

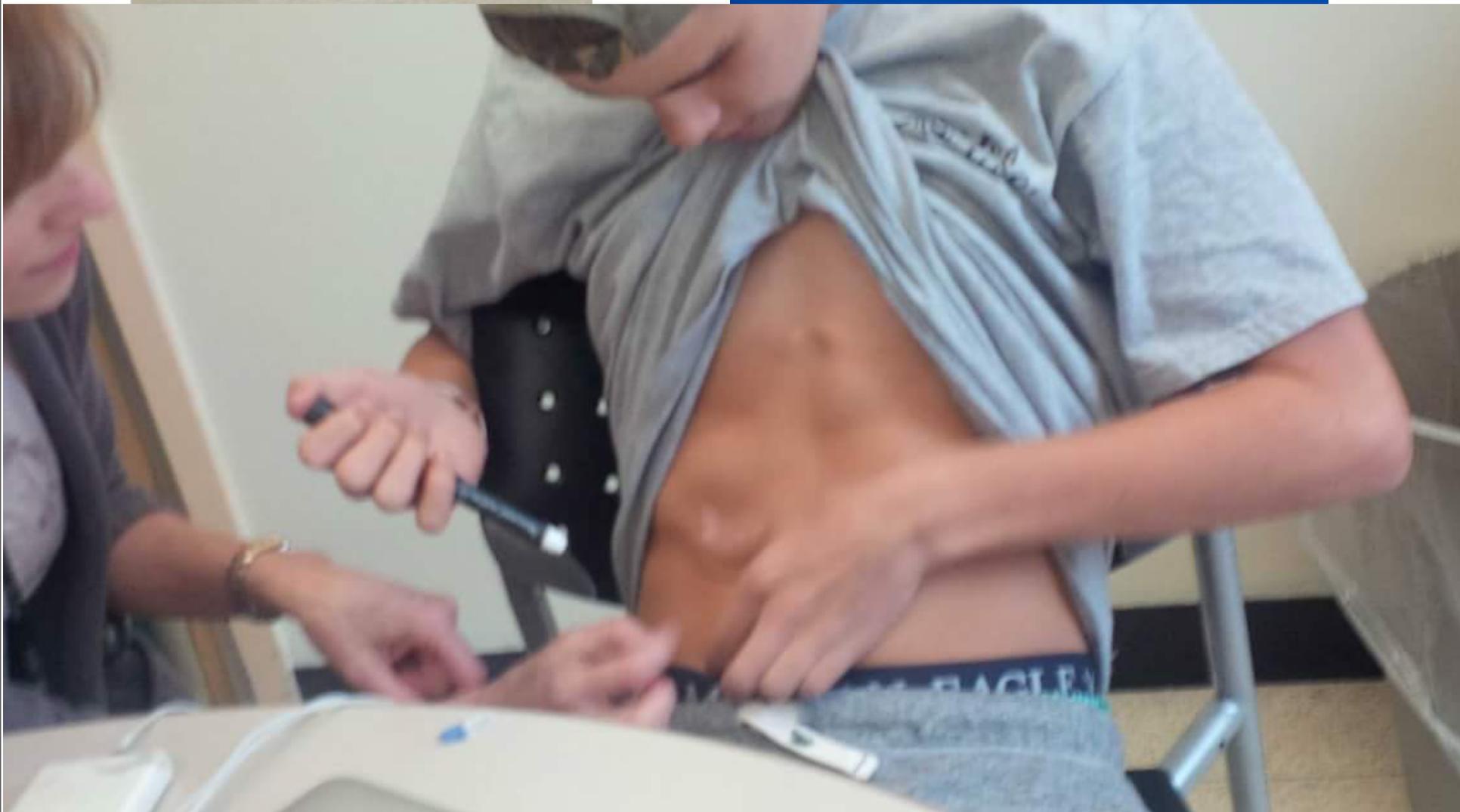
# Exercise & Type 1 Diabetes: Strategies for Glucose Control

**Michael C. Riddell, PhD. School of Kinesiology and Health Science,  
Muscle Health Research Centre, Physical Activity and Diabetes Unit, Faculty of Health, York University  
Toronto, Canada**

# Until a cure is found.....

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





ASCENSA family of products  
Diabetes Care



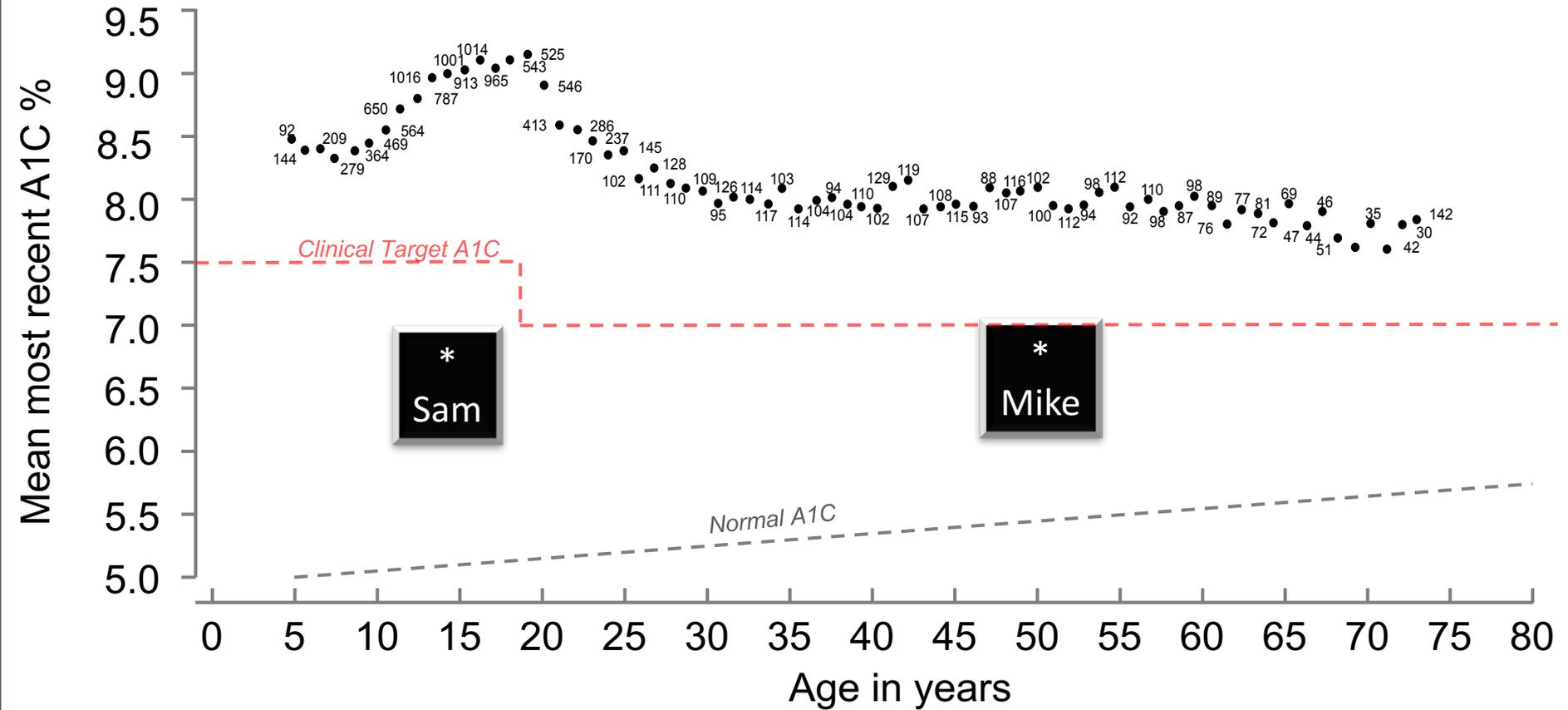
 **Dskate**

 **Medtronic**



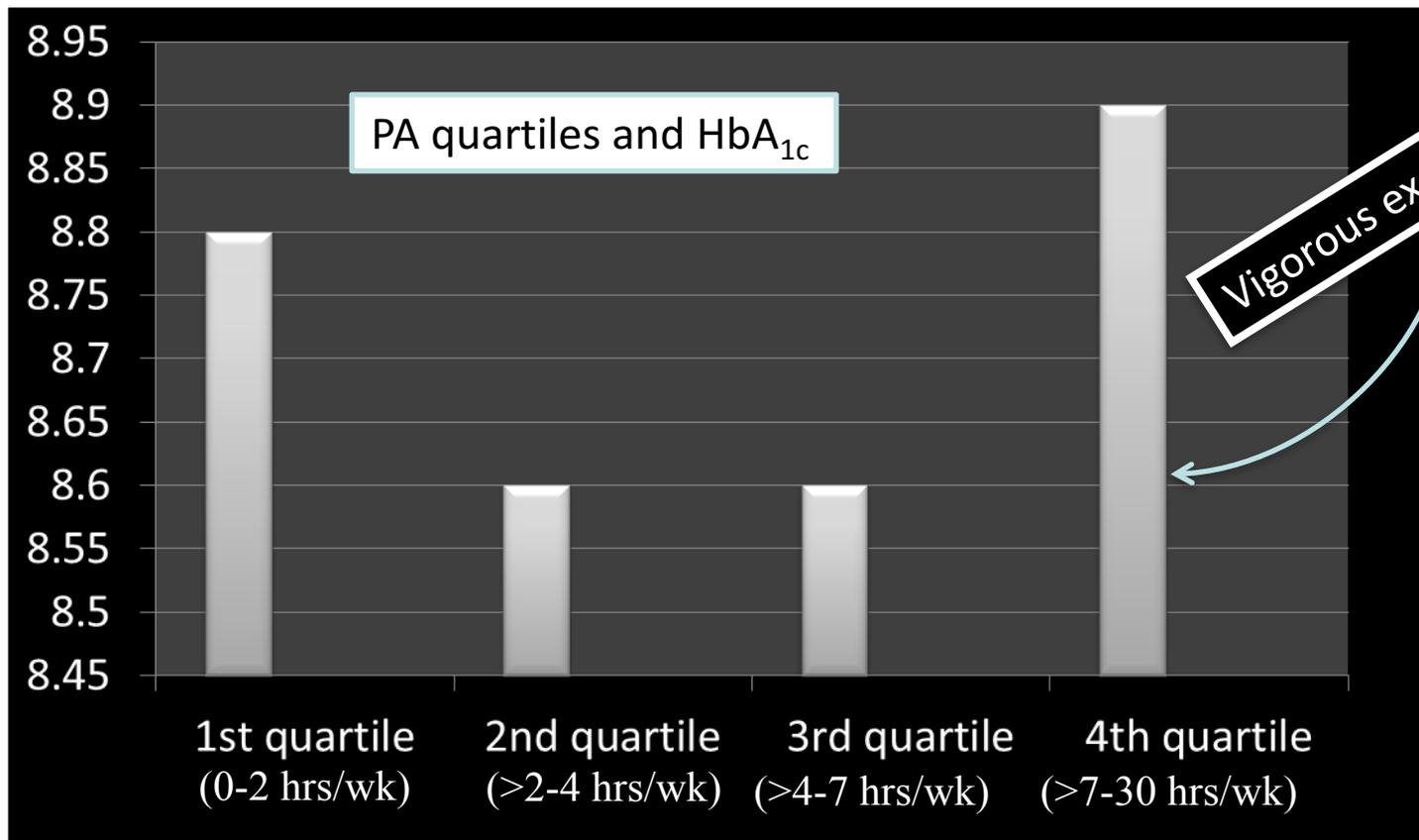
# Despite advances in care, glycemic control is still challenging in T1D

Modified from Miller et al., Diabetes Care. 2015; 38:971



# Associations between physical activity and glycemic control in children, adolescents, and young adults with type 1 diabetes.

