



Exercise- A Type 1 Perspective

Sponsored by Medtronic Diabetes Canada

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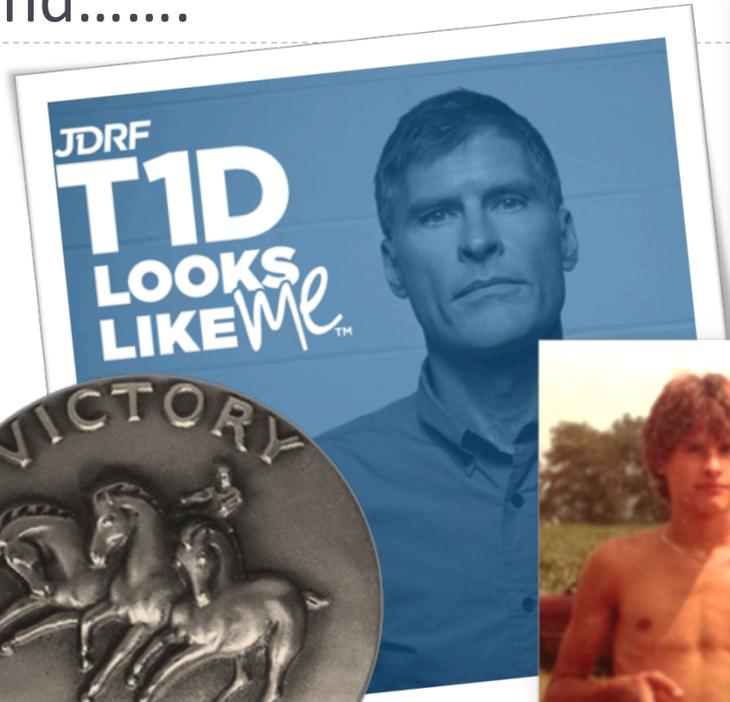
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YORK
UNIVERSITÉ
UNIVERSITY 

 **LMC** **DIABETES &
ENDOCRINOLOGY**

Until a cure is found.....

1. Insulin Therapy
2. Regular Exercise
3. A Healthy Diet





Medtronic

For People with Diabetes



LIONS CAMPS

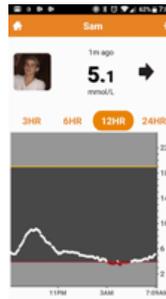
Diabetes Sport Camp
Specialized programming to excel with diabetes and exercise



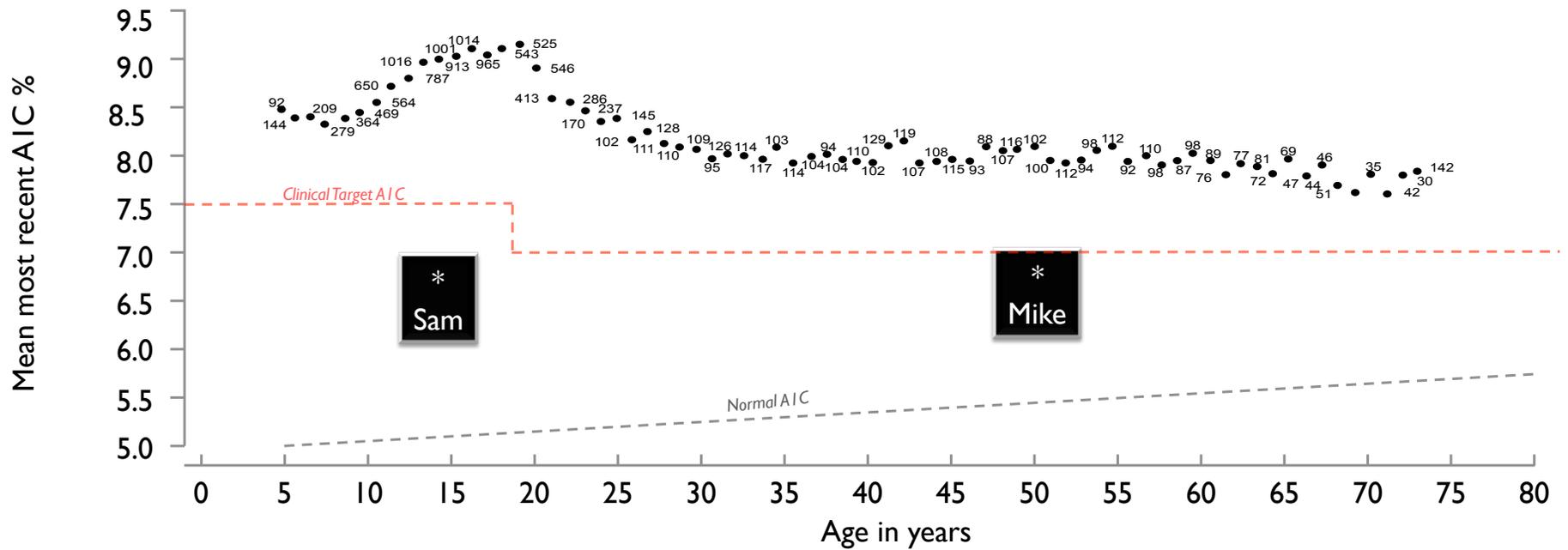




What is new in type 1 care?

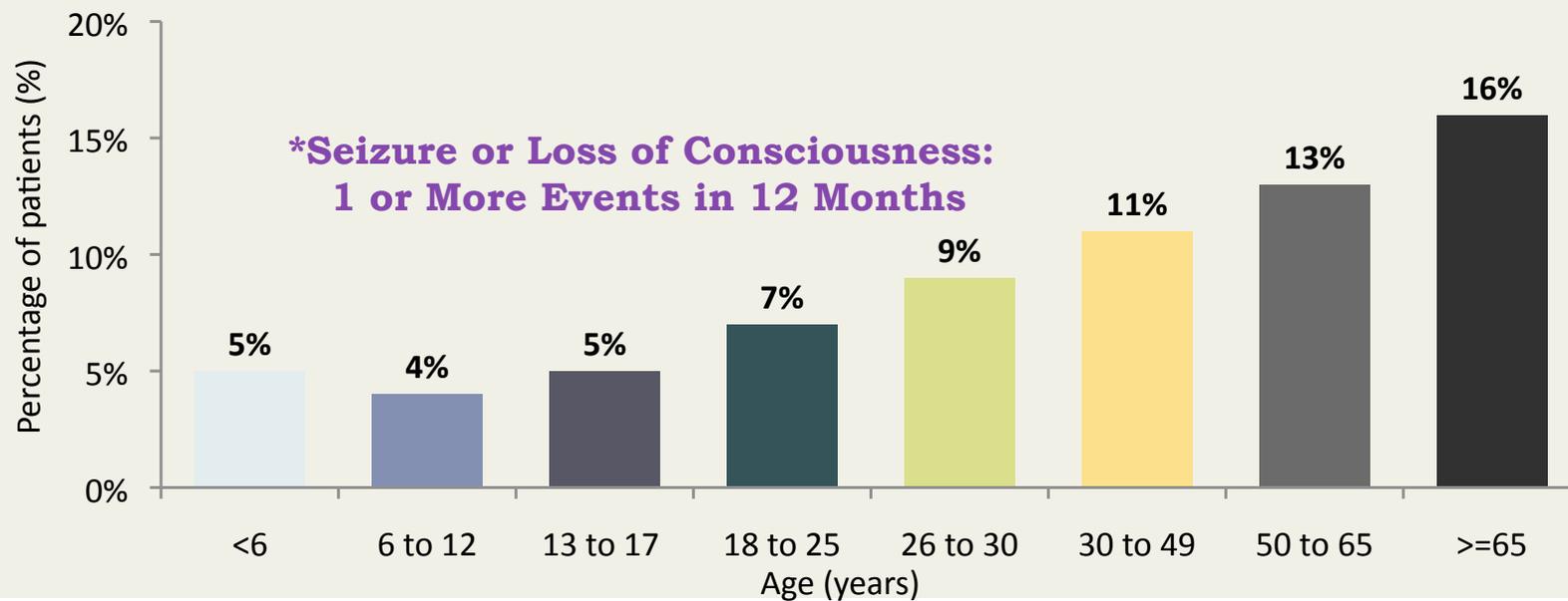


Despite advances in care, glycemic control is still challenging in T1D, particularly in youth...



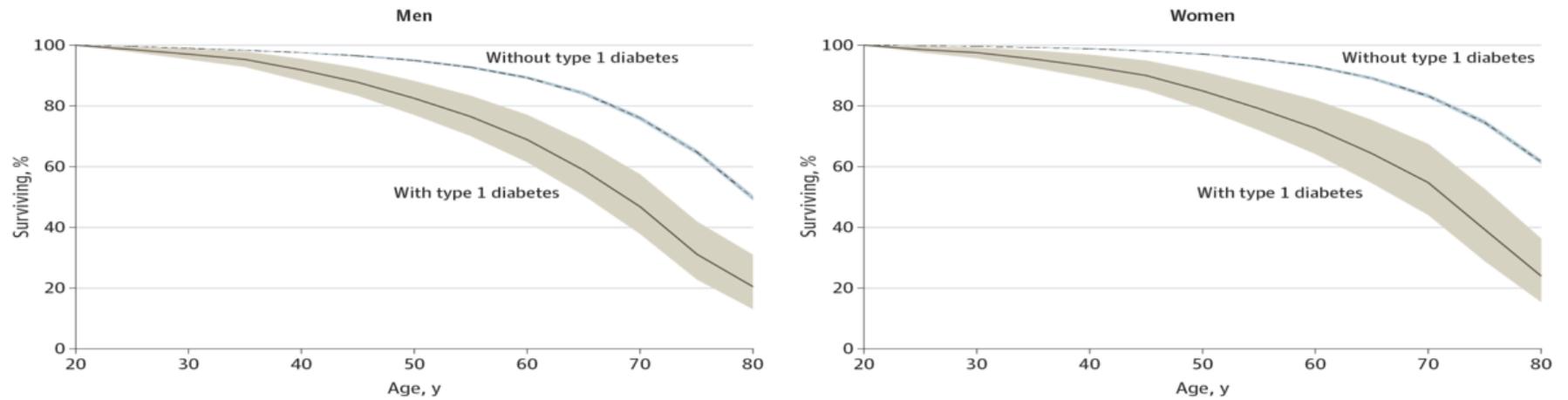
Episodes of Severe Hypoglycaemia are Common (US Data)

1/6 to 1/20 persons with type 1 diabetes experience severe hypoglycaemia each year



From: **Estimated Life Expectancy in a Scottish Cohort With Type 1 Diabetes, 2008-2010**

JAMA. 2015;313(1):37-44. doi:10.1001/jama.2014.16425



Percentage Surviving by Age Among Those With Type 1 Diabetes Compared With the General Population Without Type 1 Diabetes See the Methods section for life table calculations.



Can J Diabetes 37 (2013) S40–S44



Contents lists available at SciVerse ScienceDirect

Canadian Journal of Diabetes

 Canadian Diabetes



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Can J Diabetes xxx (2017) 1–10



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Canadian Journal of Diabetes

journal homepage:
www.canadianjournalofdiabetes.com

 DIABETES CANADA



2018 Clinical Practice Guidelines

Physical Activity and Diabetes

Diabetes Canada Clinical Practice Guidelines Expert Committee

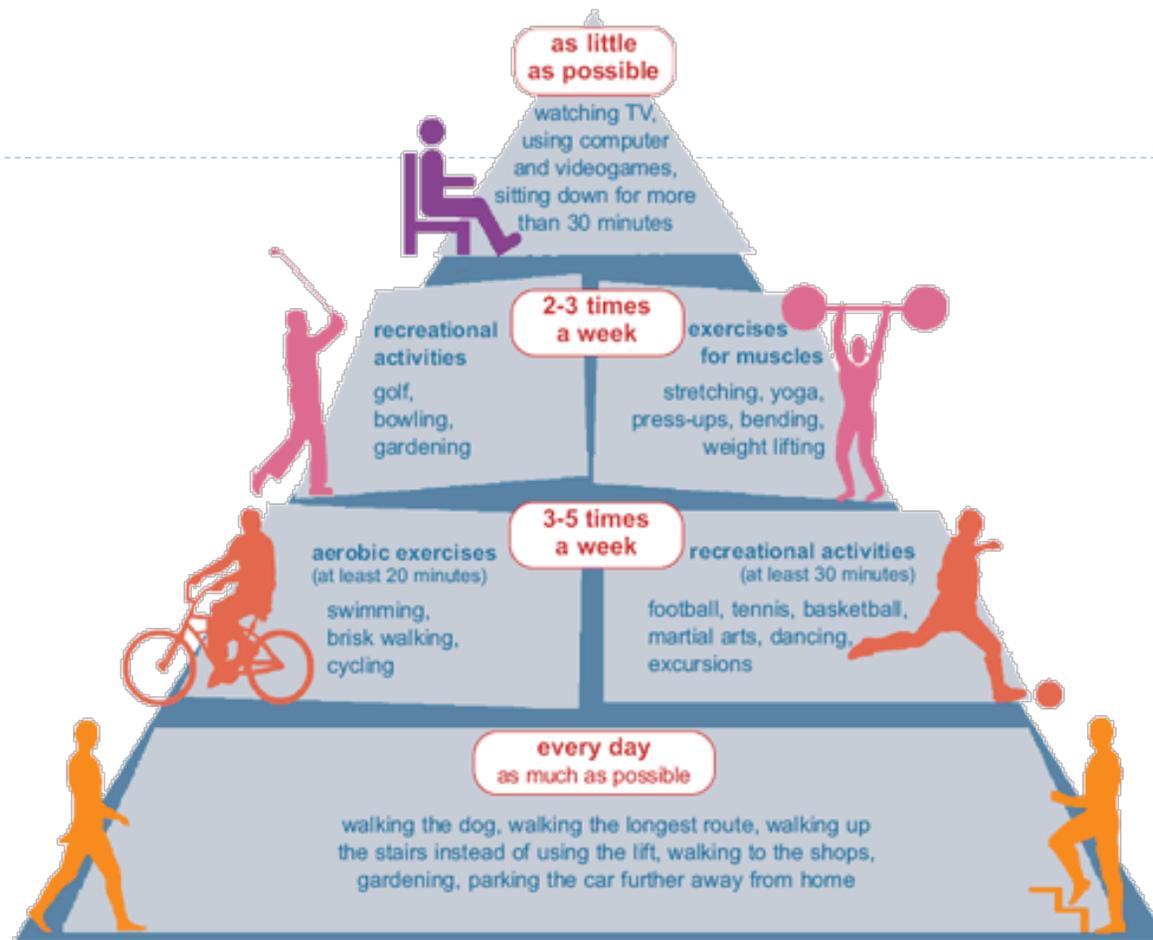
Michael C Riddell, Ian W Gallen, Carmel E Smart, Craig E Taplin, Peter Adolfsson, Alistair N Lumb, Aaron Kowalski, Remi Rabasa-Lhoret, Rory J McCrimmon, Carin Hume, Francesca Annan, Paul A Fournier, Claudia Graham, Bruce Bode, Pietro Galassetti, Timothy W Jones, Iñigo San Millán, Tim Heise, Anne L Peters, Andreas Petz, Lori M Laffel

Type 1 diabetes is a challenging condition to manage for various physiological and behavioural reasons. Regular exercise is important, but management of different forms of physical activity is particularly difficult for both the individual with type 1 diabetes and the health-care provider. People with type 1 diabetes tend to be at least as inactive

Lancet Diabetes Endocrinol 2017
Published Online
January 23, 2017

Recommendations

- Prolonged sitting should be interrupted with bouts of light activity every 30 min for blood glucose benefits.
- Daily exercise is recommended to enhance insulin action.
- Adults should ideally perform both aerobic and resistance exercise for optimal glycemic and health outcomes (**150 min/week or more**).
- Children and adolescents with diabetes should be encouraged to meet the same physical activity goals set for youth in general (**60 minutes/day of physical activity**). C
 - Vigorous-intensity activities **at least 3 days per week**.
 - Activities that strengthen muscle and bone at least 3 days per week.



