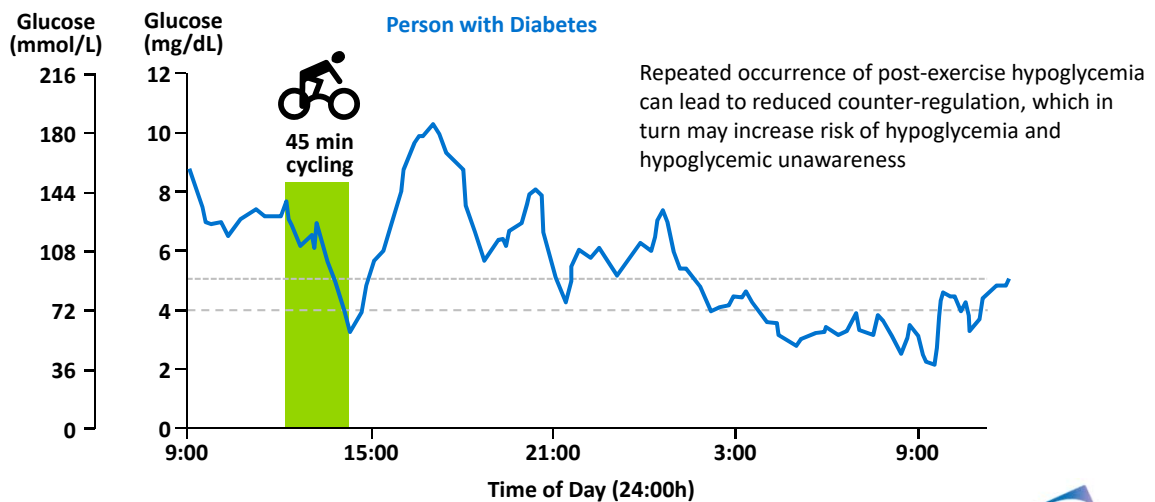
Cool Down Can Attenuate Hyperglycemia Risk After Vigorous Exercise

- Counter-regulatory hormones and high lactate levels may increase blood glucose levels in early recovery
- Hyperglycemia in early recovery can be attenuated by a prolonged passive cool down at a moderate intensity (30–50% VO_2 max)
- Monitoring of glucose is essential

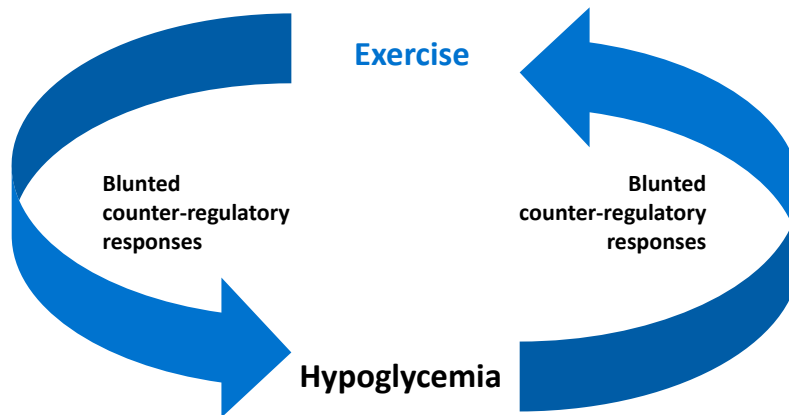


KEY POINT #9
SHORT TERM RISK OF HYPOGLYCEMIA DURING EXERCISE IS INCREASED BY RECENT HYPOGLYCEMIA AND RECENT EXERCISE

Exercise Can Increase Hypoglycemia Due to Multiple Mechanisms



Vicious Cycle of Hypoglycemia and Exercise



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

Summary

1. Different forms of exercise have different effects
2. Physiologic mechanisms maintain tight glucose levels during exercise in the absence of diabetes
3. Exercise in T1D leads to glucose imbalance due to altered physiologic responses
4. Glucose uptake is high due to both insulin action and muscle contraction
5. Exercise has both immediate and delayed effects on blood glucose
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 glucose levels due to multiple mechanisms
9. Short-term risk of hypoglycemia during exercise is increased by recent hypoglycemia and recent exercise