Galler et al., Diabetes Care 2011



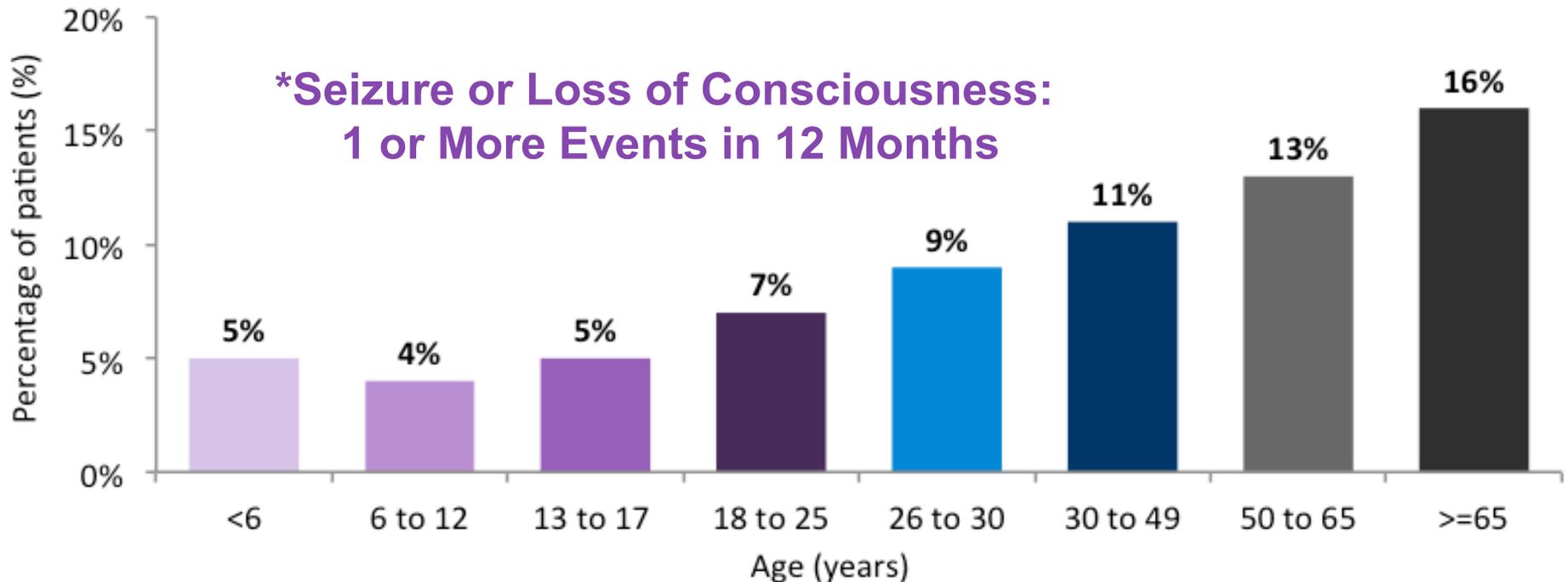
N= 296 children, adolescents, and young adults with type 1 diabetes

**Note:** Youth with T1D spend  $20 \pm 13$  hrs/wk watching television and using computers and  $5.1 \pm 4.5$  hrs/wk engaged in physical activity

# Prevalence of Severe Hypoglycemia (US Data)

1/6 to 1/20 persons with T1D experience severe hypoglycemia each year

**\*Seizure or Loss of Consciousness:  
1 or More Events in 12 Months**

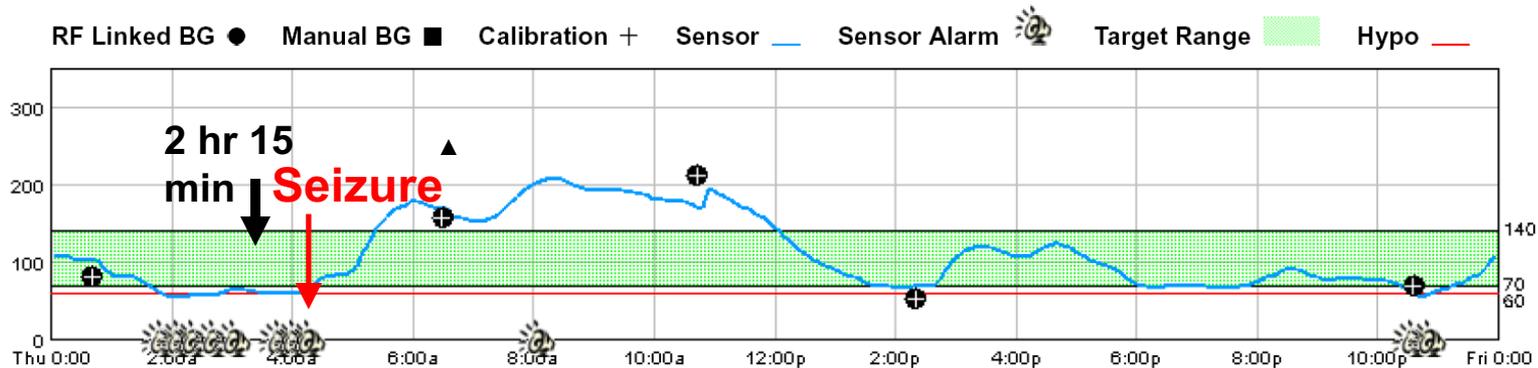


Miller et al. Current State of Type 1 Diabetes Treatment in the U.S.: Updated Data From the T1D Exchange Clinic Registry. Diabetes Care. 2015; 38:971-8.

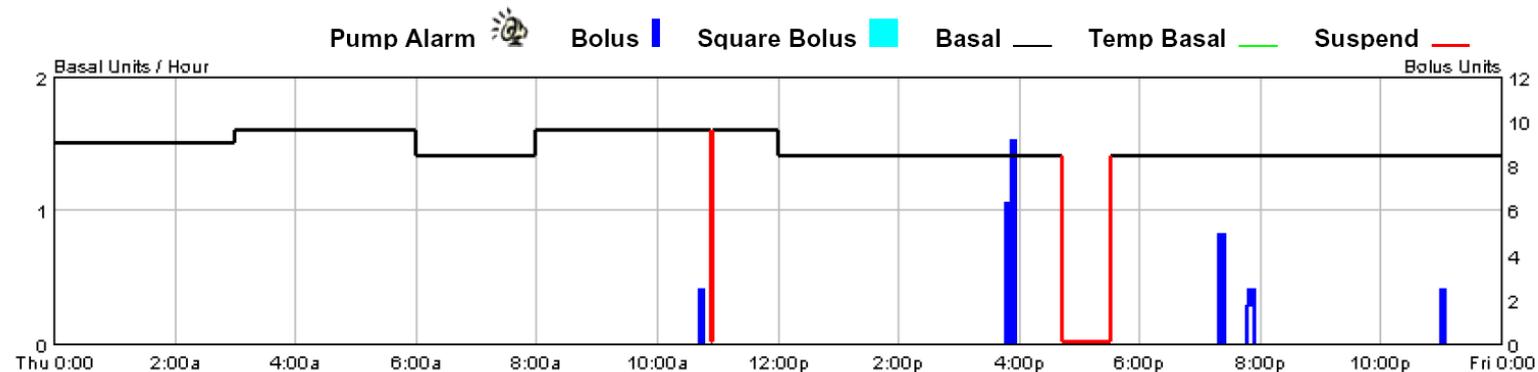
# Nocturnal Hypoglycemia Prior to a Seizure - 16 year old