What Type of 'Aerobic' Exercise?



A) 150-170 min/week of brisk walking, post meals



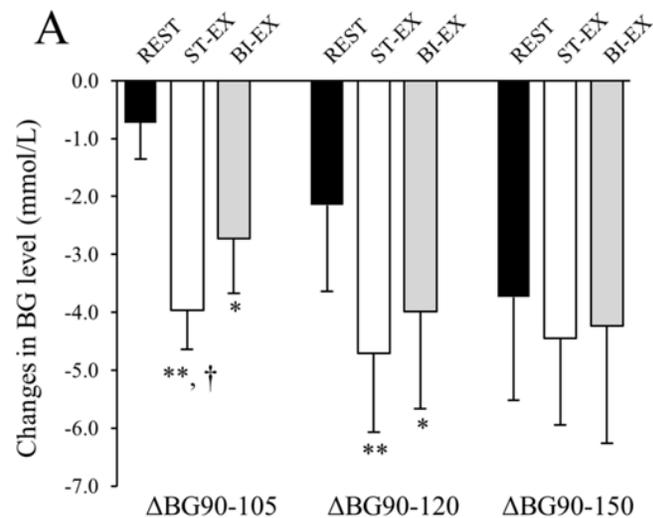
B) 2-3 x 30 min weekly sessions of high intensity circuit training



C) High intensity interval training (e.g. 10 x 60 second bouts of intense cycling, running or even brisk walking, spaced with 2 min breaks)

Stair ascending–descending exercise accelerates the decrease in postprandial hyperglycemia more efficiently than bicycle exercise

Tetsuo Takaishi,¹ Tatsuya Hayashi²



Significance of this study

What is already known about this subject?

Stair climbing–descending exercise (ST-EX) is an easy-to-perform method to increase exercise intensity in daily life.

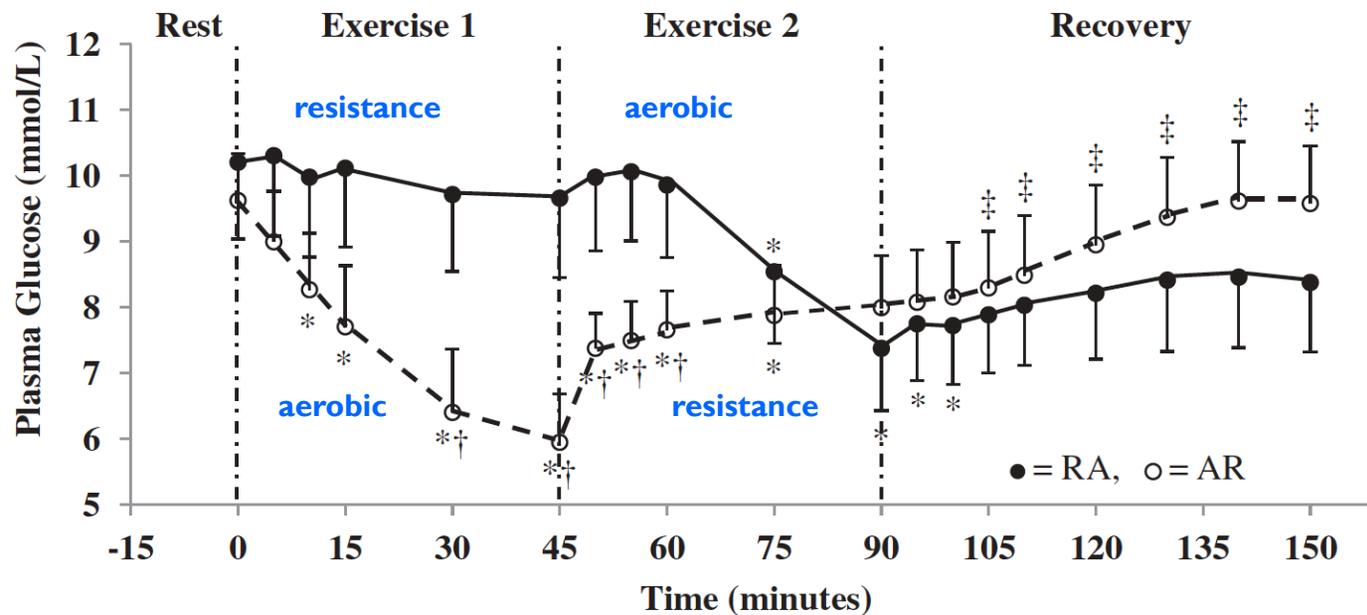
What are the new findings?

ST-EX performed after a meal more rapidly decreased postprandial blood glucose level than bicycle exercise performed at the same heart rate.

How might these results change the focus of research or clinical practice?

ST-EX might be a clinically useful modality for efficient amelioration of postprandial hyperglycemia.

Resistance then Aerobic vs. Aerobic then Resistance: An Important Order Effect



Yardley et al. Diabetes Care 2012; 35: 669-675

Immediate and long-term effects of exercise in type 1 diabetes

Immediate effects

- Increases the effectiveness of insulin for ~24 hrs
- Lowers blood sugar immediately, and blood sugar response to the next meal and overnight
- Improves mood, energy levels and sleep
- Expend calories

Long-term effects

- Lowers A1C (0.5-1.5%)
- Lowers body fat and increases muscle mass
- Helps protect the pancreas, kidneys, eyes and nerves
 - May be associated with improved beta cell mass and function
- Reduces risk of heart attack, stroke and premature death

BG: Blood glucose

Riddell et al., Lancet Diabetes & Endocrinol. 2017; Colberg SR et al. Diabetes Care 2016; Chimen M et al., Diabetologia 2012; Armstrong MJ and Sigal RJ. Can J Diabetes 2015.



Physical Activity Reduces Risk of Premature Mortality in Patients With Type 1 Diabetes With and Without Kidney Disease

<https://doi.org/10.2337/dc17-0615>

*Heidi Tikkanen-Dolenc,^{1,2,3}
Johan Wadén,^{1,2,3} Carol Forsblom,^{1,2,3}
Valma Harjutsalo,^{1,2,3,4} Lena M. Thorn,^{1,2,3}
Markku Saraheimo,^{1,2,3} Nina Elonen,^{1,2,3}
Heikki O. Tikkanen,^{5,6,7} and
Per-Henrik Groop,^{1,2,3,8} on behalf
of the FinnDiane Study Group*

Physical activity is associated with a lower risk of premature mortality in patients with type 1 diabetes and CKD

* note- the following all likely matter...

- ✓ Intensity
- ✓ Frequency
- ✓ Duration

Table 2—Ten-year cumulative incidence rates for all-cause mortality by LTPA and by exercise intensity, duration, and frequency

	Low*	Moderate*	High*	P value
LTPA				
Incidence	14.4 (12.2, 16.6)	6.6 (5.1, 8.1)	4.8 (2.7, 6.8)	<0.001
Participants (n)	833	1,109	427	
Events (n)	141	95	34	
Exercise intensity				
Incidence	17.7 (15.1, 20.2)	6.4 (5.1, 7.7)	2.3 (1.0, 3.6)	<0.001
Participants (n)	631	1,224	459	
Events (n)	141	101	15	
Exercise frequency				
Incidence	19.9 (16.5, 23.1)	6.6 (2.9, 10.2)	6.7 (5.6, 7.8)	<0.001
Participants (n)	375	158	1,813	
Events (n)	87	16	161	
Exercise duration				
Incidence	16.6 (12.9, 20.1)	6.6 (5.1, 8.1)	6.4 (4.7, 8.0)	<0.001
Participants (n)	300	1,149	726	
Events (n)	59	103	62	

Data are % (95% CI) unless otherwise indicated. *LTPA: low <10 MET-h/week; moderate 10–40 MET-h/week, and high >40 MET-h/week. Intensity: low (no self-reported subjective shortness of breath and no sweating), moderate (a moderate degree of self-reported subjective shortness of breath and sweating), and high (a high degree of subjective shortness of breath and sweating). Frequency: low fewer than one session/week, moderate one to two sessions/week, and high more than two sessions/week. Duration: low ≤30 min/session, moderate 31–60 min/session, and high >60 min/session.

Physical activity is associated with a lower risk of premature mortality in patients with type 1 diabetes and CKD, even after adjusting for common known health risks

Table 3—Cox proportional hazards regression models for low and moderate versus high total LTPA and exercise intensity, frequency, and duration for all-cause mortality

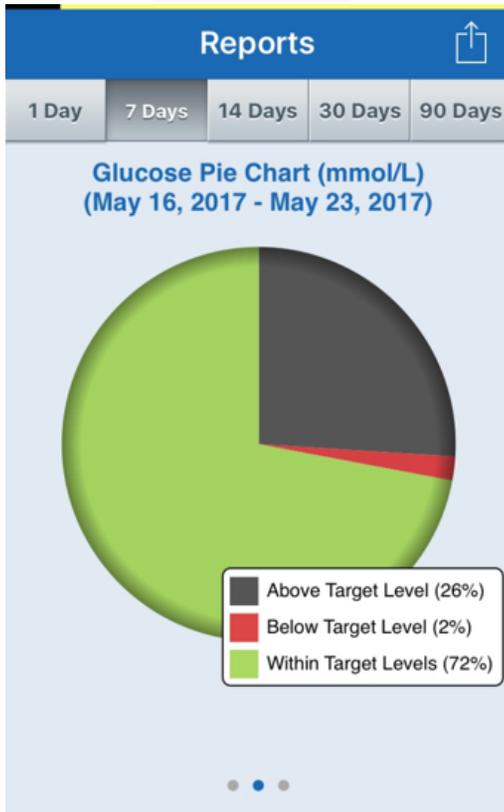
	Model 1	Model 2	Model 3
LTPA			
Low*	2.49 (1.71, 3.62)	2.07 (1.40, 3.06)	1.92 (1.29, 2.86)
Moderate*	1.11 (0.75, 1.64)	1.34 (0.89, 2.02)	1.37 (0.91, 2.07)
High*	1.00	1.00	1.00
Participants (<i>n</i>)	2,369	2,315	2,274
Events (<i>n</i>)	270	261	255
Exercise intensity			
Low	7.83 (4.60, 13.33)	2.78 (1.57, 4.90)	2.39 (1.34, 4.25)
Moderate	2.55 (1.48, 4.39)	1.42 (0.80, 2.50)	1.34 (0.76, 2.38)
High	1.00	1.00	1.00
Participants (<i>n</i>)	2,314	2,261	2,221
Events (<i>n</i>)	257	249	244
Exercise frequency			
Low	2.92 (2.25, 3.79)	2.35 (1.79, 3.09)	2.03 (1.53, 2.70)
Moderate	1.13 (0.68, 1.89)	1.45 (0.86, 2.43)	1.33 (0.79, 2.24)
High	1.00	1.00	1.00
Participants (<i>n</i>)	2,346	2,292	2,251
Events (<i>n</i>)	264	255	249
Exercise duration			
Low	2.50 (1.75, 3.57)	1.86 (1.29, 2.68)	1.79 (1.23, 2.58)
Moderate	1.08 (0.79, 1.48)	1.01 (0.73, 1.39)	1.09 (0.78, 1.51)
High	1.00	1.00	1.00
Participants (<i>n</i>)	2,175	2,126	2,092
Events (<i>n</i>)	224	217	214

Data are HR (95% CI) unless otherwise indicated. Model 1: exercise components and all-cause mortality. Model 2: model 1 plus sex, duration of diabetes, smoking status, age at onset of diabetes, and diabetic nephropathy. Model 3: model 2 plus SBP, triglycerides, BMI, and HbA_{1c}. *LTPA: low <10 MET-h/week; moderate 10–40 MET-h/week, and high >40 MET-h/week. Intensity: low (no self-reported subjective shortness of breath and no sweating), moderate (a moderate degree of self-reported subjective shortness of breath and sweating), and high (a high degree of subjective shortness of breath and sweating). Frequency: low fewer than one session/week, moderate one to two sessions/week, and high more than two sessions/week. Duration: low ≤30 min/session, moderate 31–60 min/session, and high >60 min/session.

Exercise can cause rapid changes in blood sugar in diabetes...



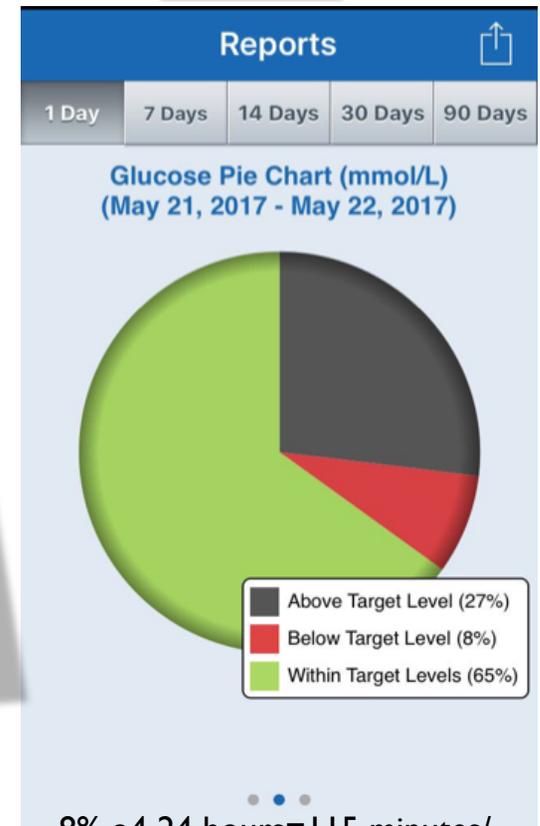
Inactive day



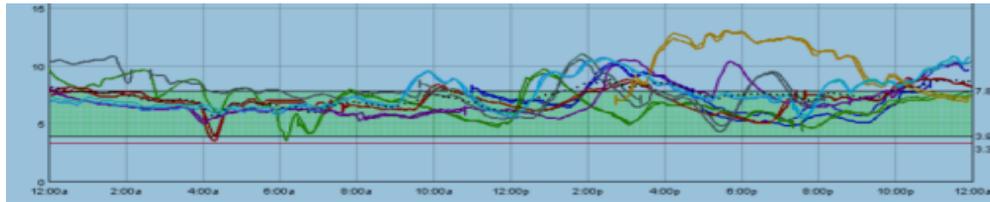
2% of 24 hours = 29 minutes/
day below target



Active day



8% of 24 hours = 115 minutes/
day below target



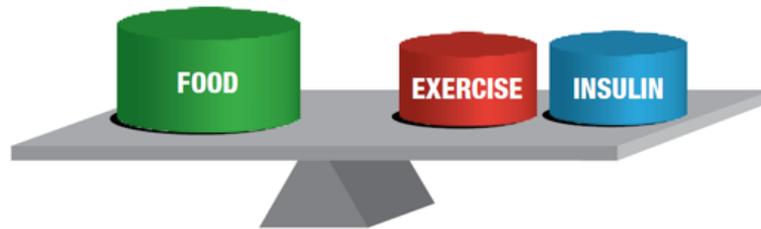
Glucose control during and after exercise is challenging...