Buckingham. Diabetes Care 31:2110. 2008

## Glucose (mg/dL)

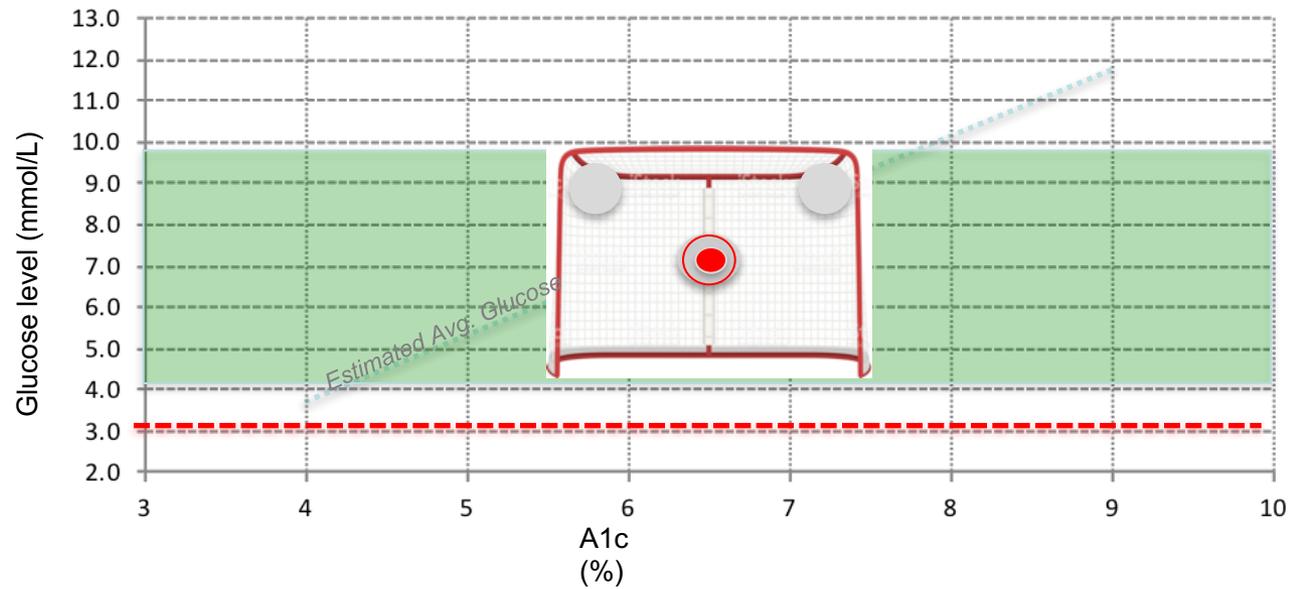


## Insulin Delivery

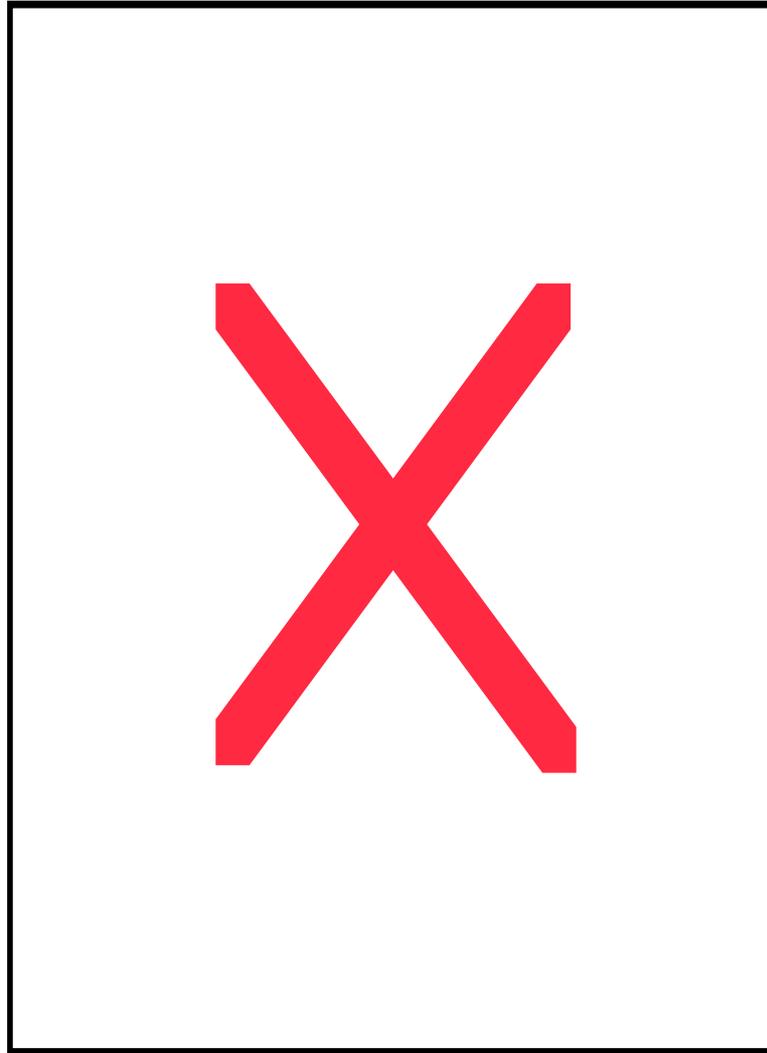




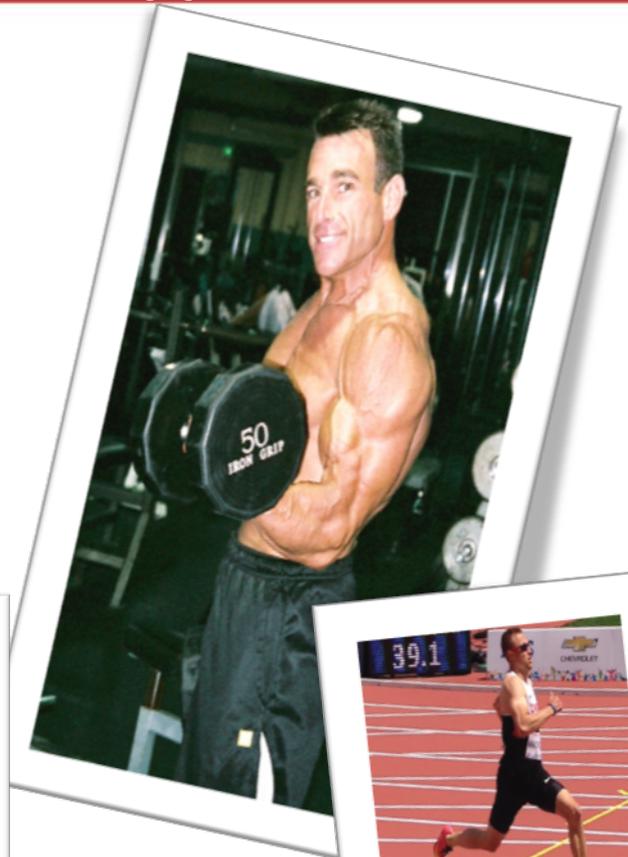
- Pump and continuous glucose monitoring
- MOTIVATION!
- Regular predictable physical activity
- Moderate carb diet (nuts, seeds, fruits, vegetables, protein, milk...)



# Targets (D-net)

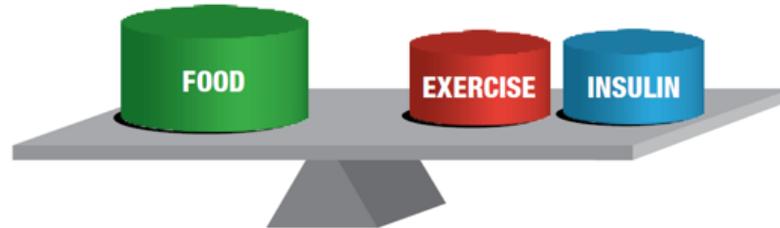


# Exercise of different types...



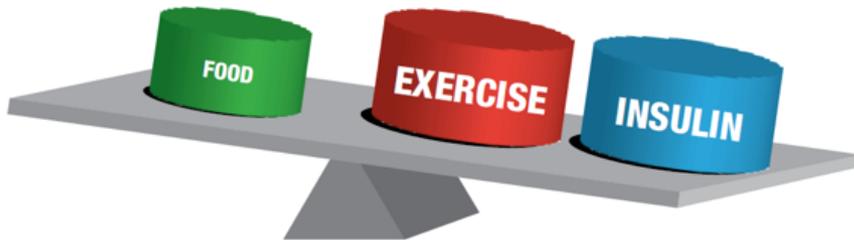
**EUGLYCEMIA** (4 to 7 mmol/L)

*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)

*Intense, stressful exercise*

*Too little insulin*



# The challenge of glucose control

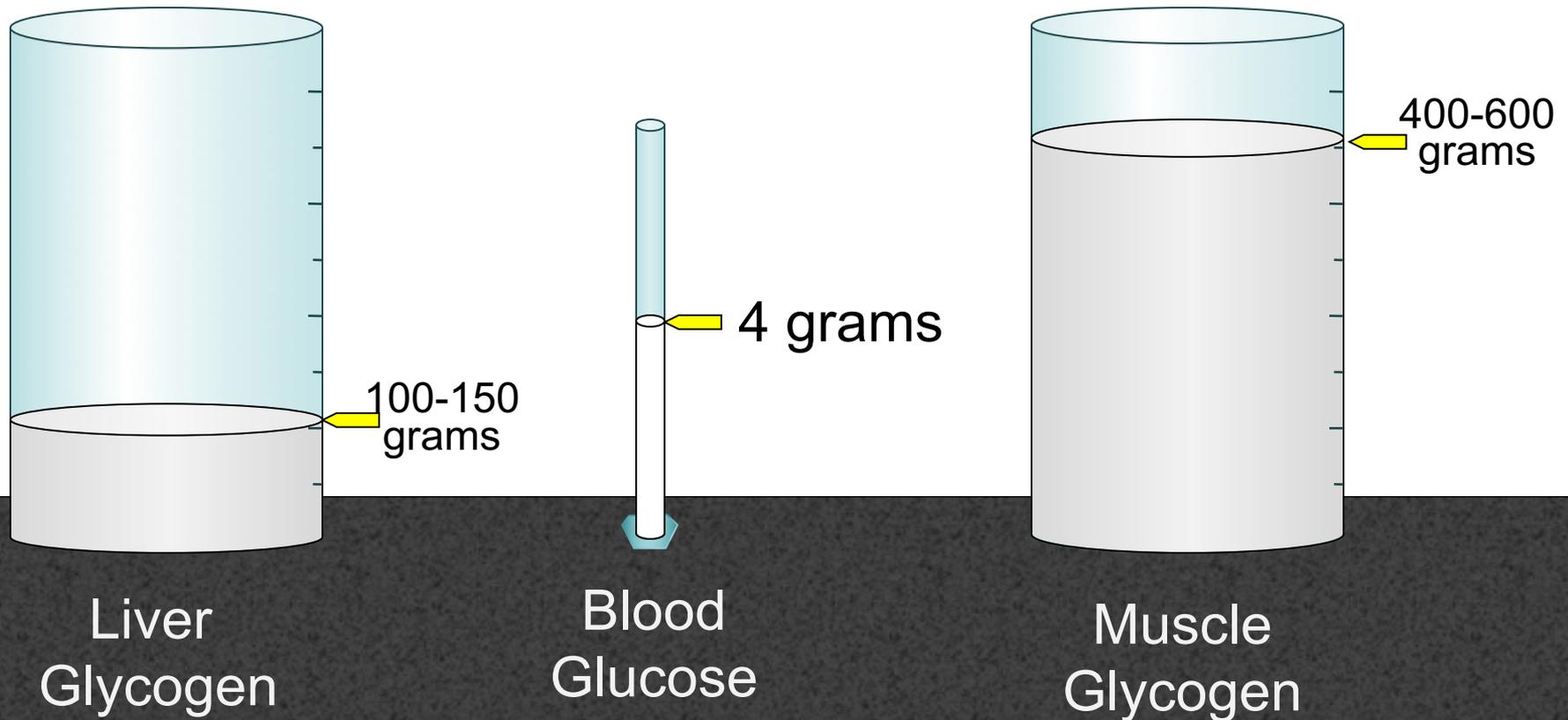
4 grams of glucose circulates in the blood  
of a person weighing 70 kg



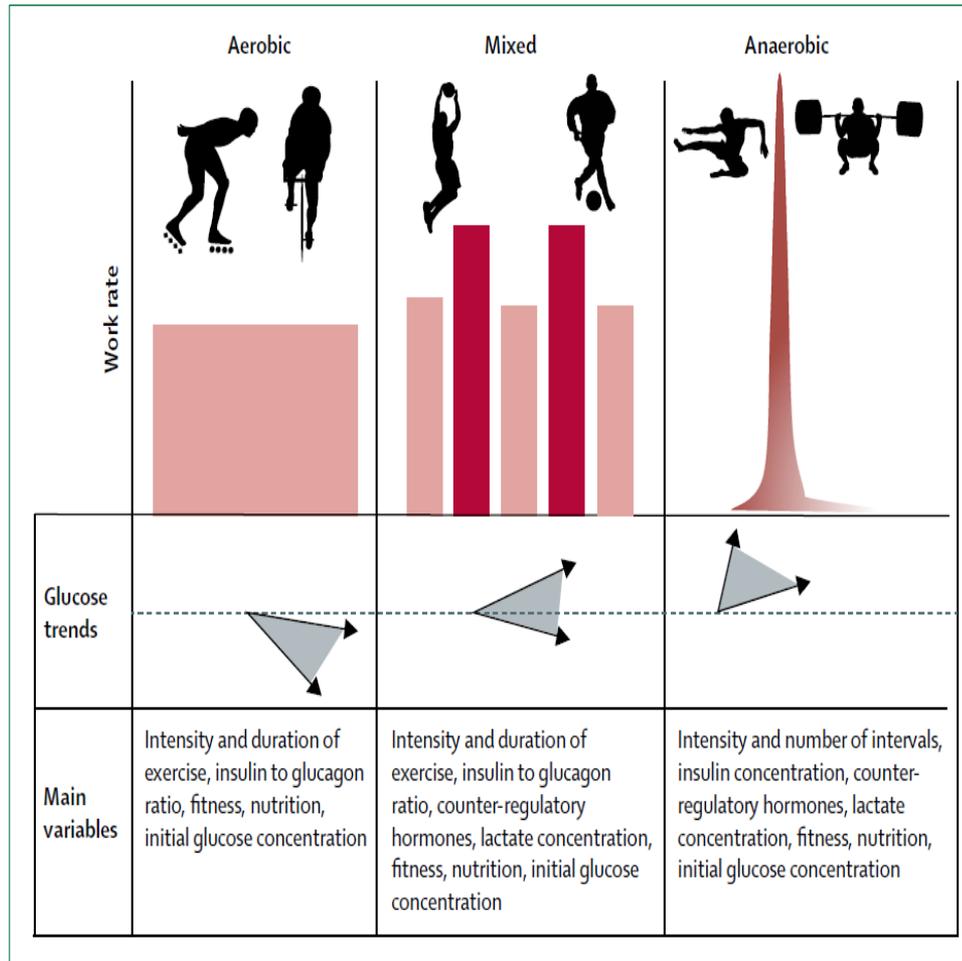
Wasserman DH. *Four grams of glucose*. Am J Physiol Endocrinol Metab 2009;296:E11-21

A main challenge with diabetes is the limited glucose stores in the blood

Typical Carbohydrate Stores of a 170lb male "athlete"



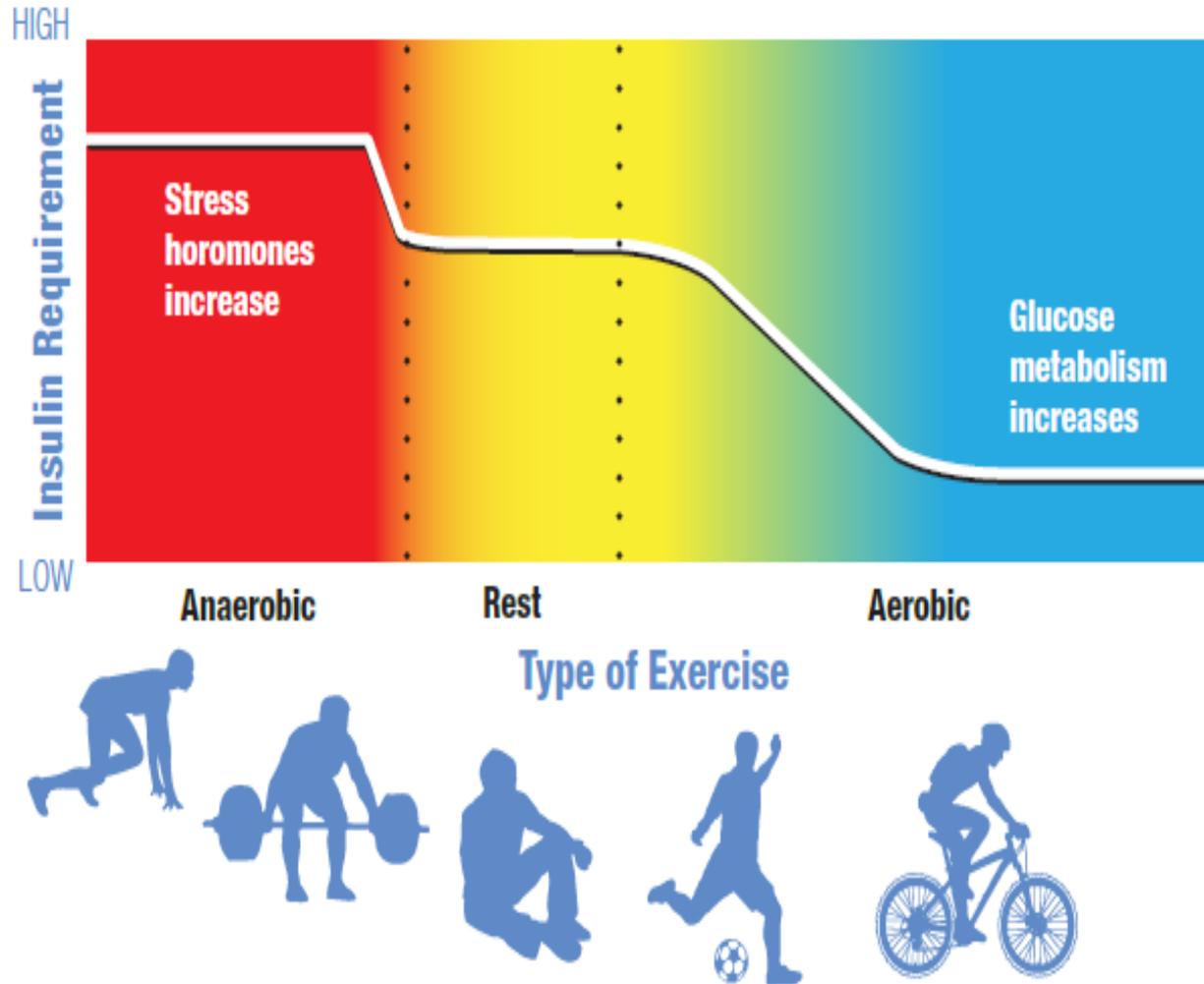
# General trends in blood glucose responses to exercise in T1D



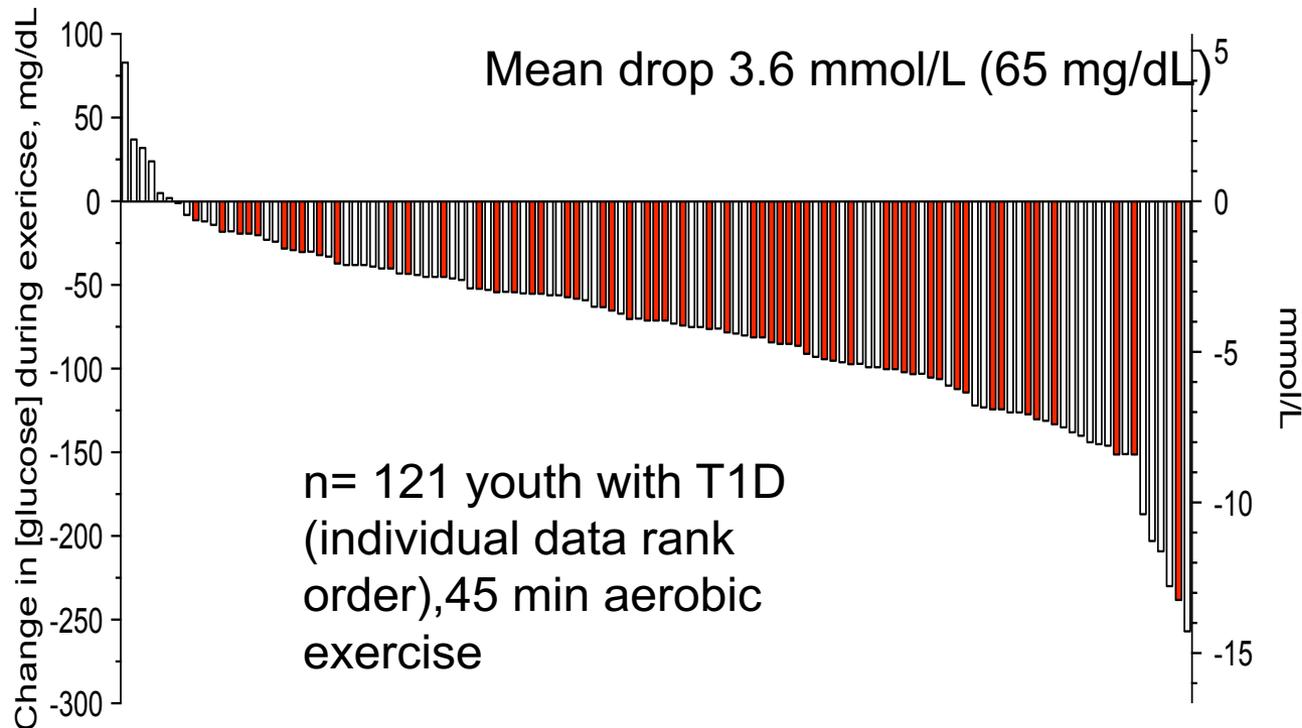
Riddell MC et al., Lancet Diabetes Endocrinol. 2017

# Insulin needs and the exercise spectrum

M.C. Riddell. Getting Pumped: A Insulin Pump Guide for Active Individuals with Type 1 Diabetes