- CGM can reveal problems
- CGM allows for proactive adjustments
- A sensor-augmented pump helps overnight



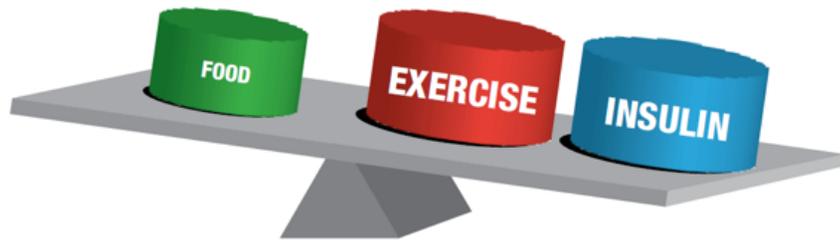
EUGLYCEMIA (4 to 7 mmol/L)

The amount of food, exercise and insulin is in balance



HYPOGLYCEMIA (<4 mmol/L)

Too little food, or too much exercise or insulin



EXERCISE-RELATED HYPERGLYCEMIA

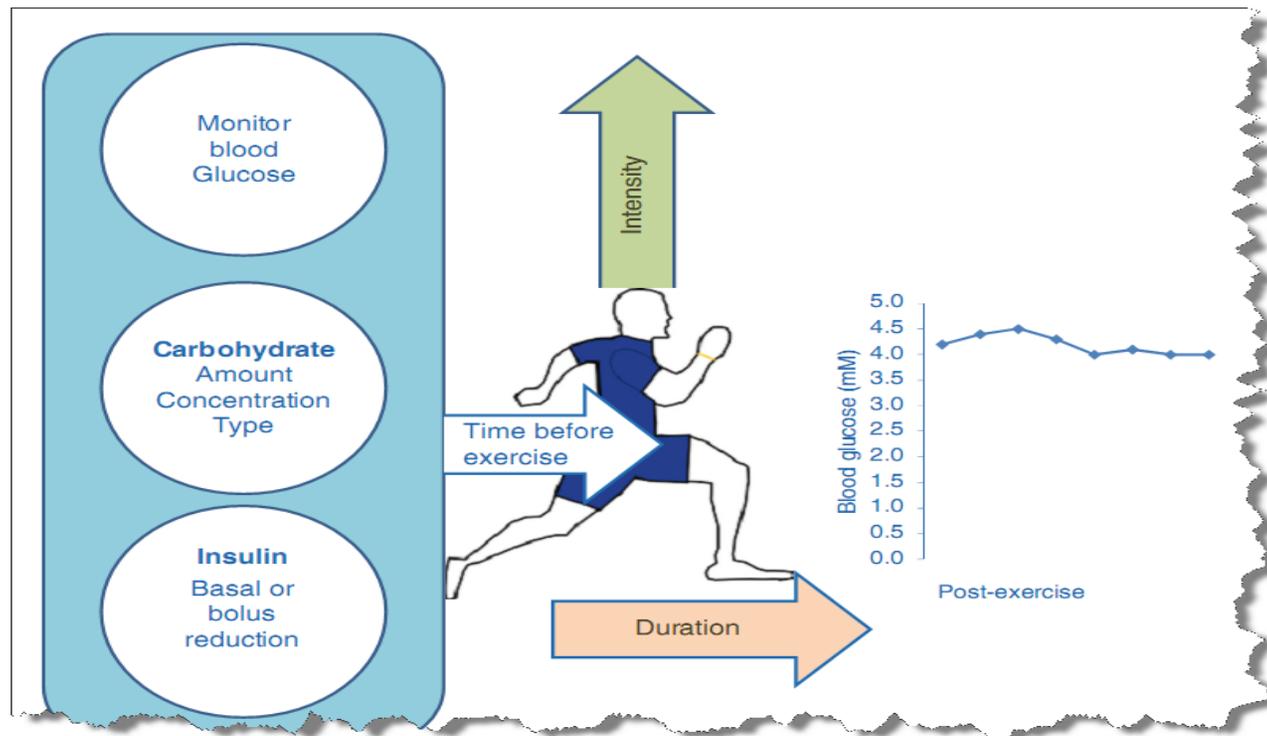
(> 9 mmol/L)

Too little insulin

Intense, stressful exercise

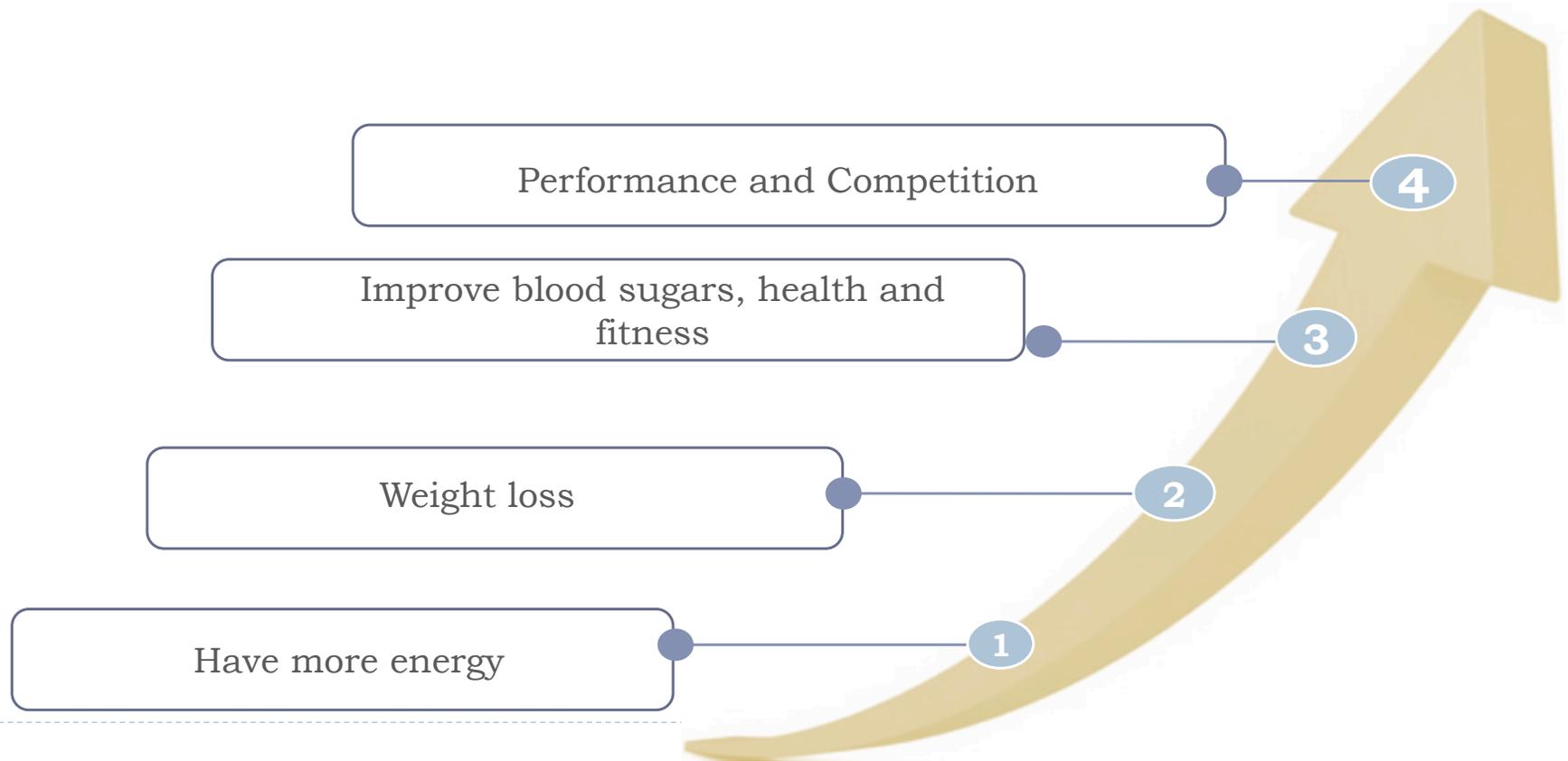


Planning for exercise requires vigilance in glucose monitoring, consideration of the type of exercise being performed and changes to nutrition and insulin therapy



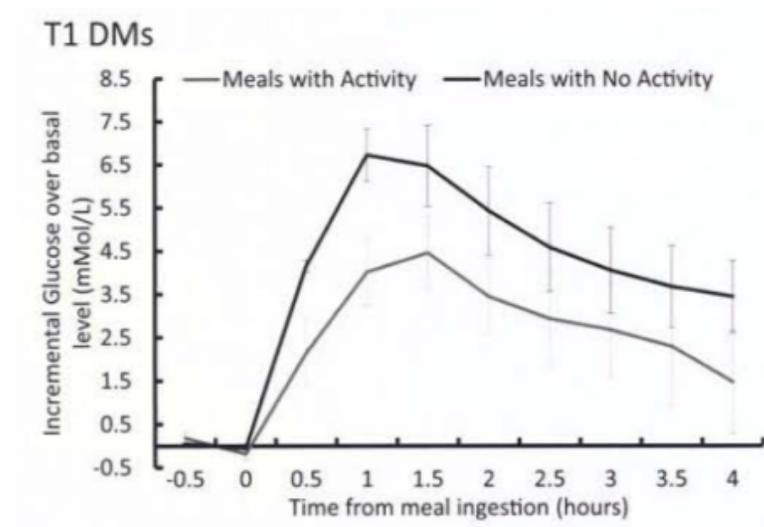
Bracken, West and Bain, *Pre-exercise Insulin and Carbohydrate Strategies in the Exercising T1DM Individual*. In **Clinical Management of the Athlete** Editor: Ian Gallen. Springer-Verlag, London 2012

What are your goals for exercise and your diabetes?



When is it the safest time to perform mild aerobic exercise?

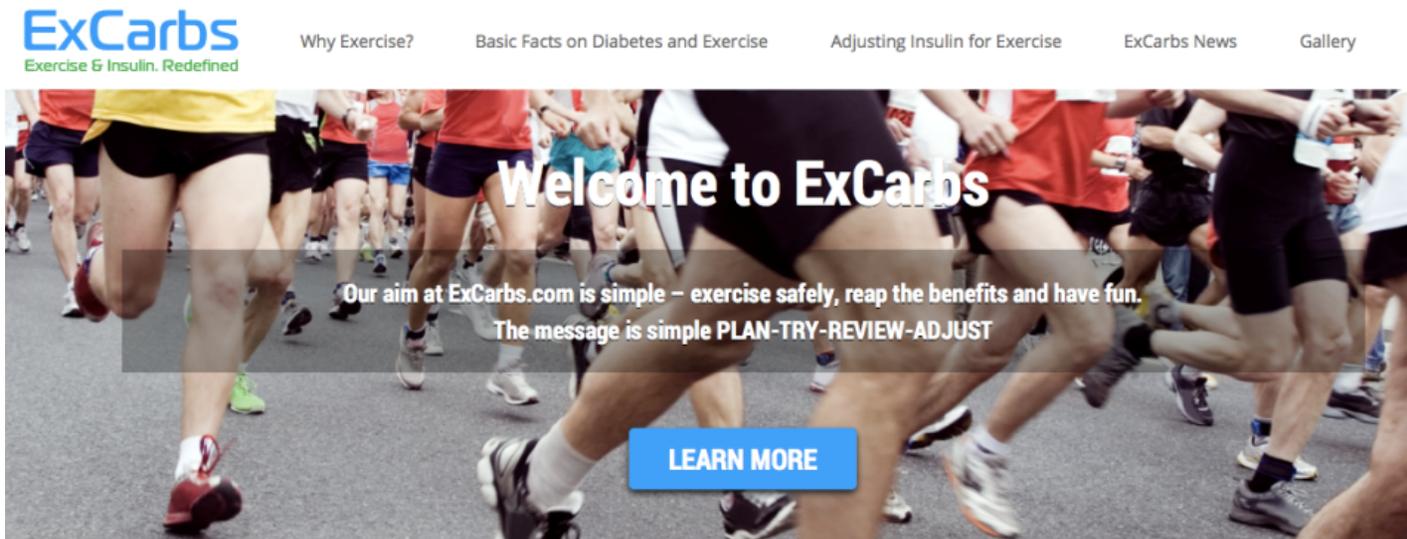
Soon after a meal



60 minutes of mild exercise can be performed right after a meal without insulin dose adjustments or snacking

▶ Manohar C, et al. Diabetes Care 2012;35:2493-9.

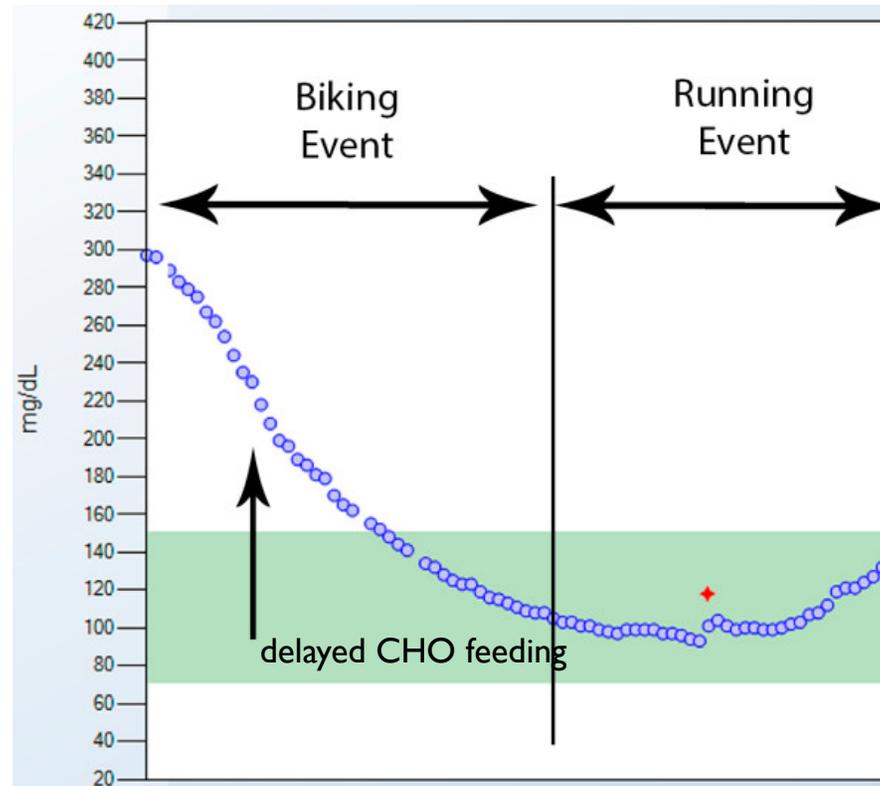
Carbohydrate “snacking” to prevent exercise-induced hypoglycemia



ExCarbs are based on estimated glucose oxidation rates during exercise. These are ingested without insulin administration to maintain glucose levels.

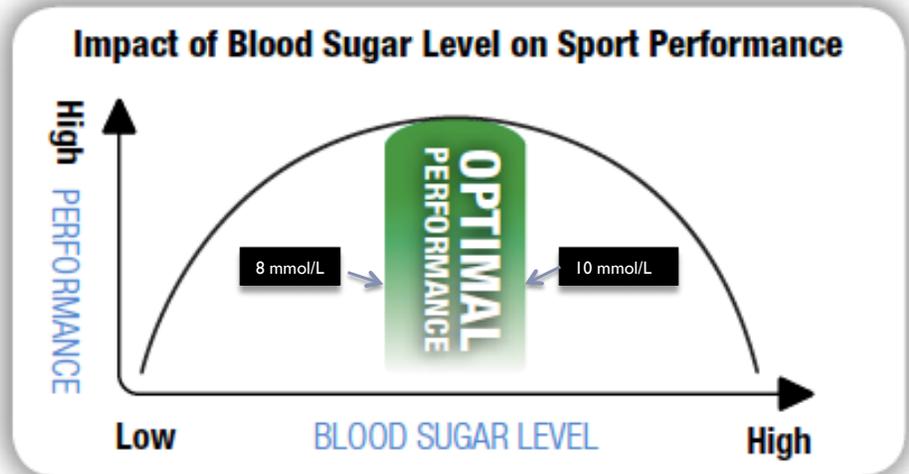
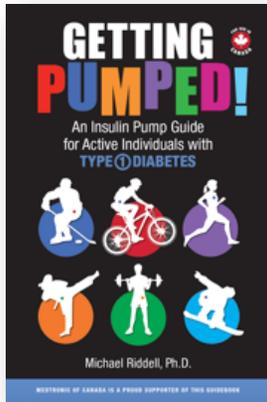
www.excarbs.com

This 18-year-old male used RT-CGM while training for and competing in a 13h Ironman Triathlon



Larson and Pinsky Int. J. Ped End. 2013

Blood sugar control impacts
exercise performance in T1D?

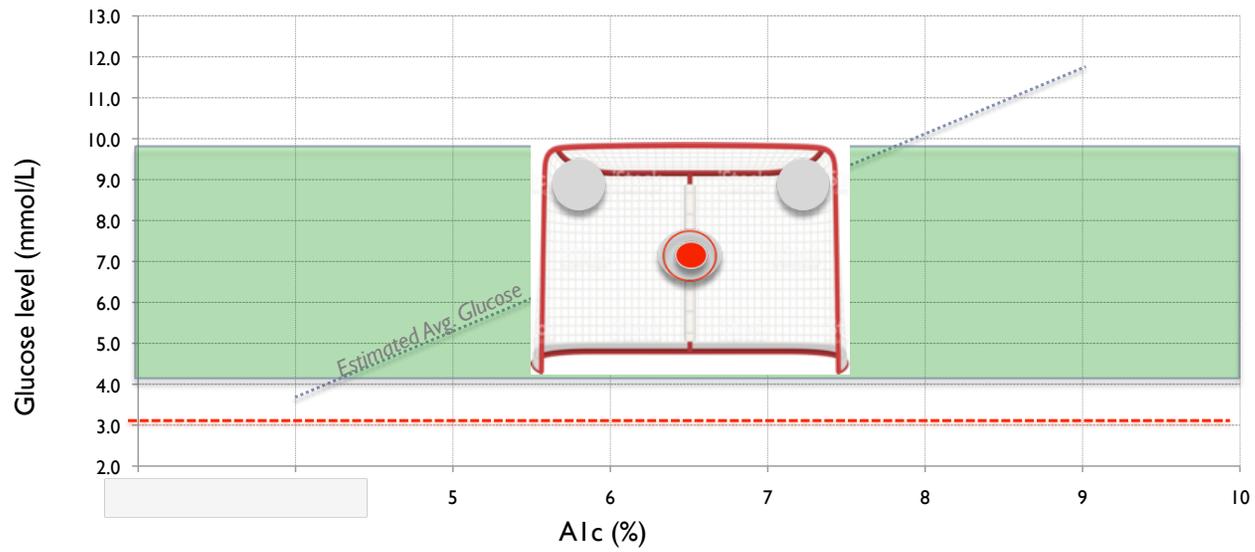


- ### CONSEQUENCES OF BLOOD SUGAR LEVEL
- | | |
|----------------------|---------------------|
| Too Low | Too High |
| ▼ Coordination | Endurance ▼ |
| ▼ Skill Level | Muscle Strength ▼ |
| ▼ Mental Performance | Glycogen Reserves ▼ |
| ▲ Fatigue | Fatigue ▲ |
| ▲ Risk of Injury | Dehydration ▲ |

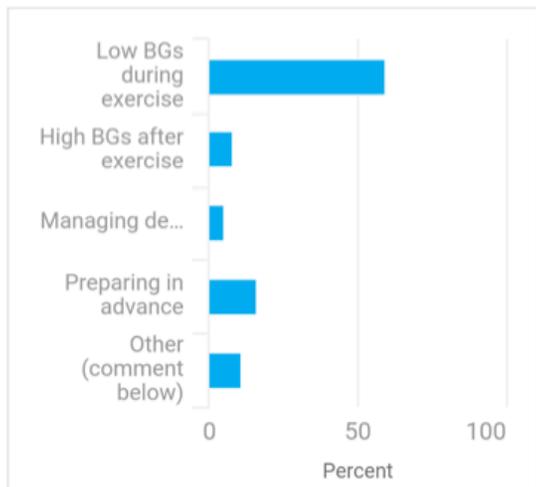


▶ M. C. Riddell, *Getting Pumped: An Insulin Pump Guide for Active Individuals with Type 1 Diabetes* 2016

- Pump and continuous glucose monitoring
- **MOTIVATION!**
- Regular predictable physical activity
- Moderate carb diet (nuts, seeds, fruits, vegetables, protein, milk...)

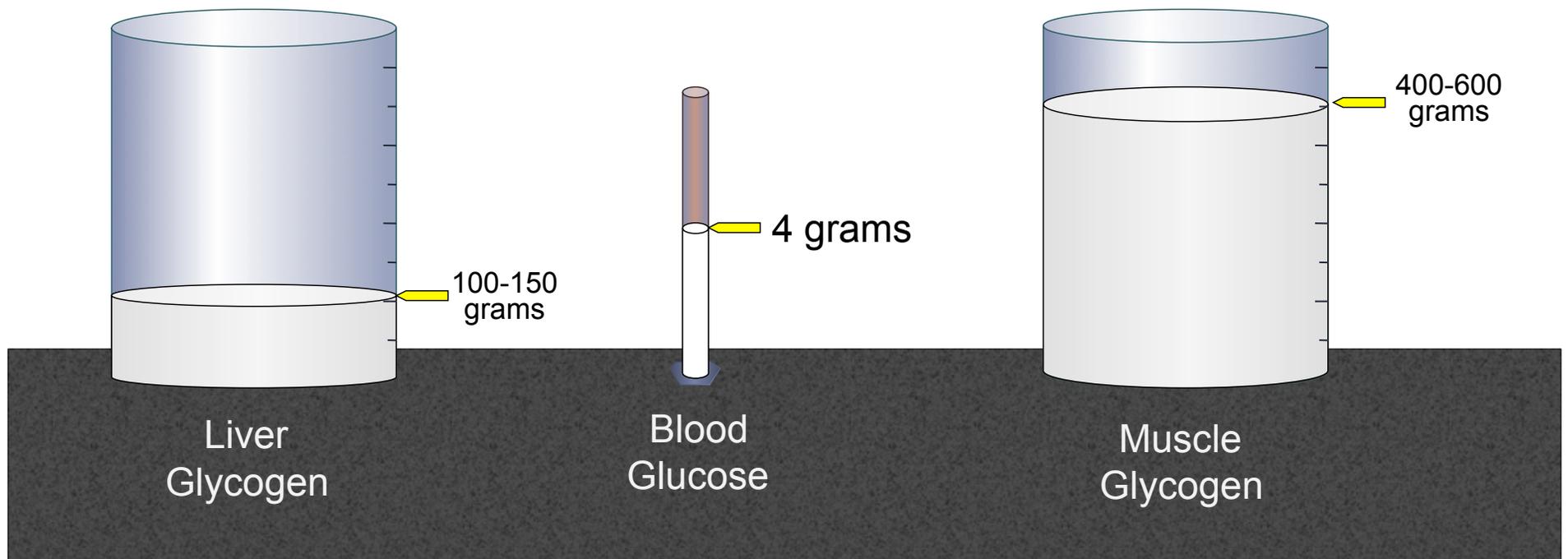


May 24
- **ANSWERED:** What is your biggest challenge when managing type 1 and exercise?
Your answer: High BGs after exercise

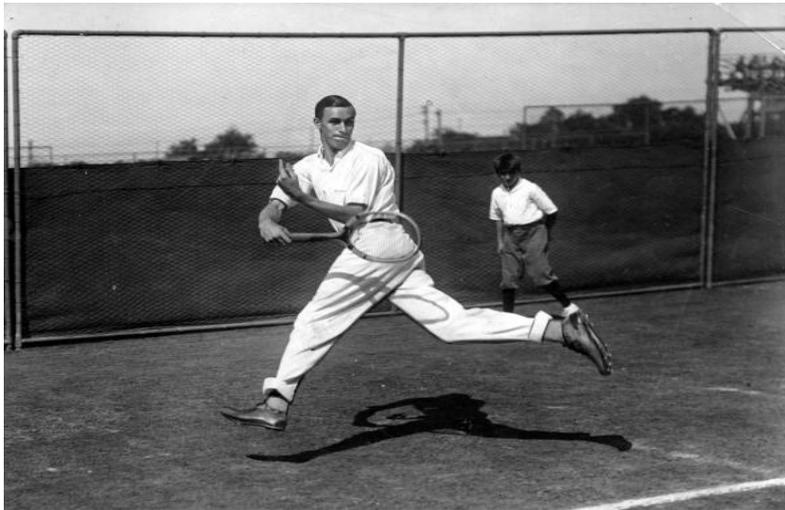


The main challenge with T1D and exercise is the limited glucose storage in blood...

Typical Carbohydrate Stores of a 170lb male "athlete"



Aerobic exercise has long been known to act like insulin to lower blood glucose levels

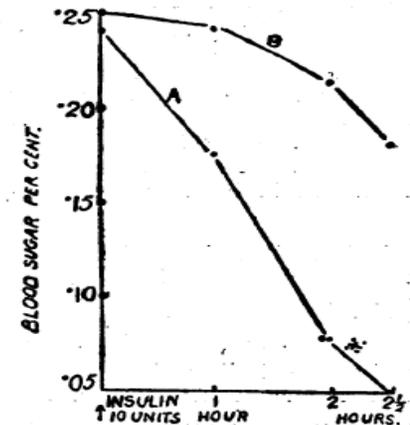


THE EFFECT OF EXERCISE ON INSULIN ACTION IN DIABETES.*

BY

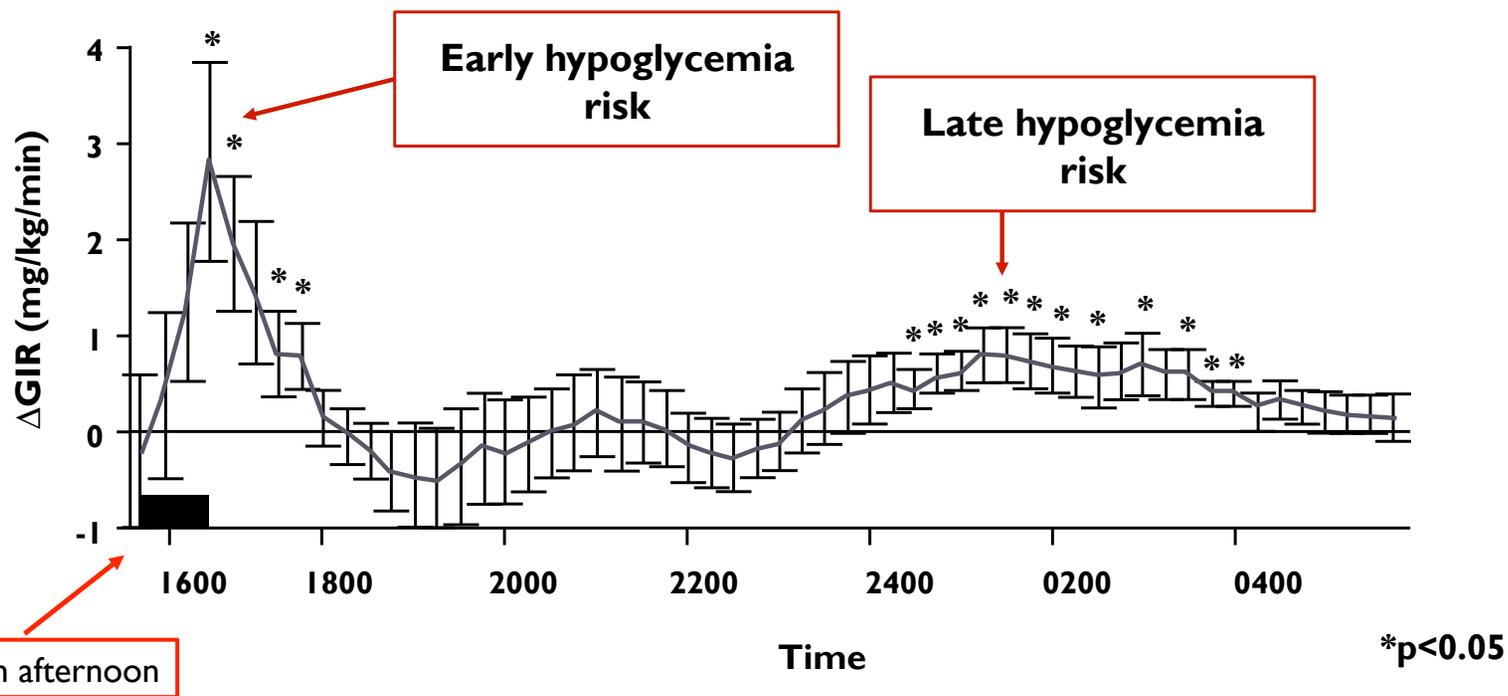
R. D. LAWRENCE, M.D.,
CHEMICAL PATHOLOGIST, KING'S COLLEGE HOSPITAL.

Time. Minutes.	A. Insulin + Exercise.	B. Insulin, no Exercise.
2 p.m.	240 Insulin 10 units	254 Insulin 10 units
20	245	—
30	—	242
45	219	—
60	175	239
90	116	230
120	73*	211
150	51*	181
4.30 p.m.		



The British Medical Journal 1926

Glucose Infusion Rates (GIR) to Maintain Euglycemia during and after exercise in T1D: Biphasic Glucose Requirements



McMahon et al., JCEM 2007

Adjusting insulin to prevent exercise-induced hypoglycemia

Consider the timing of exercise relative to insulin administration

Exercise within 1-2 hours after an insulin bolus

- Reduce pre-exercise meal bolus insulin dose by 25-75% and consume carbohydrates with a low glycaemic index at the meal before exercise¹⁻⁵

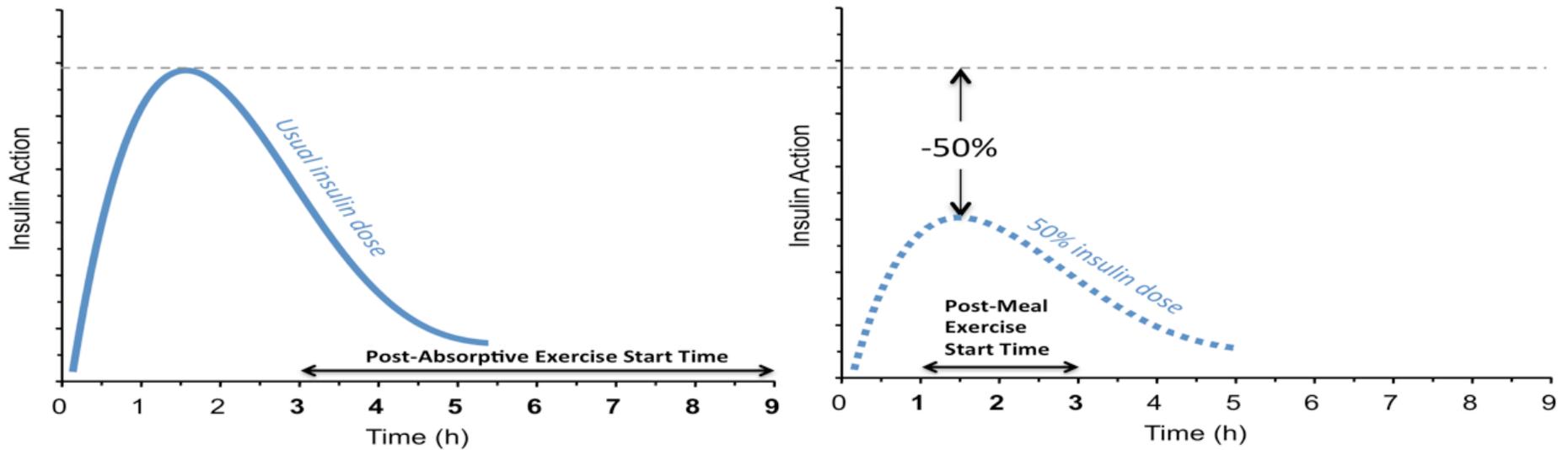
Exercise >2 hours after a bolus

- Consider basal insulin rate reduction 90 minutes before exercise onset (CSII only) and/or consume fast acting carbohydrates before/during the activity as necessary