# Individual changes in the blood glucose response to aerobic exercise with no snack or change in insulin...

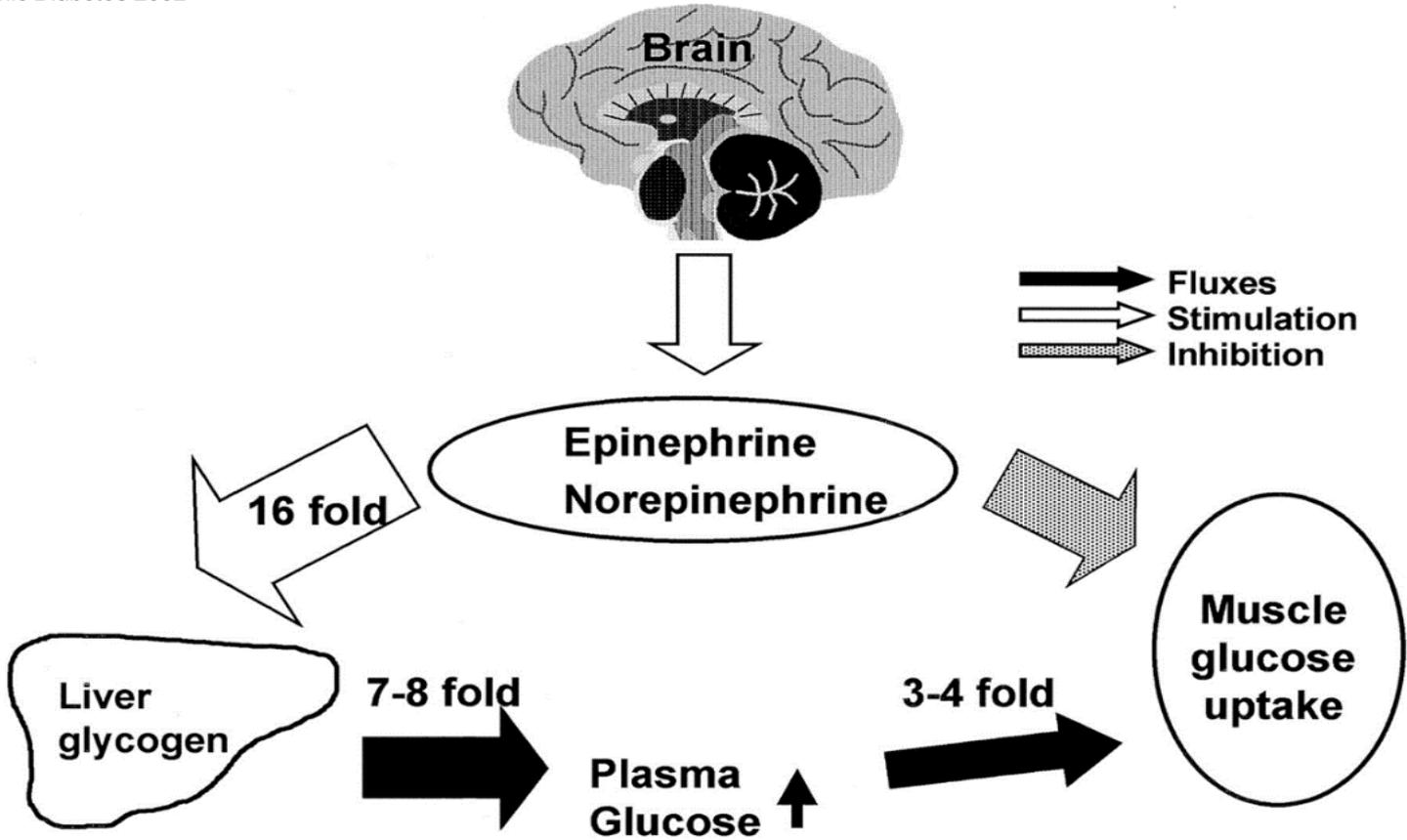


~ 55% develop hypoglycemia

Zaharieva et al., ADA June 2017

# Intense exercise causes hyperglycaemia because of stress hormones

Marliss and Vranic *Diabetes* 2002

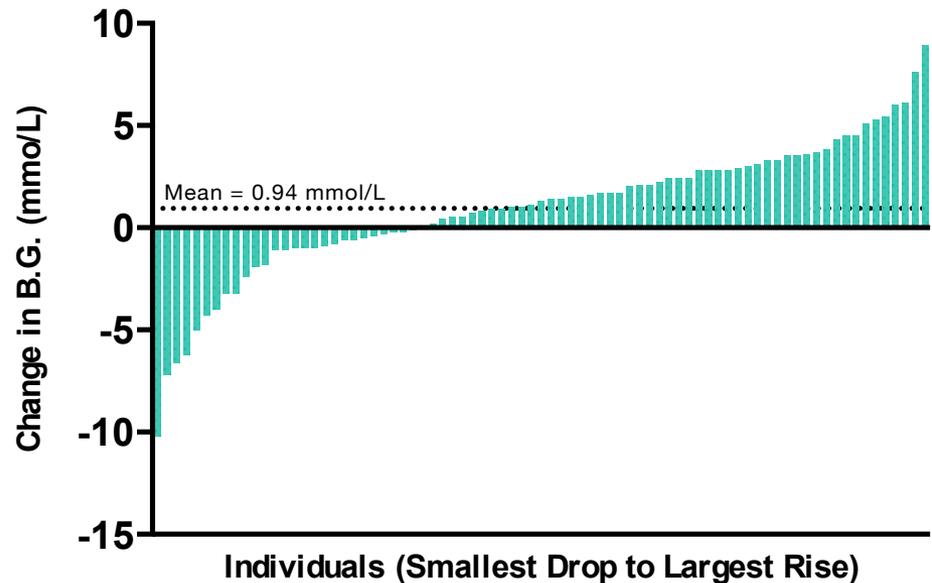


# The Dskate Camp Sprint Study (Milton 2016)

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



The Sprint Challenge - Change Post 30 Minute Recovery



Riddell et al., in preparation

Hockey can transiently cause a high (hyperglycemia).....  
Then late-onset hypoglycemia....

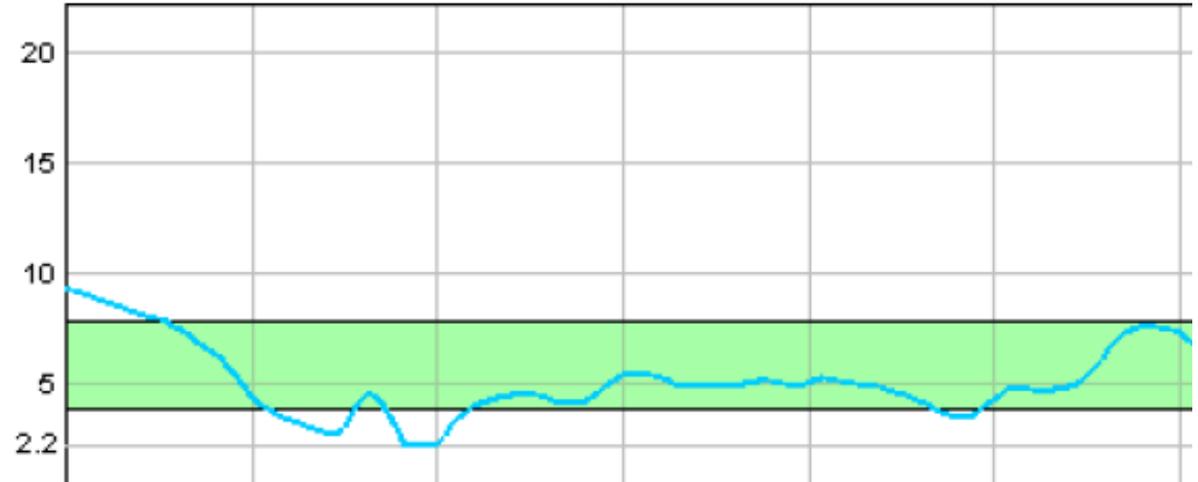
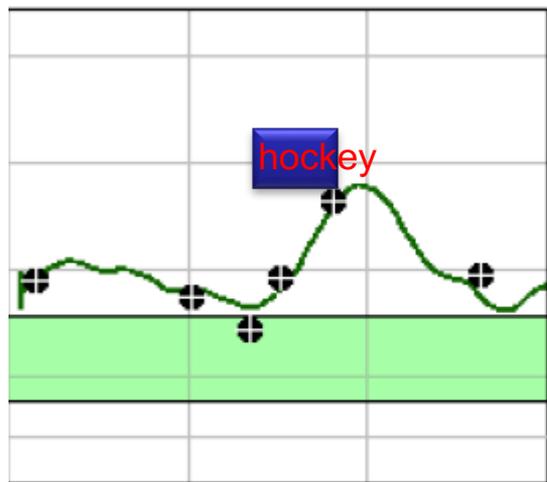


Mon 25-Jun (mmol/L) Sensor

Sensor

Tue 26-Jun (mmol/L) Sensor

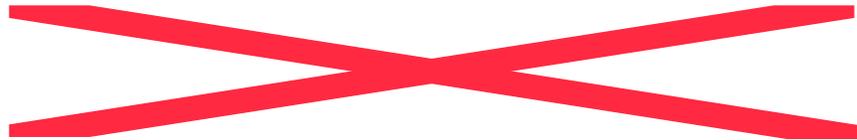
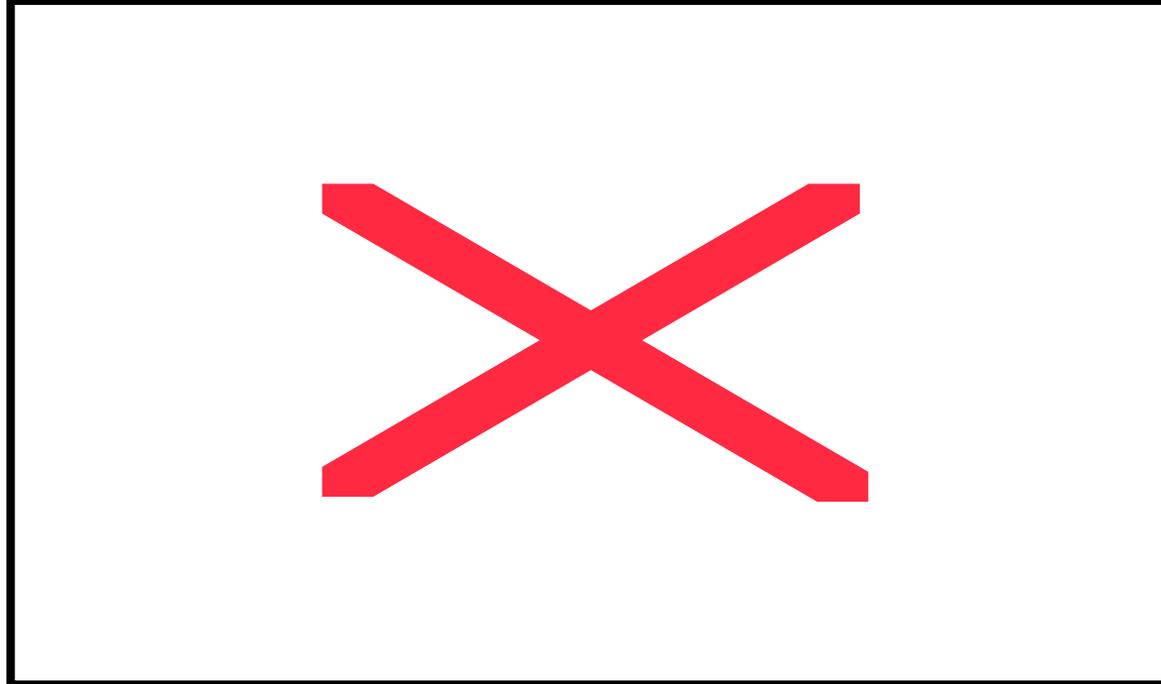
Sensor