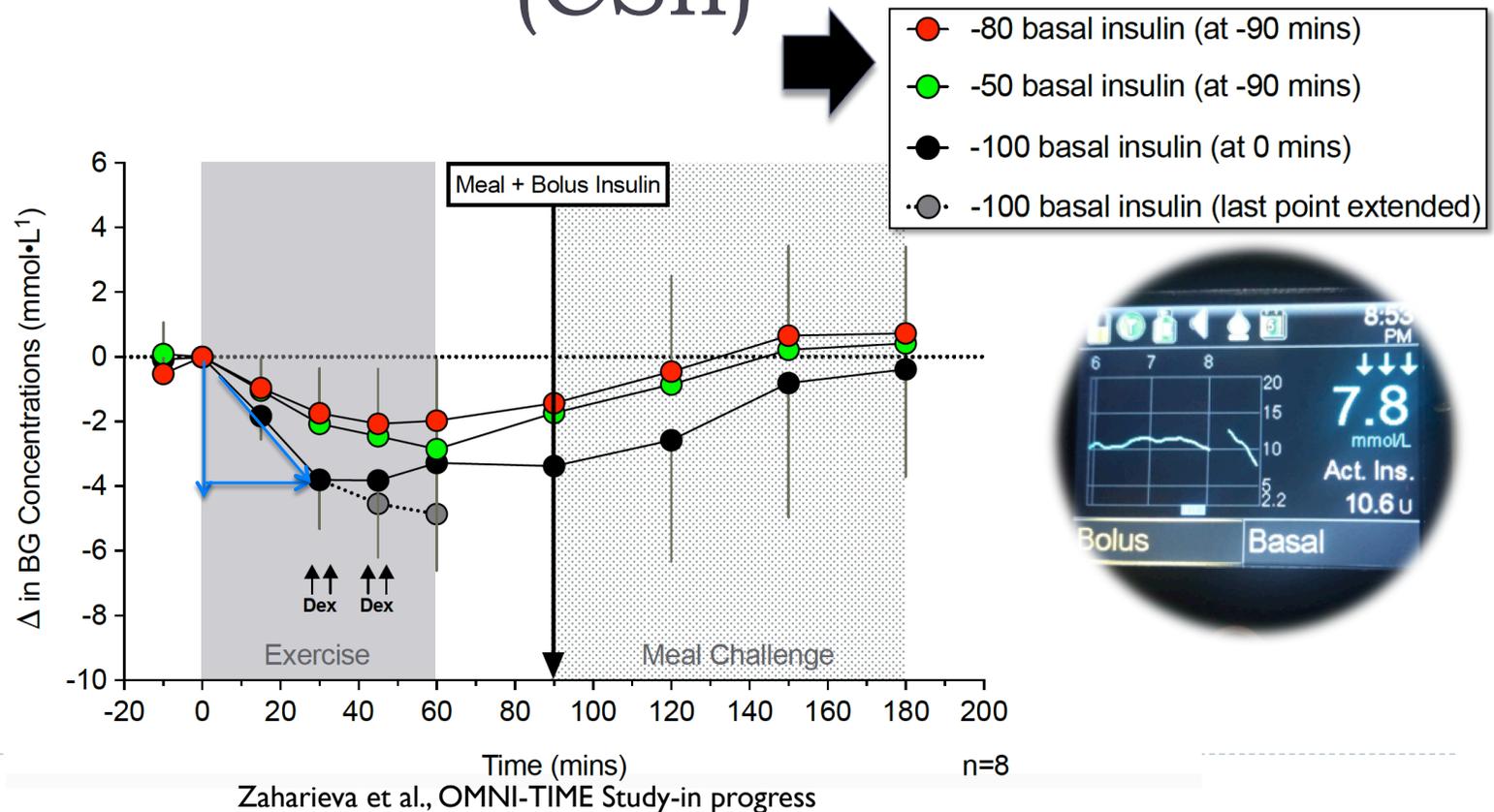
Low glycemic index carbs include whole wheat or pumpernickel bread, oatmeal, beans and lentils, whole fruit and non starchy vegetables , pasta and whole milk (or soy milk)

Bolus reductions for post meal aerobic exercise

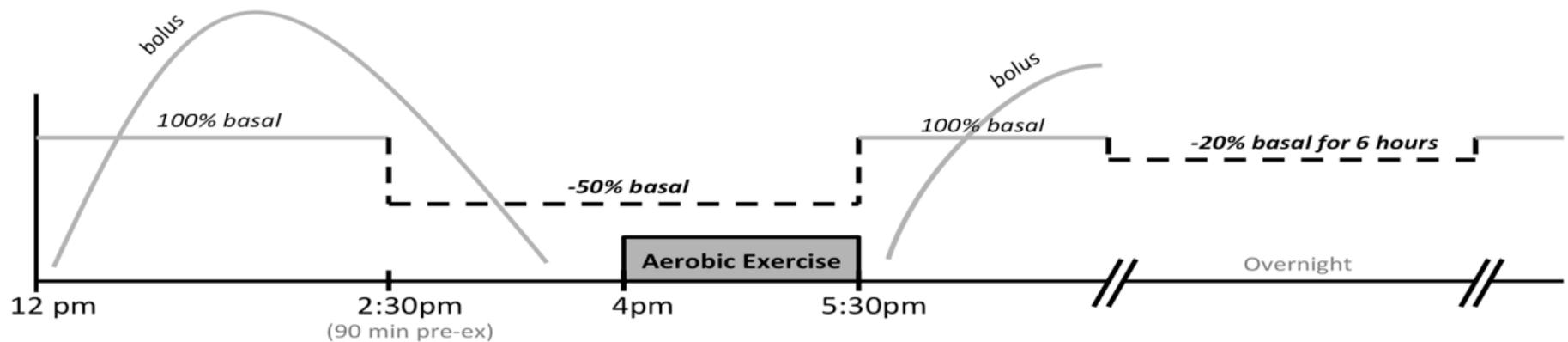


For aerobic exercise to be performed after a meal, take ~50% less insulin.

Exercise and basal adjustments (CSII)

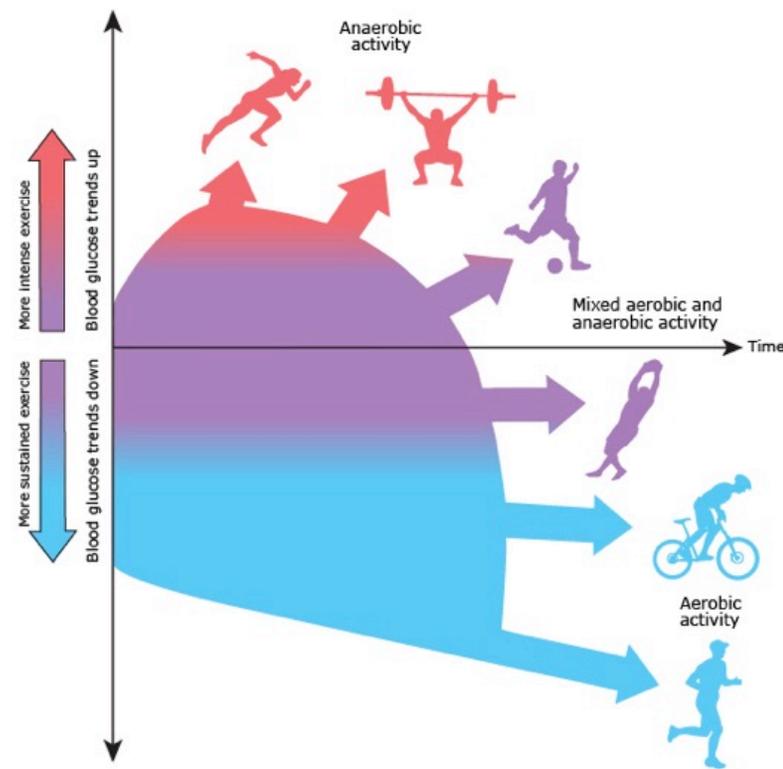


Recommended timing of basal rate reductions (pump)



For aerobic exercise performed before meals, reduce basal insulin by 50-80% well in advance of exercise (60-90 min pre exercise).

Various types of exercise can do different things to blood glucose...

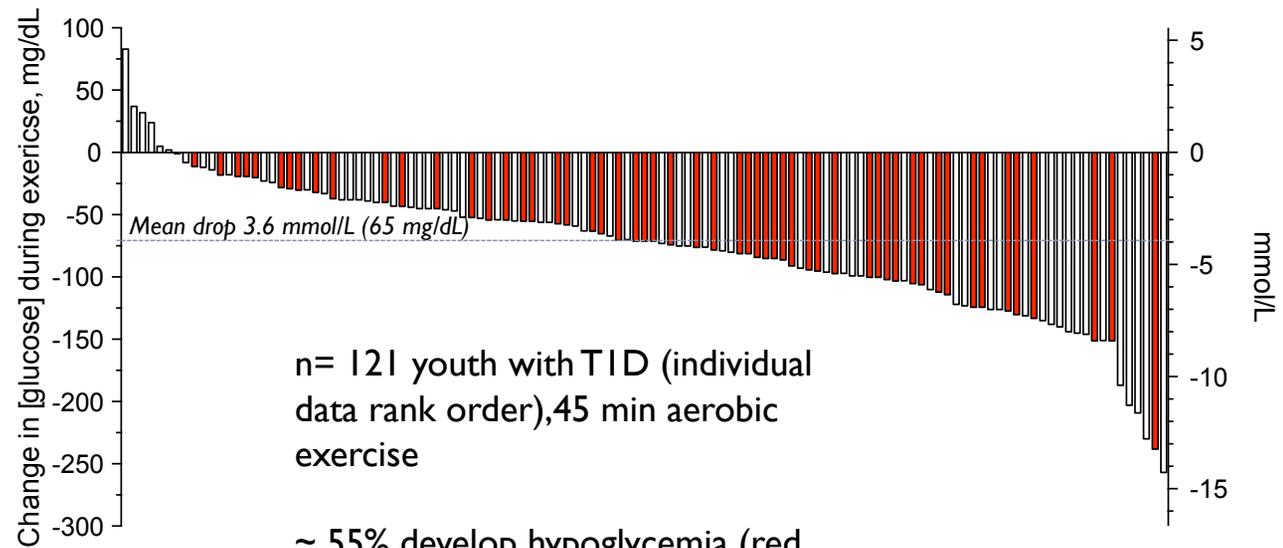


► Illustration by Anne Greene, Senior Medical Illustrator. Reproduced with permission from: Riddell MC. Management of exercise for children and adolescents with type 1 diabetes mellitus. In: UpToDate, Post TW (Ed), UpToDate, Waltham, MA. (Accessed on [Date].) Copyright © 2017 UpToDate, Inc.

Patient Variability



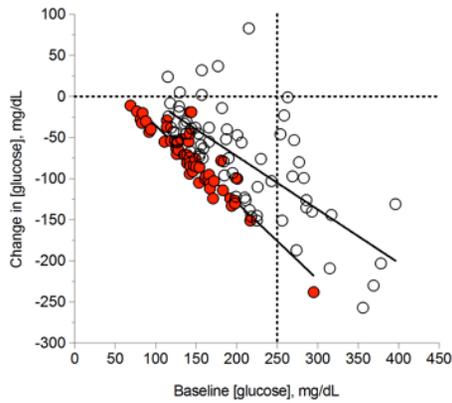
Individual changes in the blood glucose response to 45 min of standardized aerobic exercise (cycling) in youth with T1D (with no insulin adjustments or snacks)



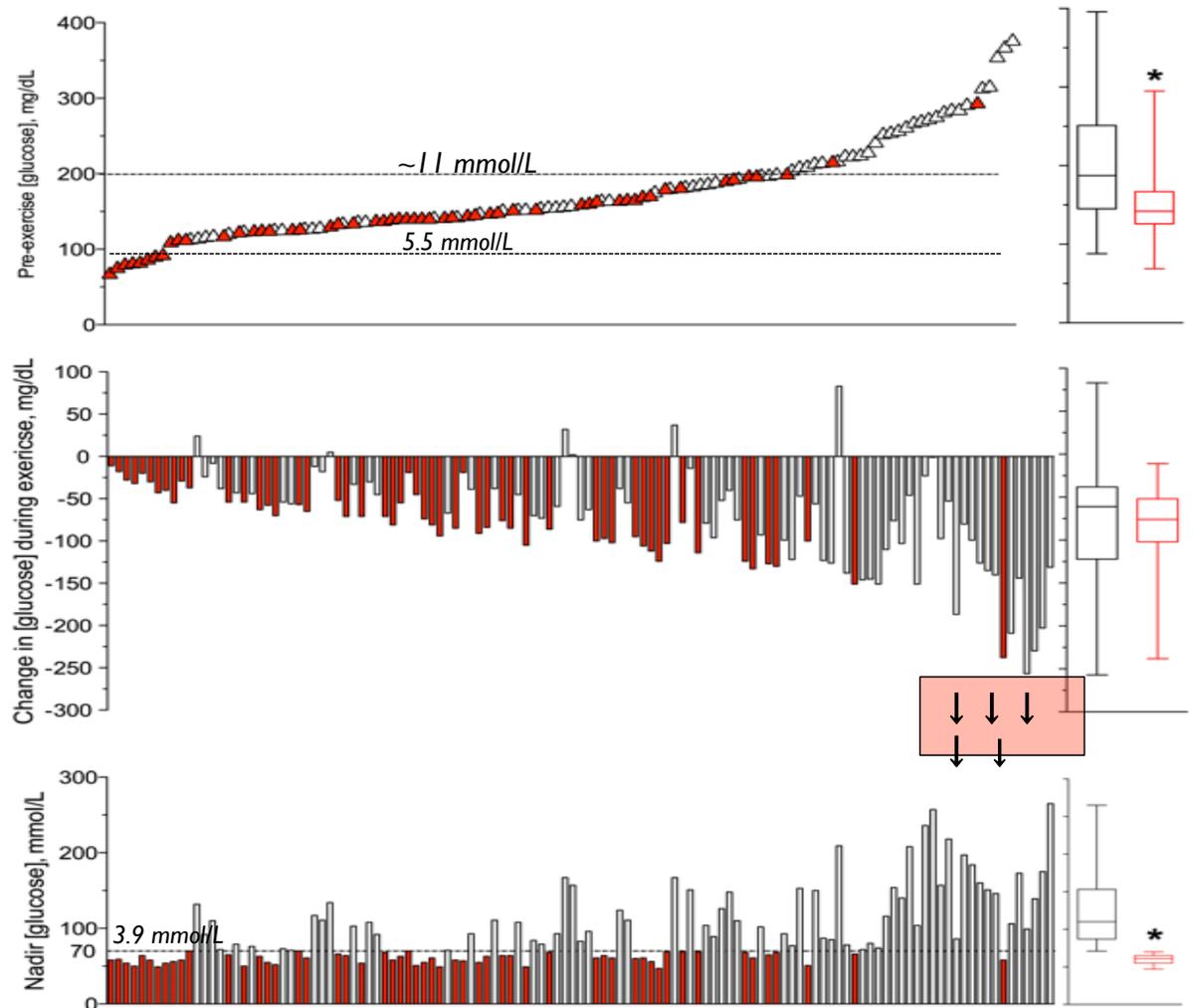
n= 121 youth with T1D (individual data rank order), 45 min aerobic exercise

~ 55% develop hypoglycemia (red bars)

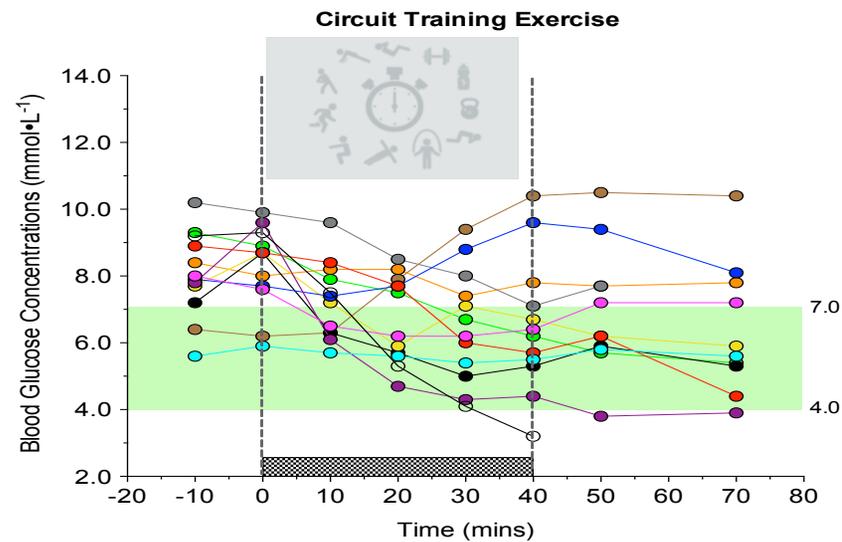
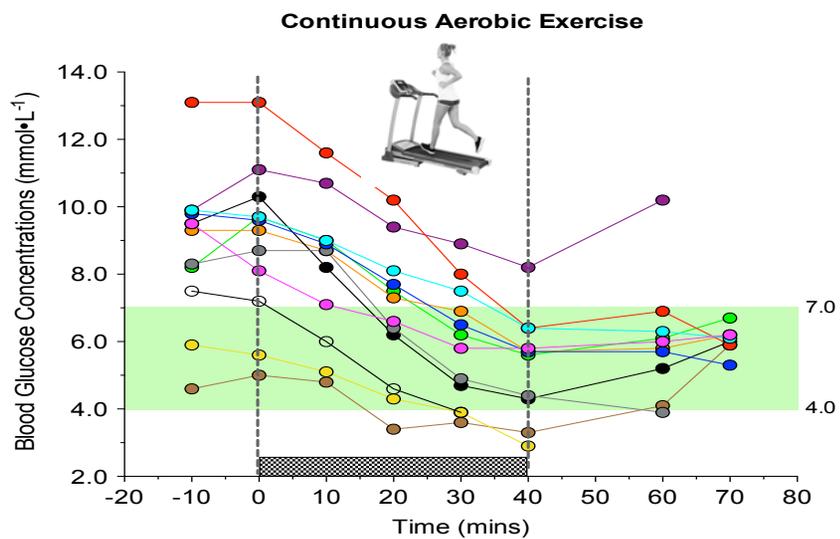
Starting glucose and change in glucose during 60-min aerobic exercise in 120 patients with T1D.



Zaharieva et al., ADA, 2017



Continuous aerobic exercise vs. circuit training exercise (pump off) in T1D

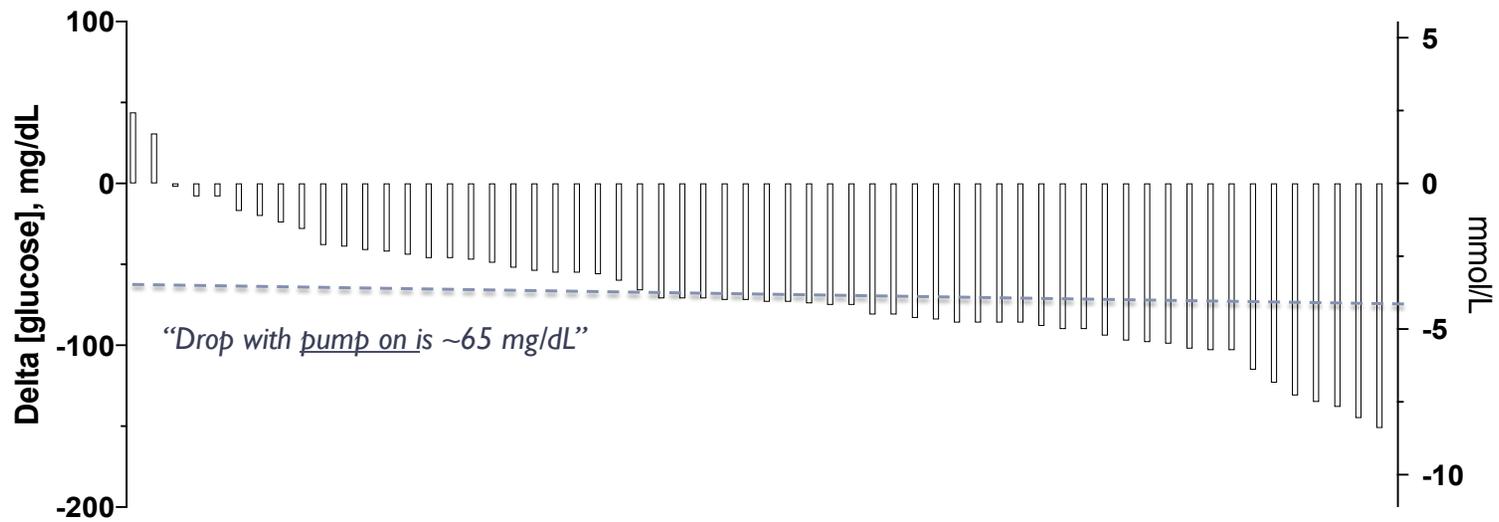


Zaharieva et al., Diabetes Technol Ther 2017

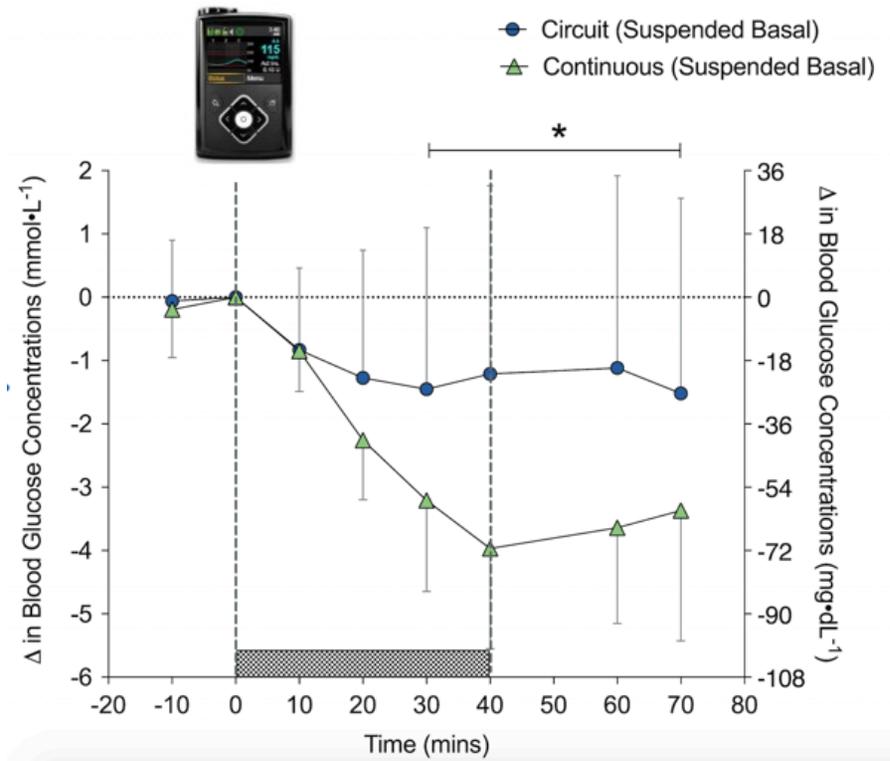
Individuality in the glucose response to CSII patients during aerobic exercise

Individual participant data extracted from Admon et al., Pediatrics. 2005; 116:e348-55 and DirecNet Study Group, Diabetes Care. 2006; 29:2200-4.

□ pump on delta



Taking the pump off for 45 minutes of aerobic exercise is usually ok

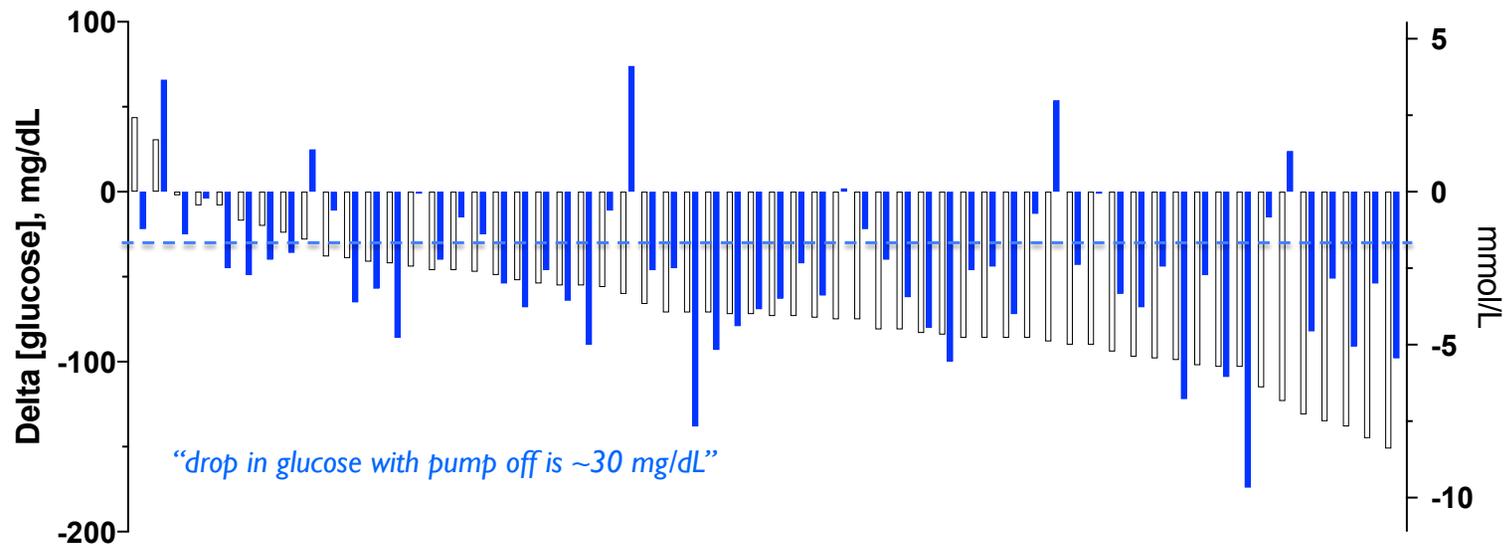


Zaharieva et al., Diabetes Tech Ther. 2017

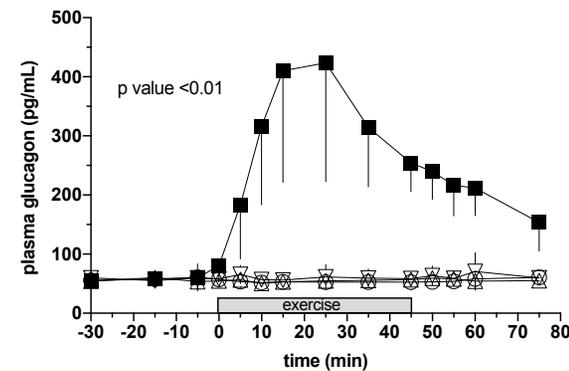
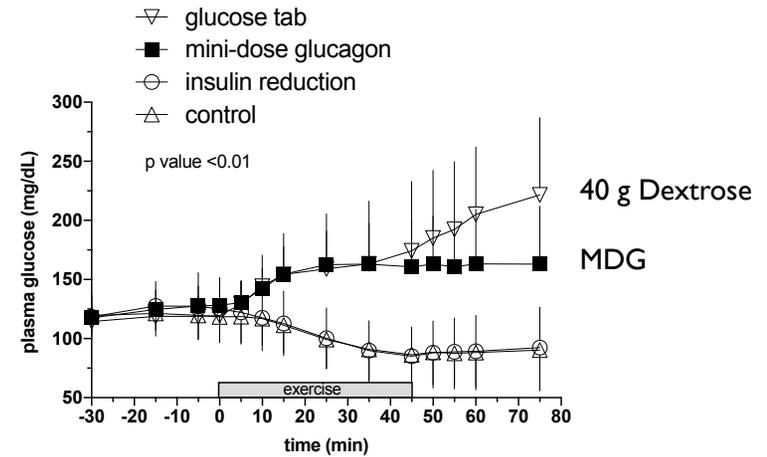
Individuality in the glucose response to insulin pump removal during aerobic exercise

Individual participant data extracted from Admon et al., Pediatrics. 2005; 116:e348-55 and DirecNet Study Group, Diabetes Care. 2006; 29:2200-4.

□ pump on delta
■ pump off delta

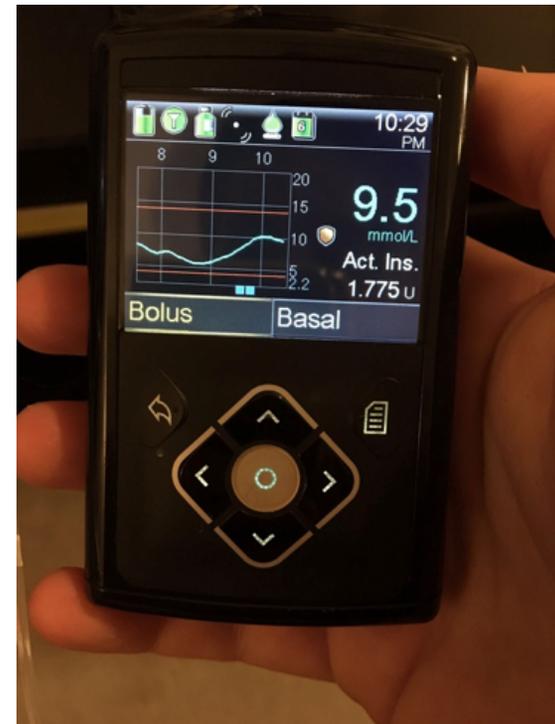


In the very near future, we may be able to administer mini dose glucagon for aerobic exercise to help prevent hypoglycemia...



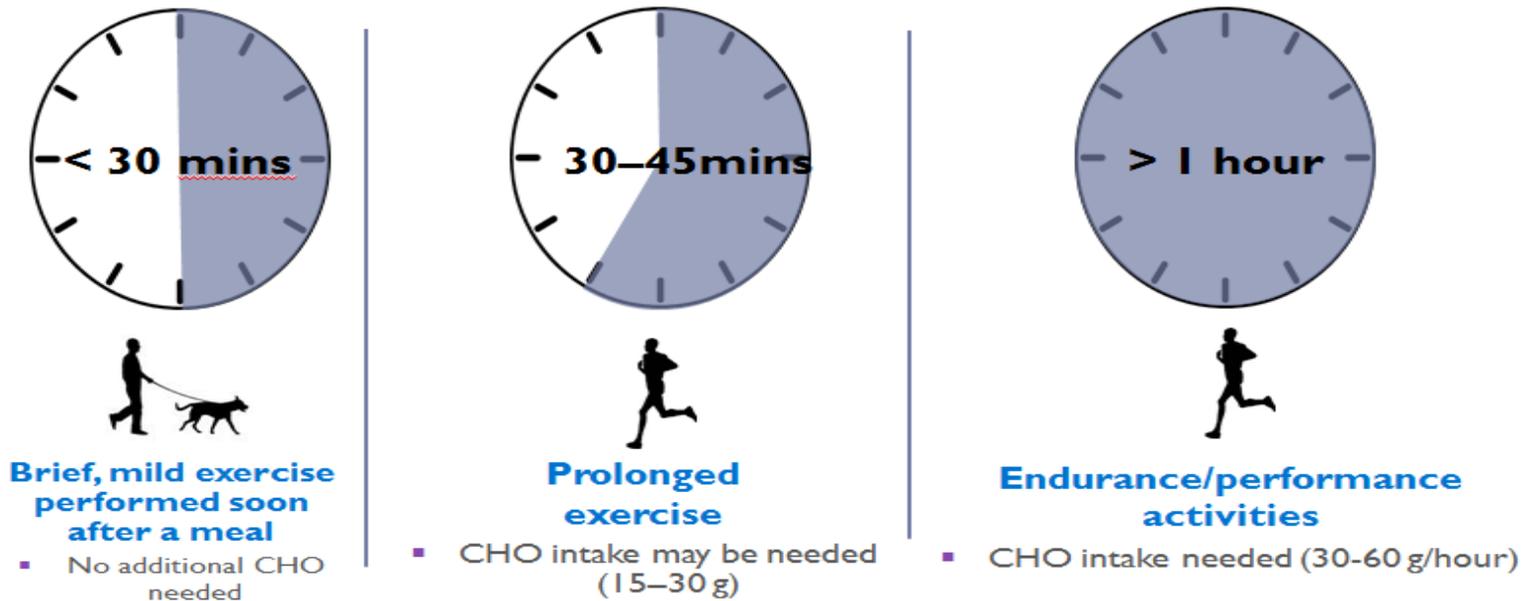
Rickels et al., ADA 2017

When it comes to exercise and T1D, on board insulin matters!