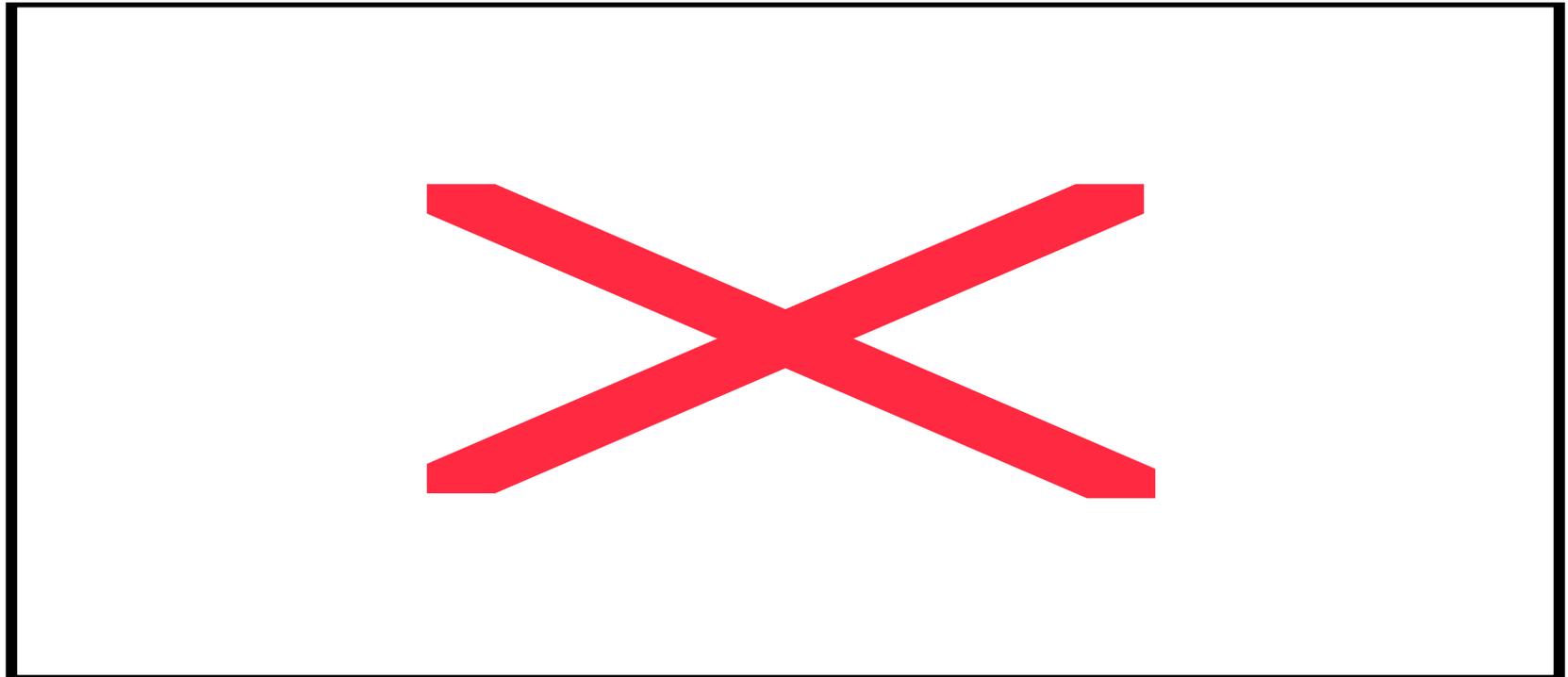
0p 8:00p 10:00p Tue 12:00a

12:00a 2:00a 4:00a 6:00a 8:00a 10:00a 12:00p

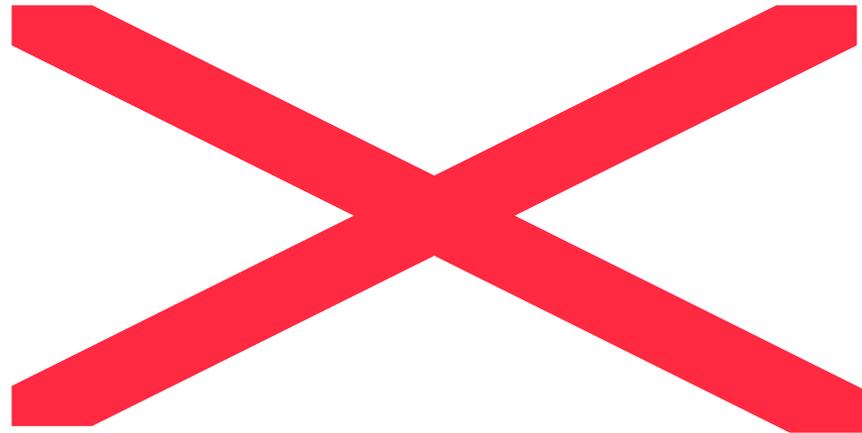
# High Intensity Interval Exercise and Hyperglycemia



# Correcting Post Exercise Hyperglycemia



# Post Exercise Hyperglycemia Management



- In children, ~75% of severe hypoglycemia occurred during sleep
- Real-time CGM provides nocturnal alarms
  - But 71% of alarms are not responded to

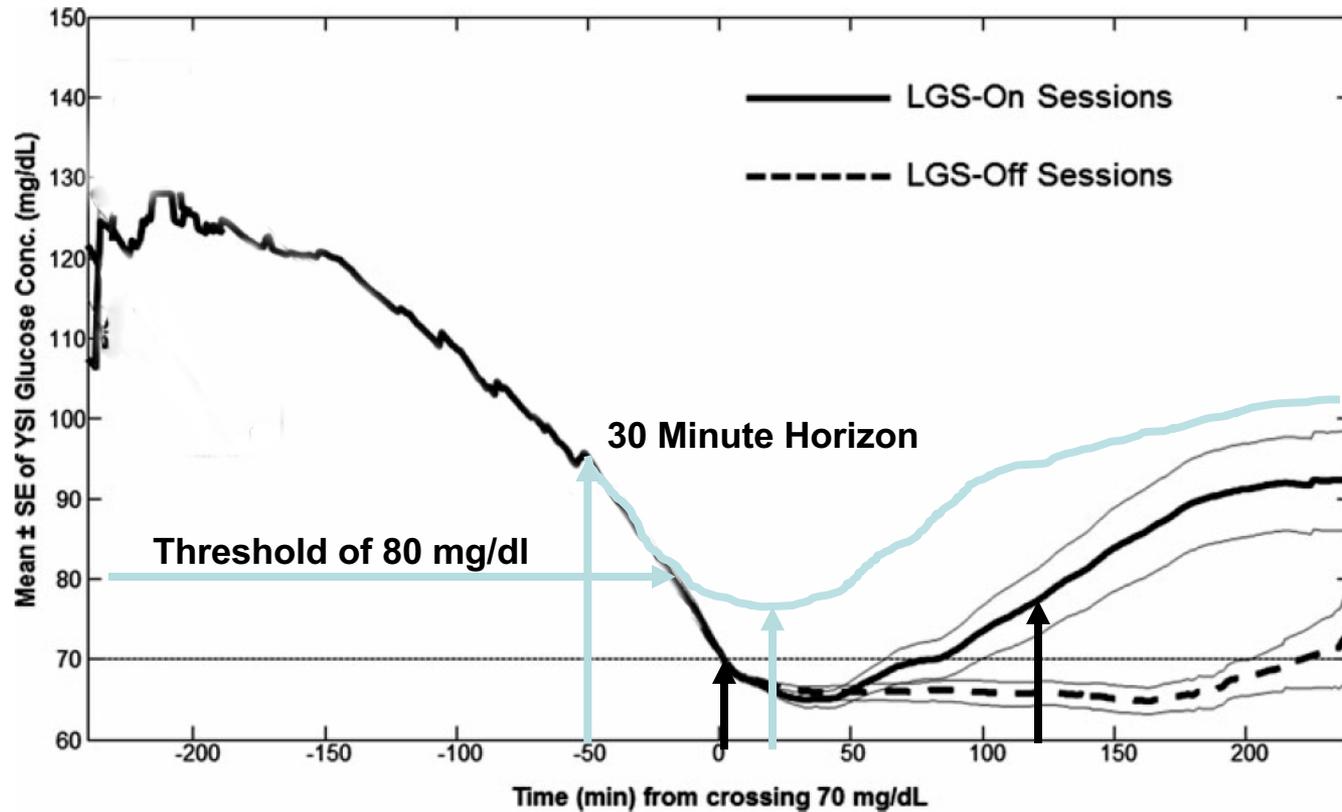
DCCT, Diabetes Care 18:1415, 1995

Davis, Diabetes Care 20:22, 1997

Buckingham, DTT 7:440, 2005

# Low Glucose Suspend with Exercise Induced Hypoglycemia (50 subjects)

DTT (2012) 14:205



# Overnight Glucose Control

- Sensor-augmented pumps reduce nocturnal hypoglycemia
  - Threshold suspend on low (suspend on low) (Medtronic 630G)
  - Predictive low glucose suspend (Medtronic 640G)
  - Full Closed-loop at night (Medtronic 670G)
  - Open APS and Looping

# Medtronic 670G



Glucometer



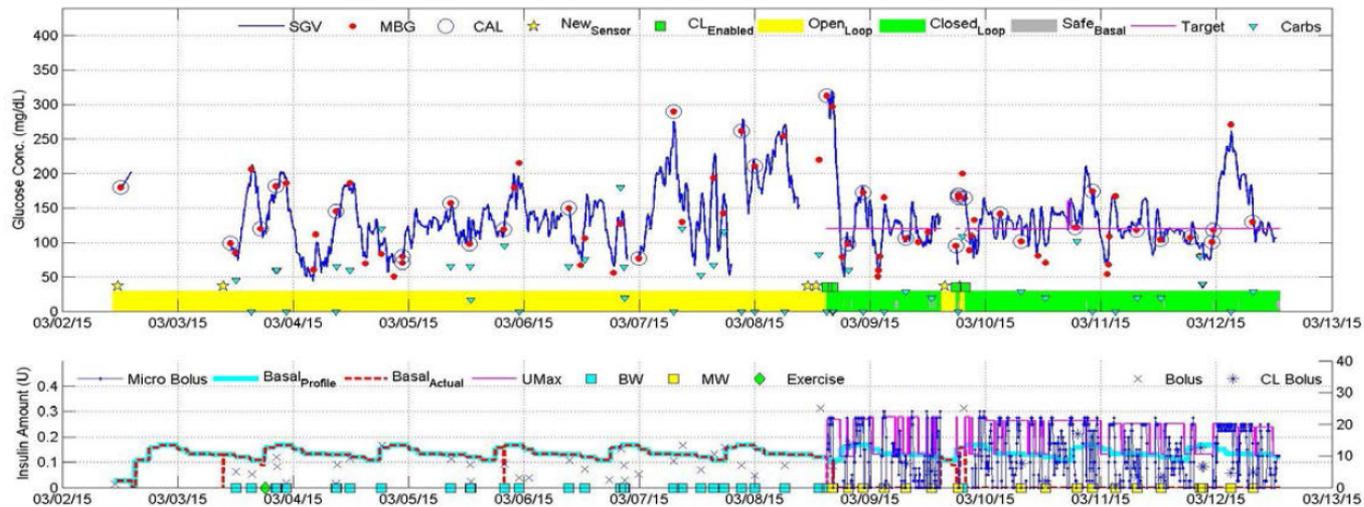
Enlite 3 sensor

# Open Loop Compared to Closed-Loop



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

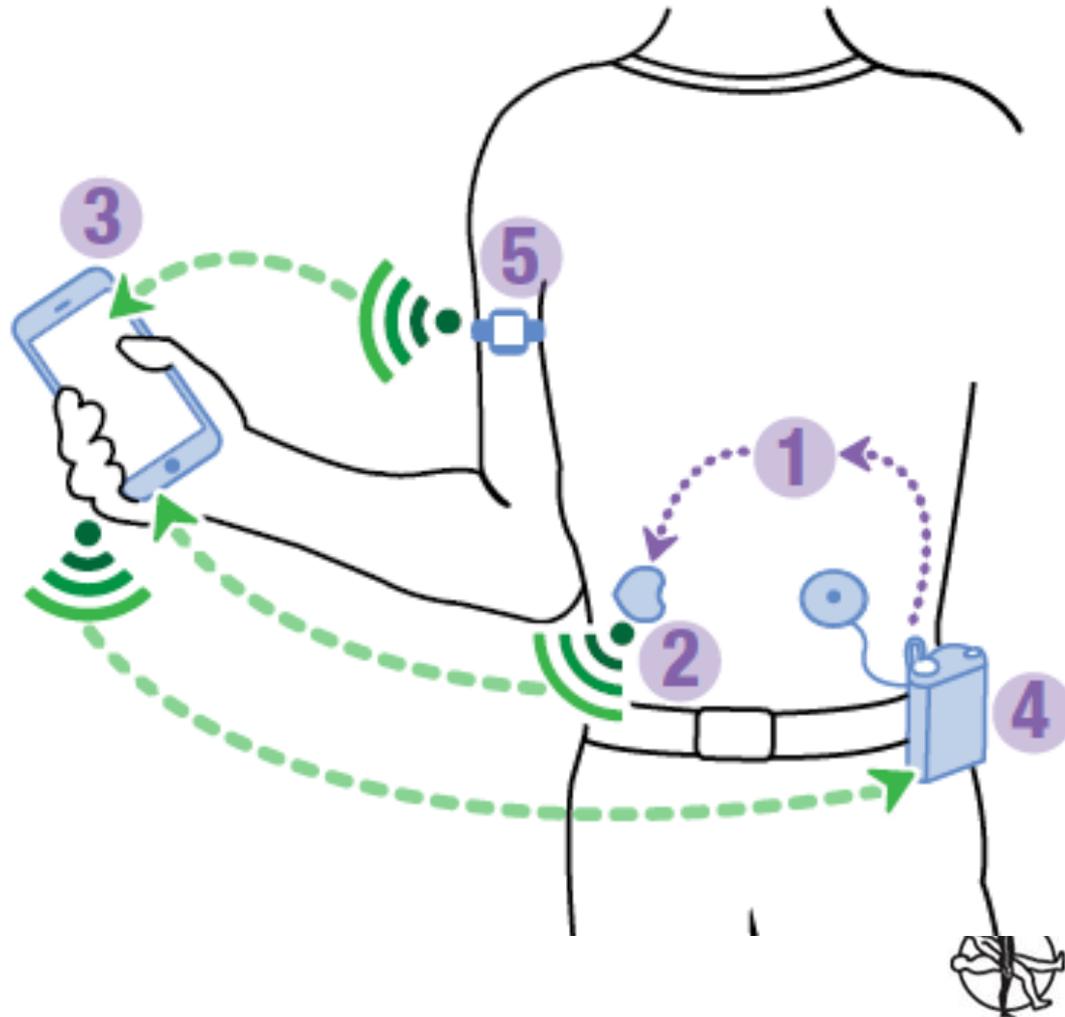
3/12/15



# Concepts and realities around the artificial pancreas

[JDRF AP project](#)