What if you don't bother with changing insulin delivery- can you still exercise?

Carbohydrate (CHO) Intake for Aerobic Exercise

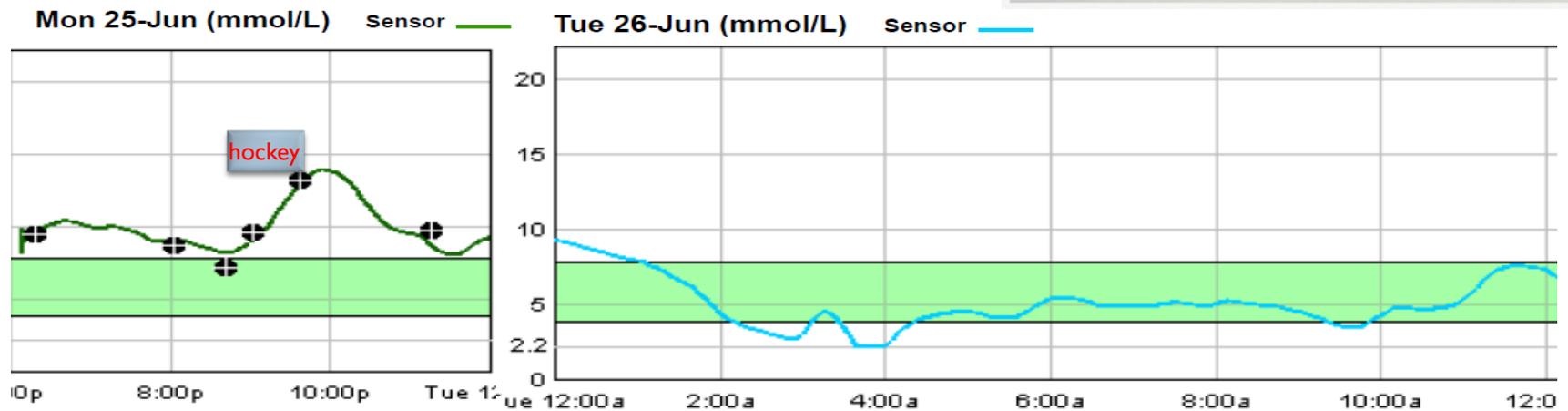


Low blood sugar overnight after exercise

- ▶ In youth with type 1 diabetes, most episodes of severe hypoglycemia occurs during sleep
- ▶ Increased exercise and a previous low during the activity increases risk for another low overnight
- ▶ Real-time CGM provides alarms that can wake you up
 - ▶ Sometimes alarms are not responded to

DCCT, Diabetes Care 18:1415, 1995
Davis, Diabetes Care 20:22, 1997
Buckingham, DTT 7:440, 2005

Exercise can transiently cause hyperglycemia.....
Then late-onset hypoglycemia....



Overnight Glucose Control

- ▶ Medtronic pumps and preventing lows
 - ▶ Threshold suspend on low (suspend on low) (Medtronic 630G with SmartGuard™ Technology)
 - ▶ Predictive low glucose suspend (Medtronic 640G)
 - ▶ Full Closed-loop at night (Medtronic 670G)





Persistent low* episodes reduced from **6 to 1** per year with no additional time spent high.²



OUR SYSTEMS ARE SUPERIOR TO A PUMP AND SENSOR ALONE.¹

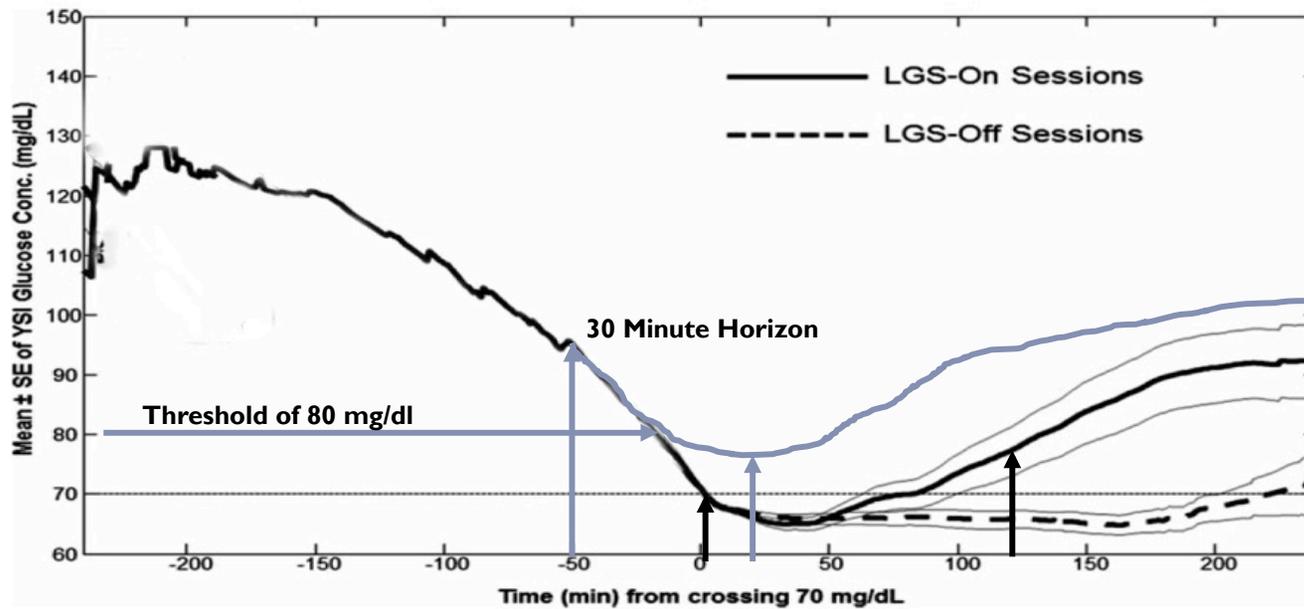
Time per day spent below 70 mg/dL



50 FEWER MINUTES PER DAY* OF SHAKING, SWEATING OR FEELING WORSE^{3,4}

Low Glucose Suspend overnight (after usual day and after exercise day, n= 50 subjects)

DTT (2012) 14:205



Medtronic 670G



Glucometer



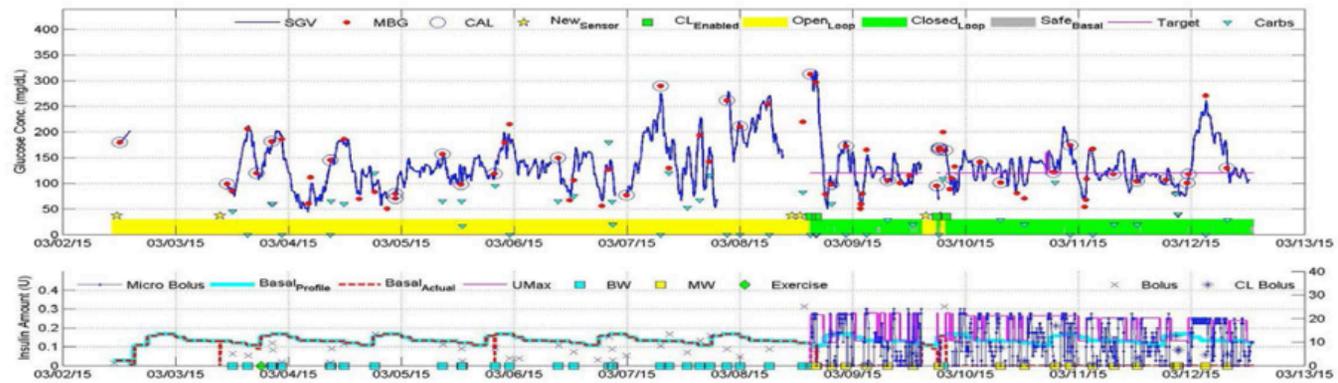
Enlite 3 sensor

Open Loop Compared to Closed-Loop



Overall Patient (304-NG1008908U) Summary [From CL Start]

3/12/15



Exercise of different types...



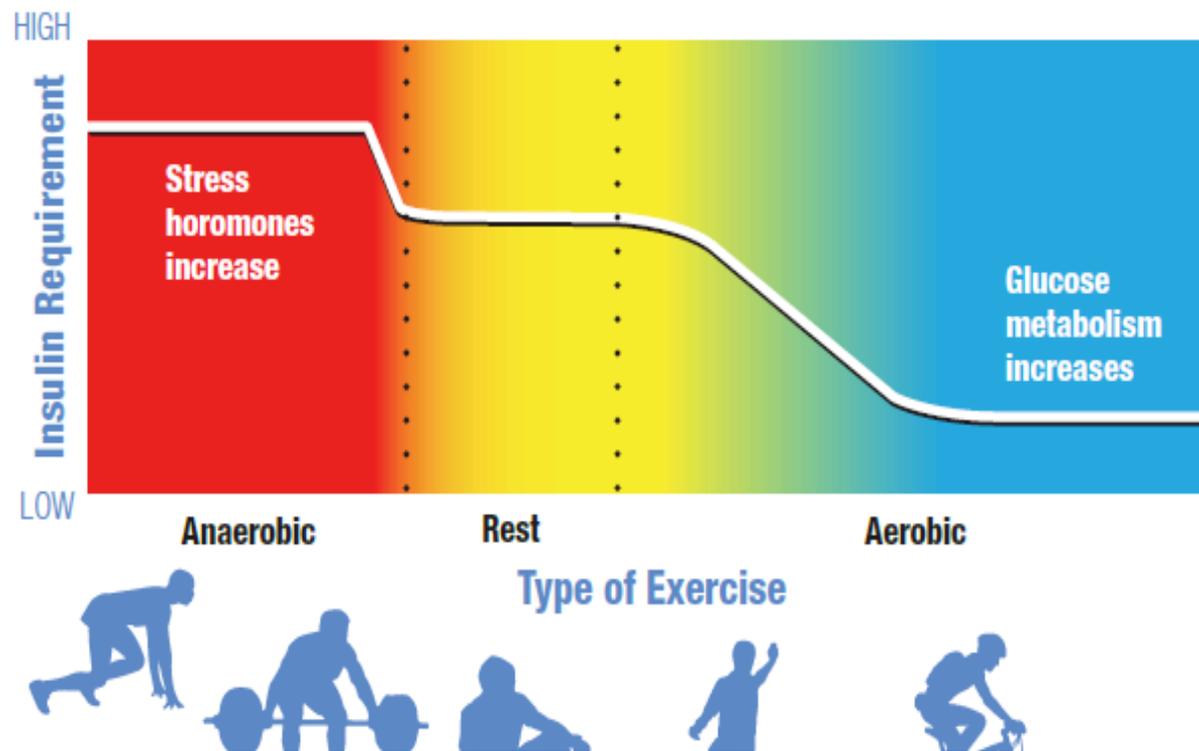
Exercise and Hyperglycemia- the importance of Monitoring



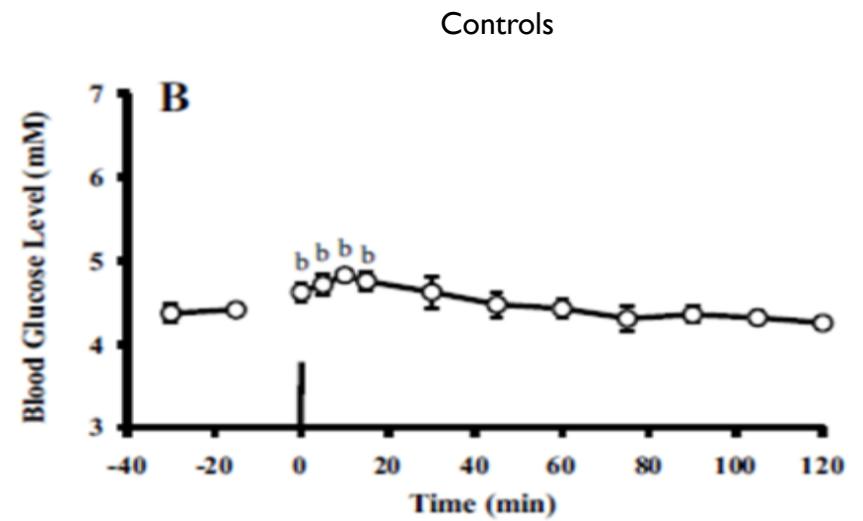
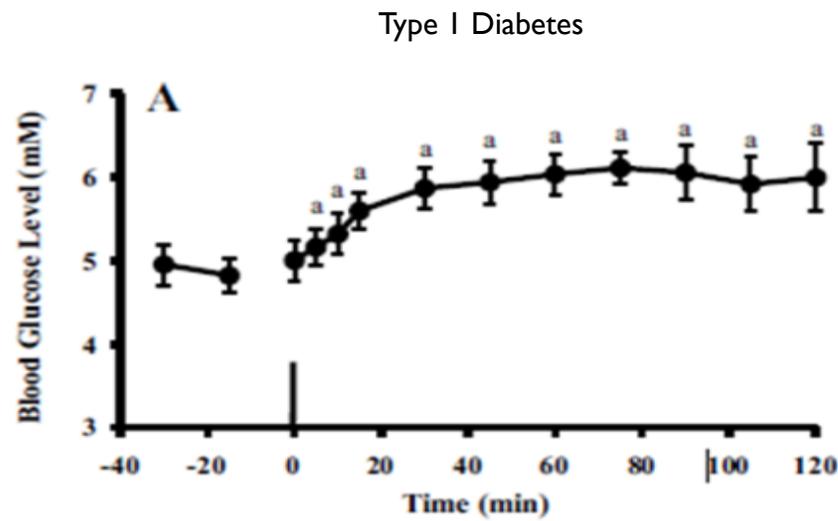
Gary Hall, Jr. (born September 26, 1974, diagnosed T1D in 1999)- US swimmer who competed in the 1996, 2000, and 2004 Olympics and won ten Olympic medals.

“You have to test your blood glucose levels often, the more the better....Nerves will send my levels sky high...When I broke the American record, I tested ten minutes before my race. I was at **7 mmol/L**. Ten minutes after the race I tested again. I was at **22 mmol/L**. The race lasted 21 seconds.”

Insulin needs and the exercise spectrum



Blood glucose response to a 10s anaerobic sprint in adolescents with and without T1D



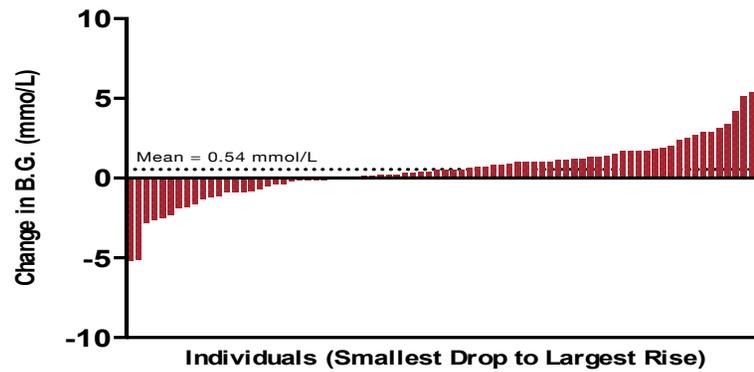
The Dskate Camp Sprint Study (Milton 2016)

~90 kids with T1D performed pre and post blood sugars with sprinting. Each participant was ranked from largest decrease to greatest rise in glycemia...