[Katie Helm Interview 670G](#)



Before the 2002 Winter Olympics in Salt Lake City, he was diagnosed with Type 1 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



The 2010 Vancouver Olympics [► Coverage](#) [► Medals](#) [► Schedule & Results](#)

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

Updated 2/20/2010 8:14 PM | [Comments 1](#) | [Recommend 8](#) | [E-mail](#) | [Save](#) | [Print](#) | [Reprints & Permissions](#) | [RSS](#)



[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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# Testing Blood Glucose Levels- when and why

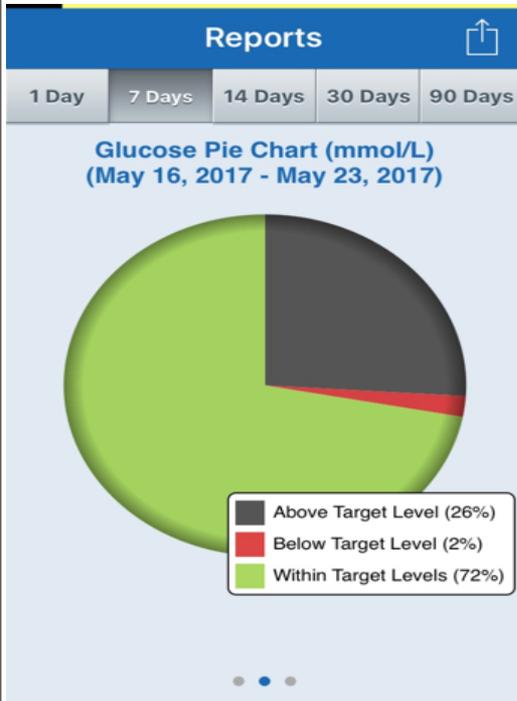


Gary Hall, Jr. (born September 26, 1974, diagnosed T1D in 1999)- US swimmer who competed in the 1996, 2000, and 2004 Olympics and won ten Olympic medals.

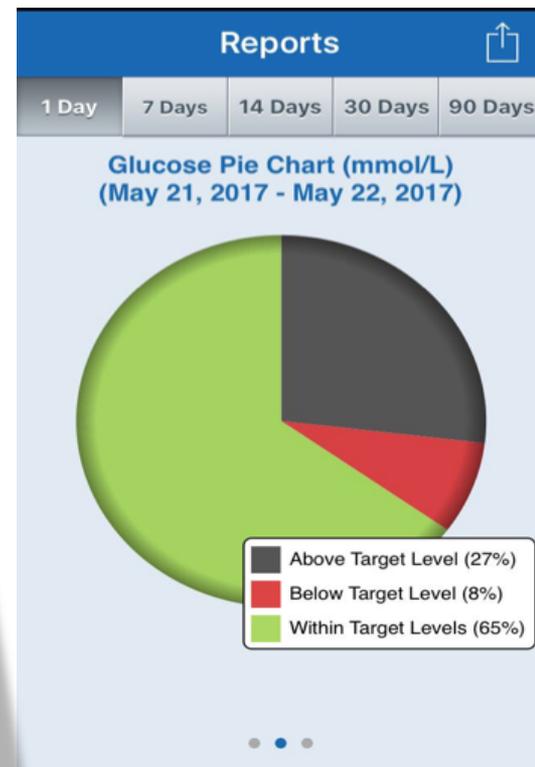
“You have to test your blood glucose levels often, the more the better... Nerves will send levels sky high... When I broke the American record, I tested ten minutes before my race. I was at 140mg/dL (7.7mmol/L). Ten minutes after the race I tested again. I was at 388mg/dL (21.6mmol/L). The race lasted 21 seconds.”

# Suggestions for post-exercise highs

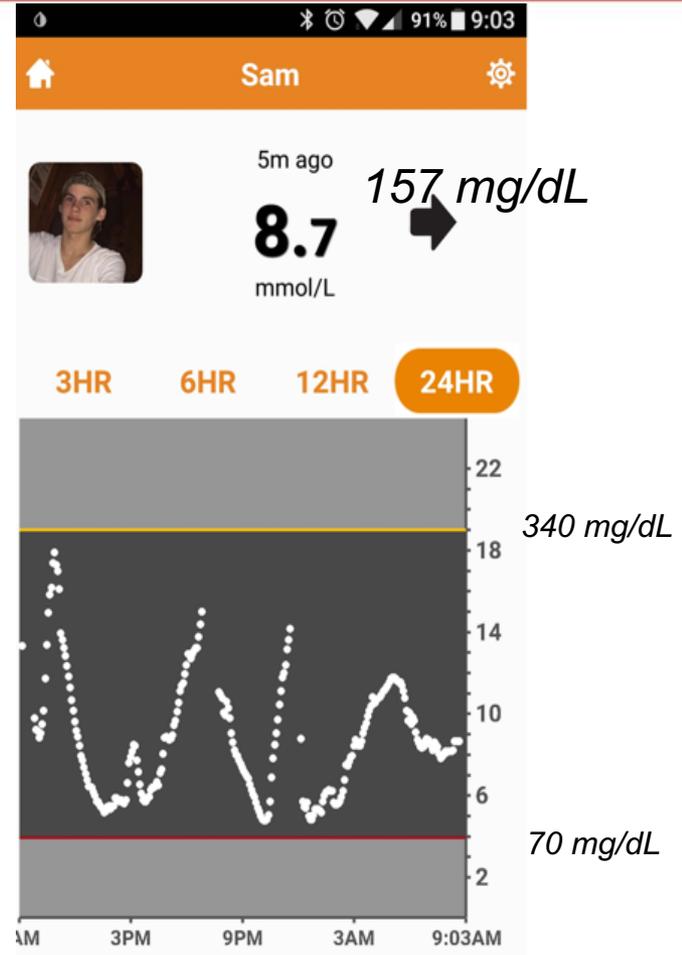
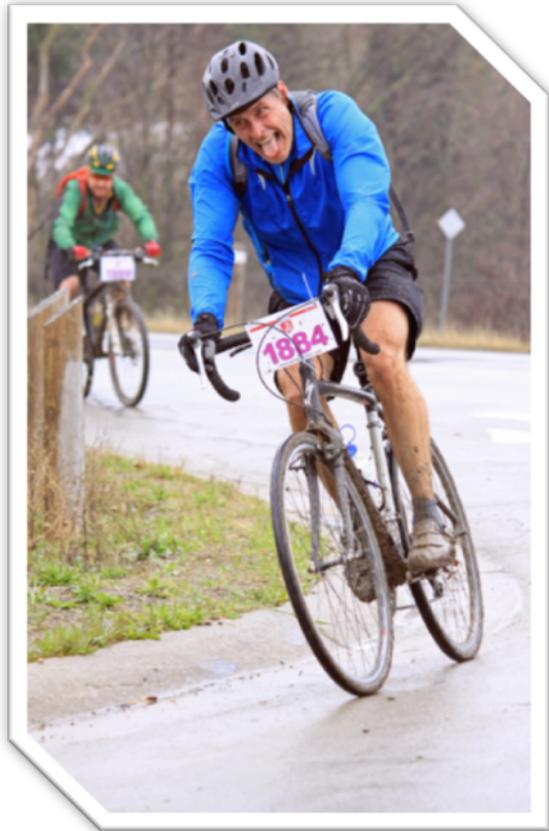
- if on a pump: try to exercise with the pump on (with usual basal rate) or resume normal insulin basal rate if on a temp basal before the end of exercise
- Do an aerobic cool down
- Do a 50% correction: calculate insulin correction bolus and divide by  $\frac{1}{2}$  (good for those on pump or needles)
- Leave it alone (particularly if close to bedtime) and correct the next morning if needed...
- Use CGM if possible

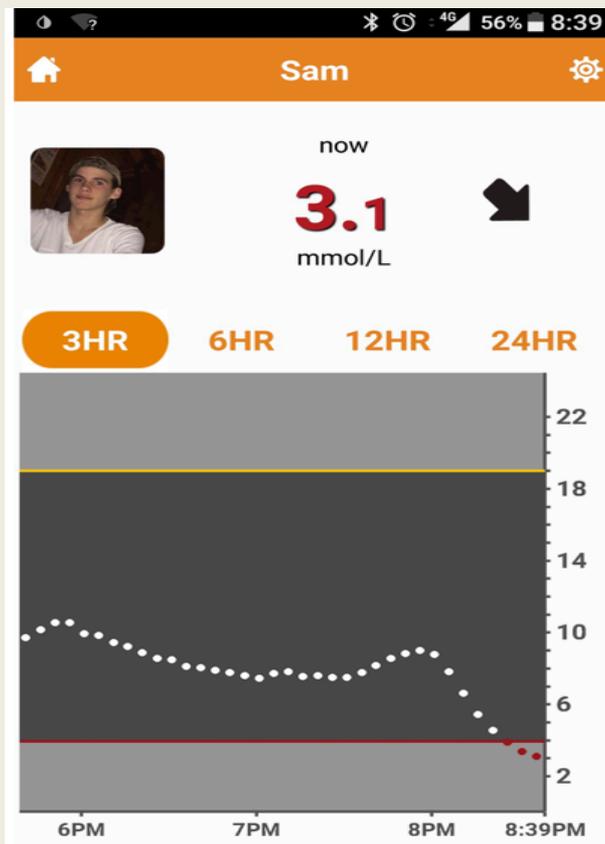


2% of 24 hours=29 minutes/day below target



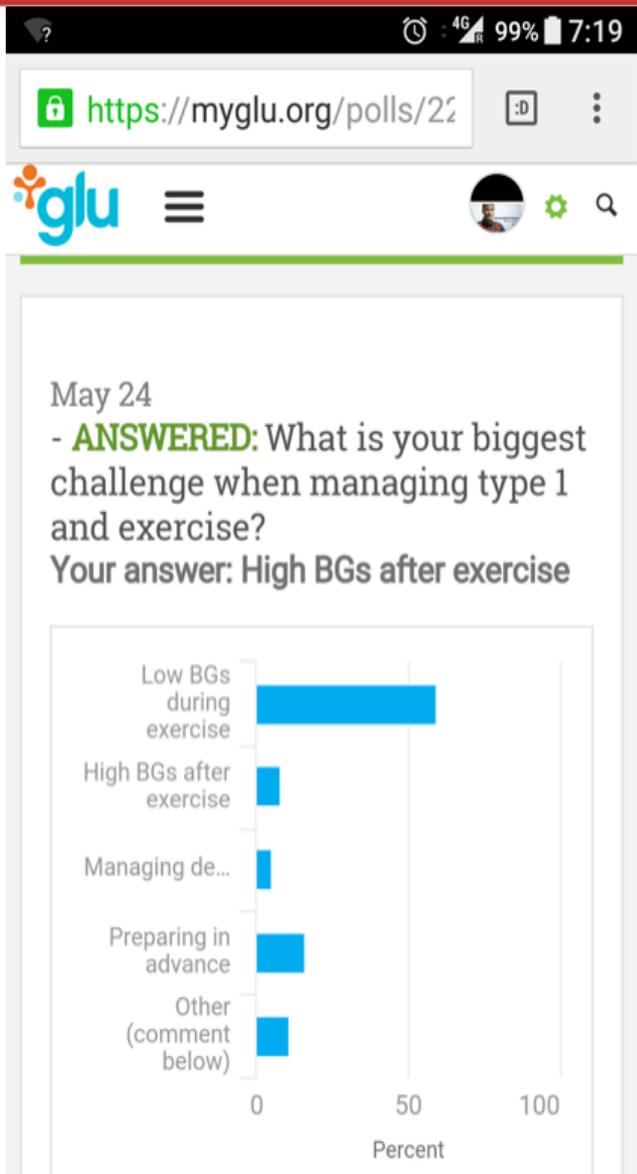
8% of 24 hours=115 minutes/day below target