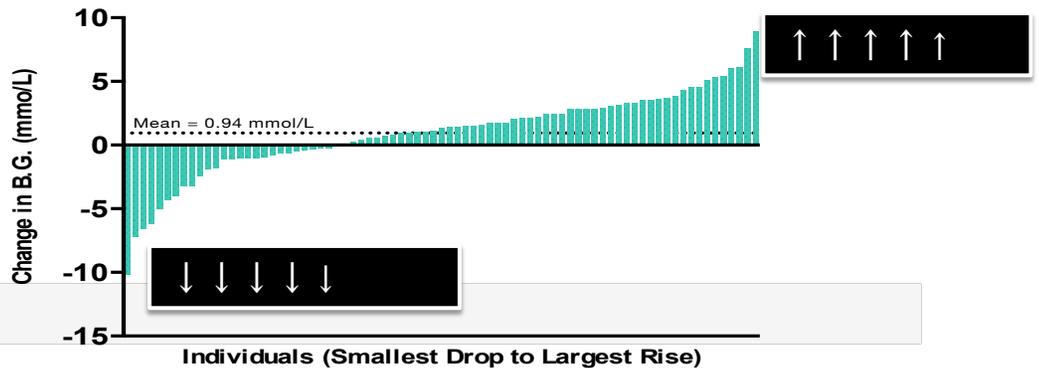


Riddell et al., *Pediatric Diabetes*, in preparation

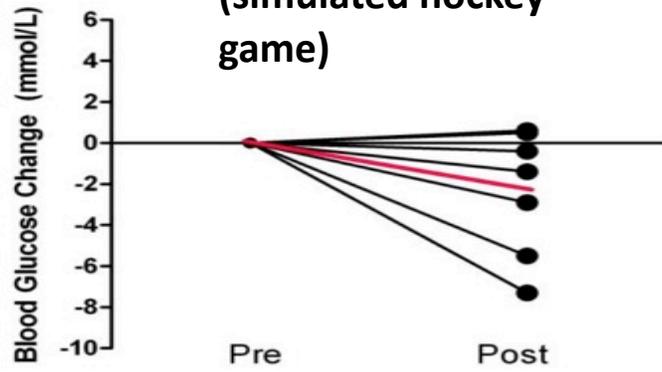
The Sprint Challenge - Change Immediate Post Sprint



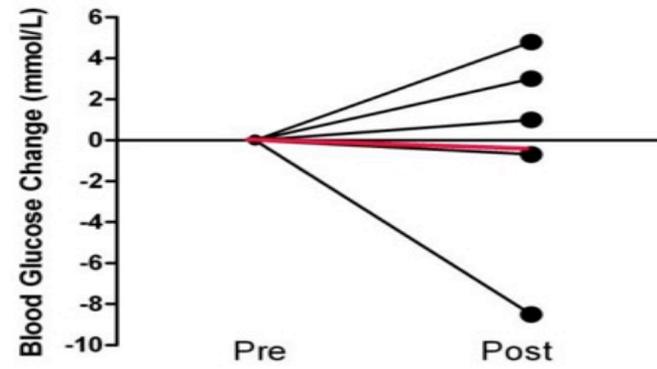
The Sprint Challenge - Change Post 30 Minute Recovery



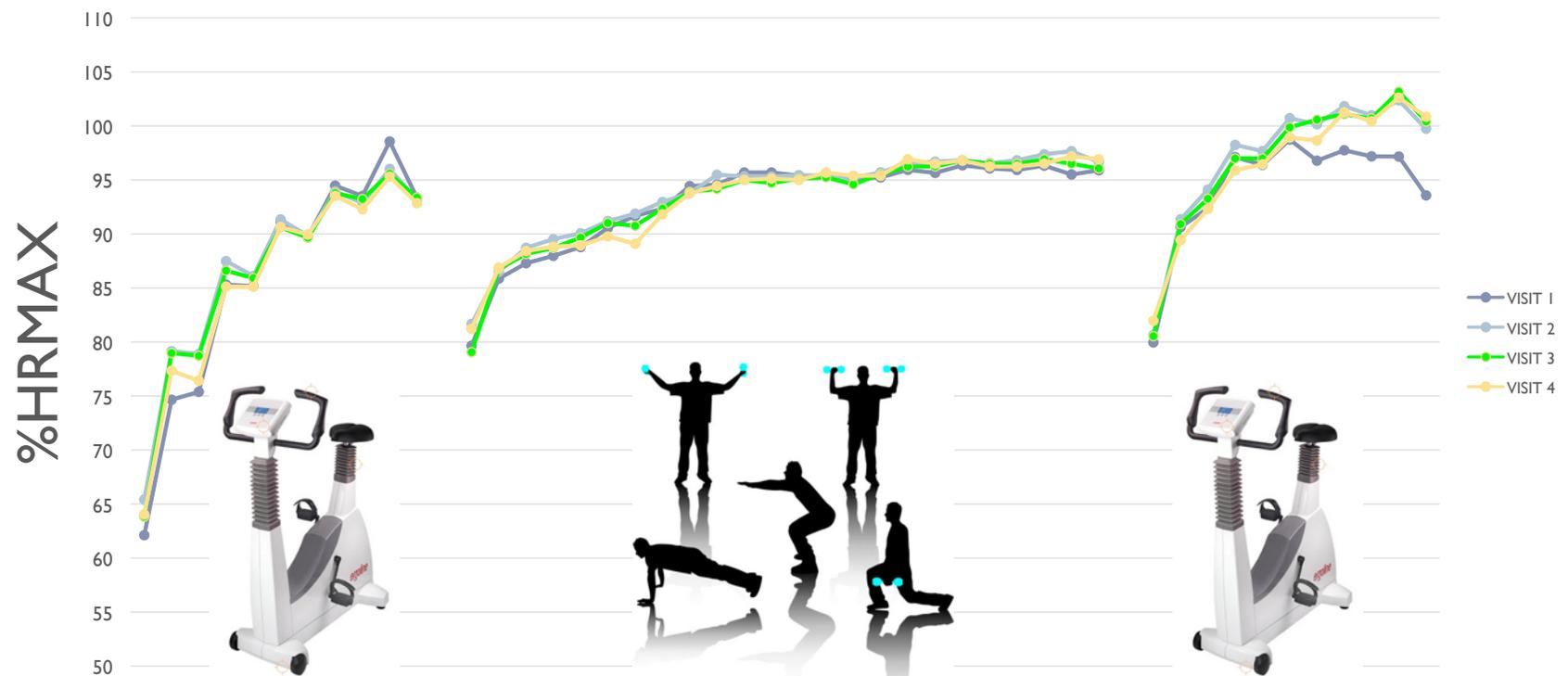
**Lab Exercise
(simulated hockey game)**



True Hockey Game

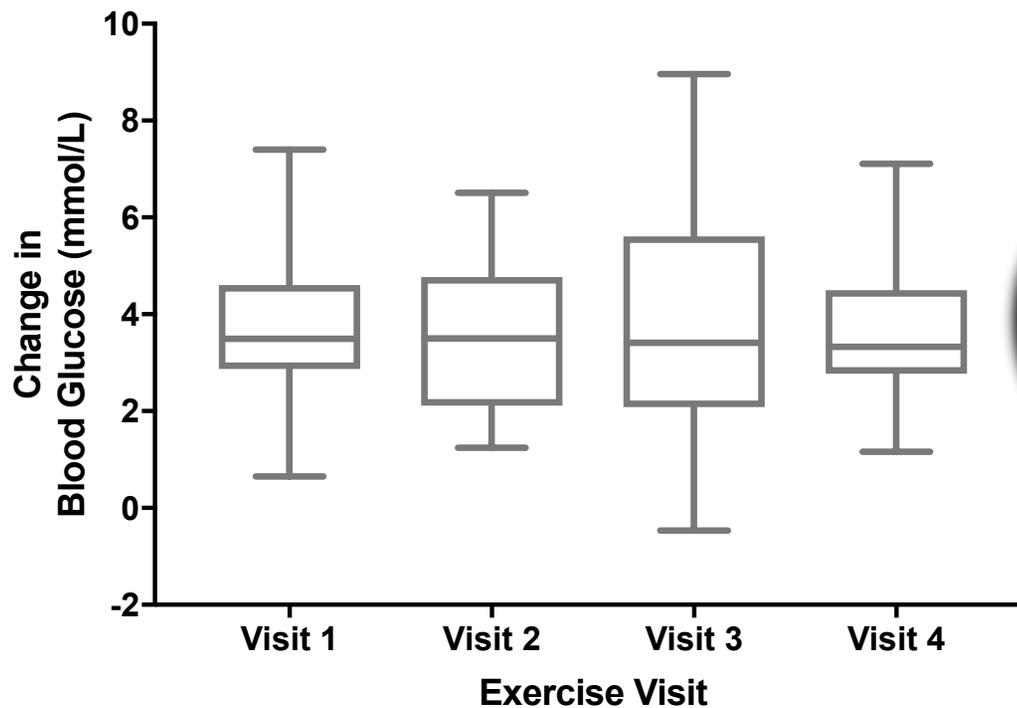


Heart rate responses to 4 separate ~15 min intense circuit training sessions in T1D



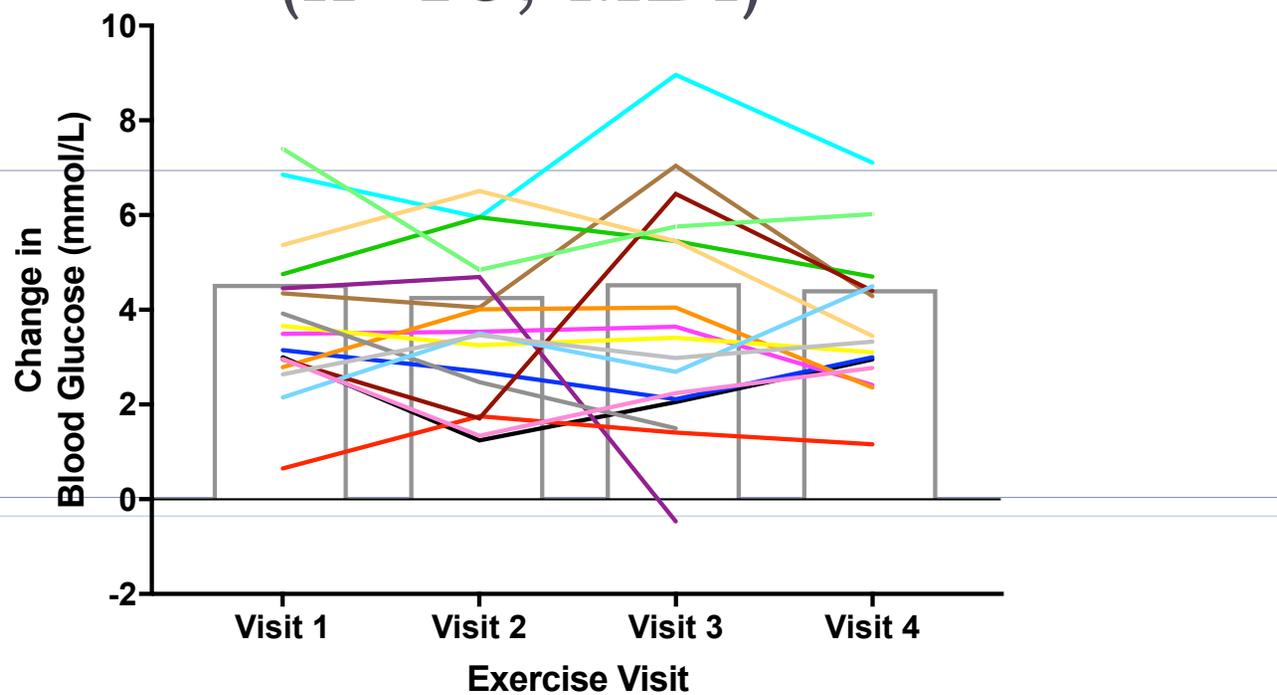
Riddell & Aronson, in progress

Blood glucose response to ~15 min intense circuit training exercise in MDI (n=15)



Riddell & Aronson, in progress

Blood glucose response to ~15 min intense circuit training exercise in T1D (n=15, MDI)



Riddell & Aronson, in progress

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**With diabetes and exercise,
assuming the 'average'
patient response is often
misleading**

**“You have to learn about thousands of diseases, but
I only have to focus on fixing what’s wrong with ME!
Now which one of us do you think is the expert?”**

Before the 2002 Winter Olympics in Salt Lake City, he was diagnosed with Type I diabetes

Kris Freeman Quick Facts

Hometown	Andover, NH
Birthplace	Concord, NH
Birthdate	10/14/1980
Years on Team	10
Club	Ski and Snowboard Club Vail
Olympics	2002, 2006, 2010
Worlds	2001, 2003, 2005, 2007, 2009, 2011



Sports » **Olympics** » Nordic



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USA's Freeman has blood sugar crash in cross-country pursuit

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Enlarge By Steve Elfers, USA TODAY

The USA's Kris Freeman (21) makes his way down a tricky curve during the men's cross-country 30-kilometer pursuit Saturday in Whistler. Freeman, who is a diabetic, was only about six seconds behind at the 11.25 kilometer mark when he had a blood sugar crisis. He finished 45th.

By **Beau Dure**, USA TODAY

WHISTLER — Kris Freeman competes in the grueling sport of cross country skiing with Type I diabetes. Most days, he manages it well; some days, he posts exceptional results such as his two fourth-place finishes in World Championship competition.

In Saturday's men's 30-kilometer mixed-style pursuit race, his condition caught up with him.

RESULTS: Men's 30K pursuit

"On the fourth lap of the classic race, I had a blood sugar crash," Freeman said. "I stopped and lied on the ground for a minute."

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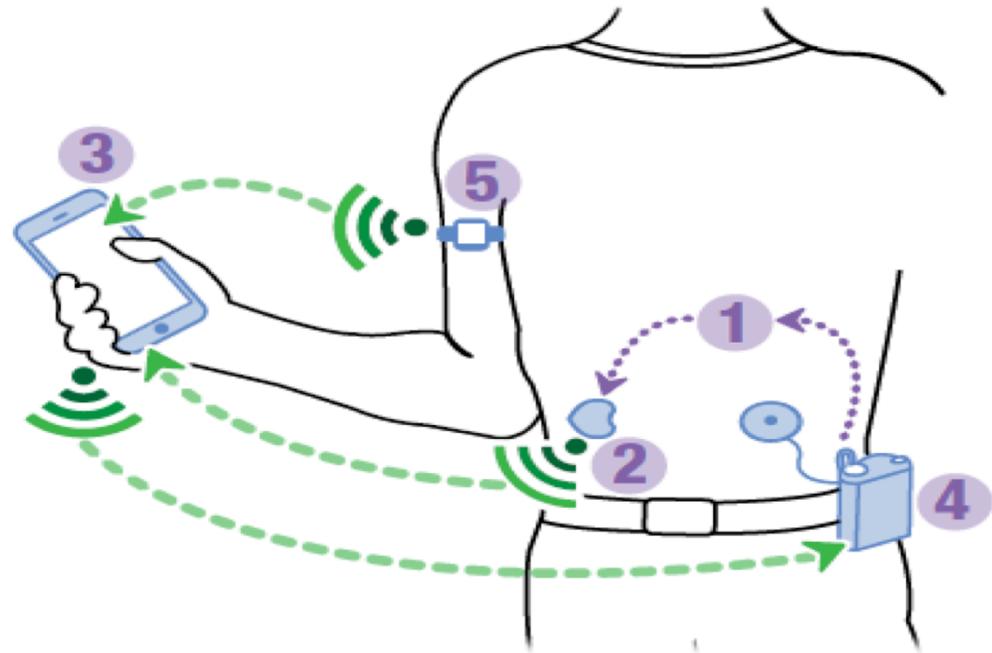
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My vision of the near future for T1D...

In the very near future, we will be using “exercise smart” artificial pancreases!



Summary

- ▶ People with type 1 diabetes can achieve all levels of sporting performance
- ▶ Insulin pumps help by allowing us to change the insulin delivery for exercise (and after exercise) and CGM allows us to see our sugars in real time
- ▶ Choose your activity based on your blood sugar
 - ▶ Pure aerobic exercise (walking, cycling), sugars tend to drop
 - ▶ Heavy/intense exercise (hockey, soccer, basketball, weight training, intervals), sugars can rise
 - ▶ For aerobic exercise to be done soon after meals, try a 50% bolus reduction at the meal before
 - ▶ For aerobic exercise done before meals, try an 80% basal rate reduction (pumpers) done 60-90 min before the exercise starts
- ▶ A sensor-augmented pump with CGM can offer protection, particularly overnight