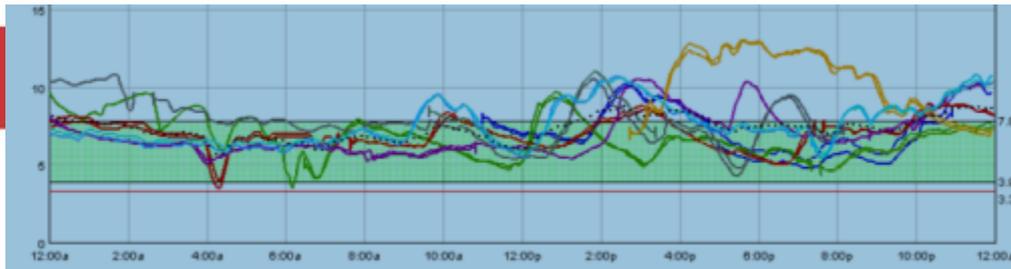




55 mg/dL

36 mg/dL

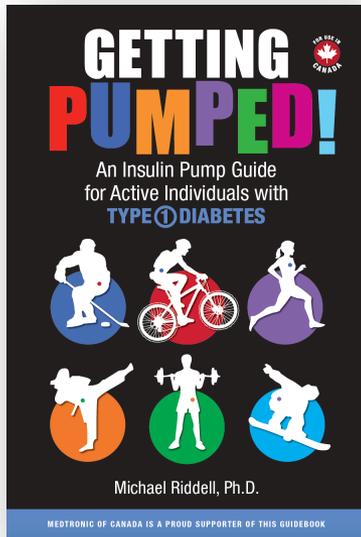




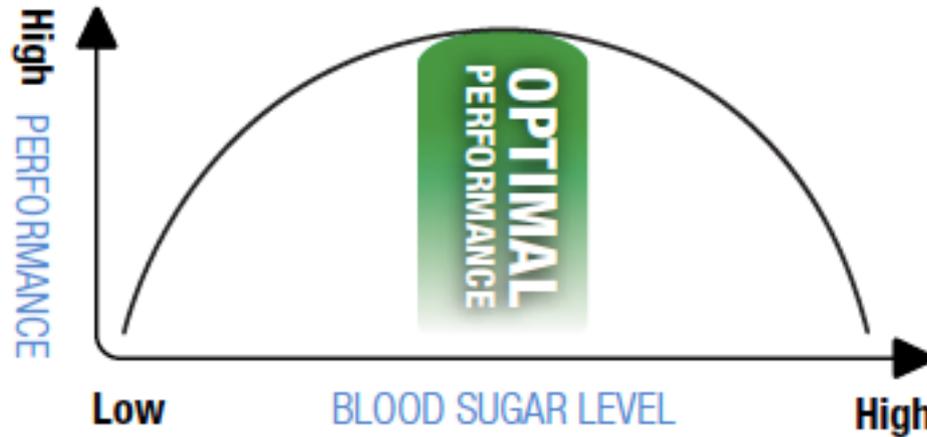
## *Glucose control during and after exercise is challenging...*

- CGM can reveal general trends
- CGM allows for proactive adjustments 'on the fly'
- A sensor-augmented pump helps overnight





## Impact of Blood Sugar Level on Sport Performance



### CONSEQUENCES OF BLOOD SUGAR LEVEL

#### Too Low

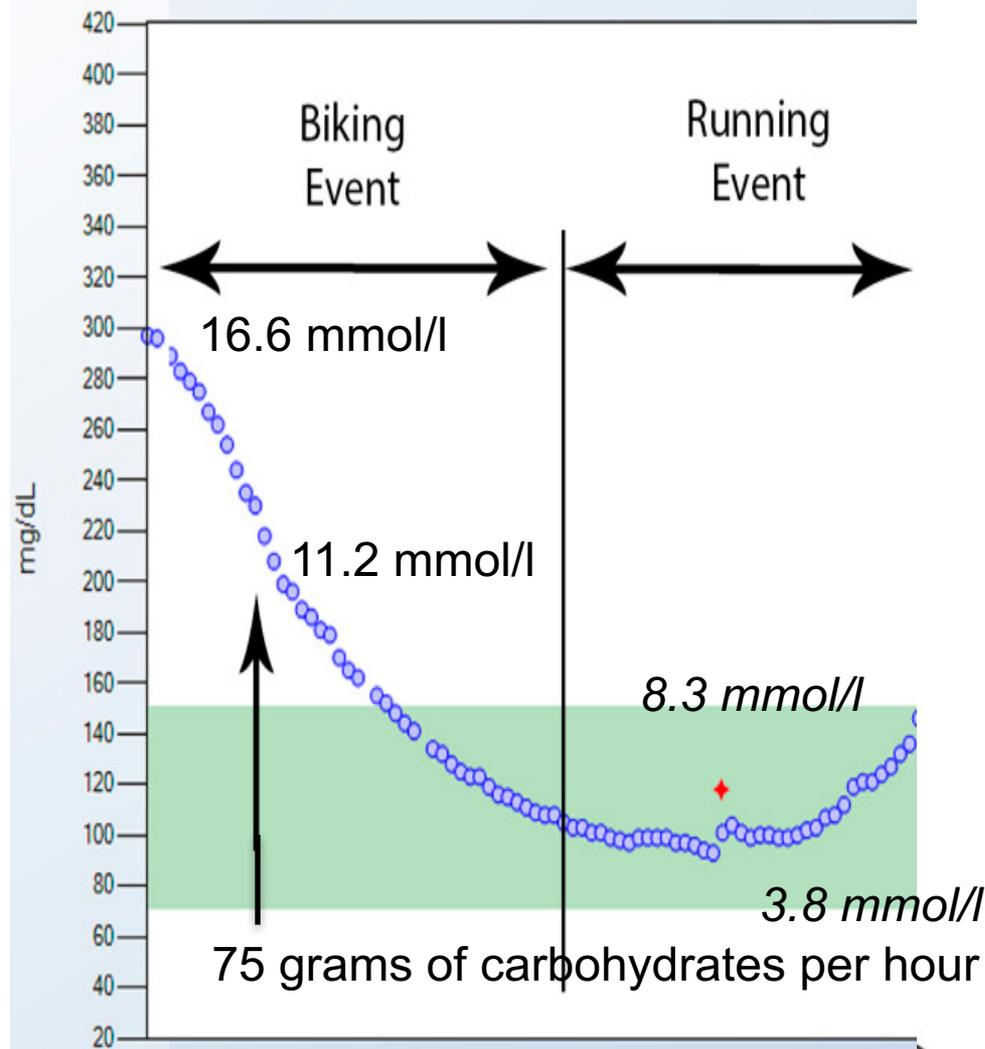
- ▼ Coordination
- ▼ Skill Level
- ▼ Mental Performance
- ▲ Fatigue
- ▲ Risk of Injury

#### Too High

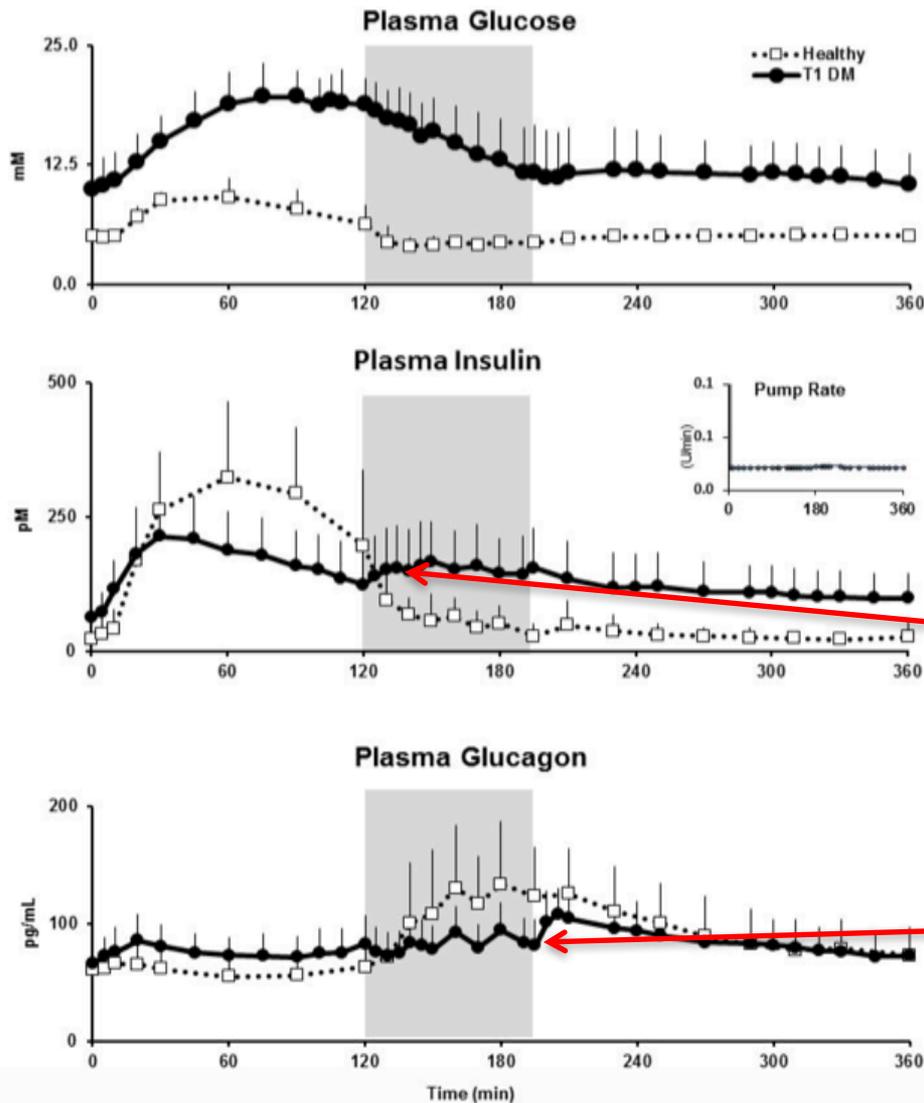
- ▼ Endurance
- ▼ Muscle Strength
- ▼ Glycogen Reserves
- ▲ Fatigue
- ▲ Dehydration

# 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



# Aerobic Exercise-Dysfunction in Insulin and Glucagon in T1D

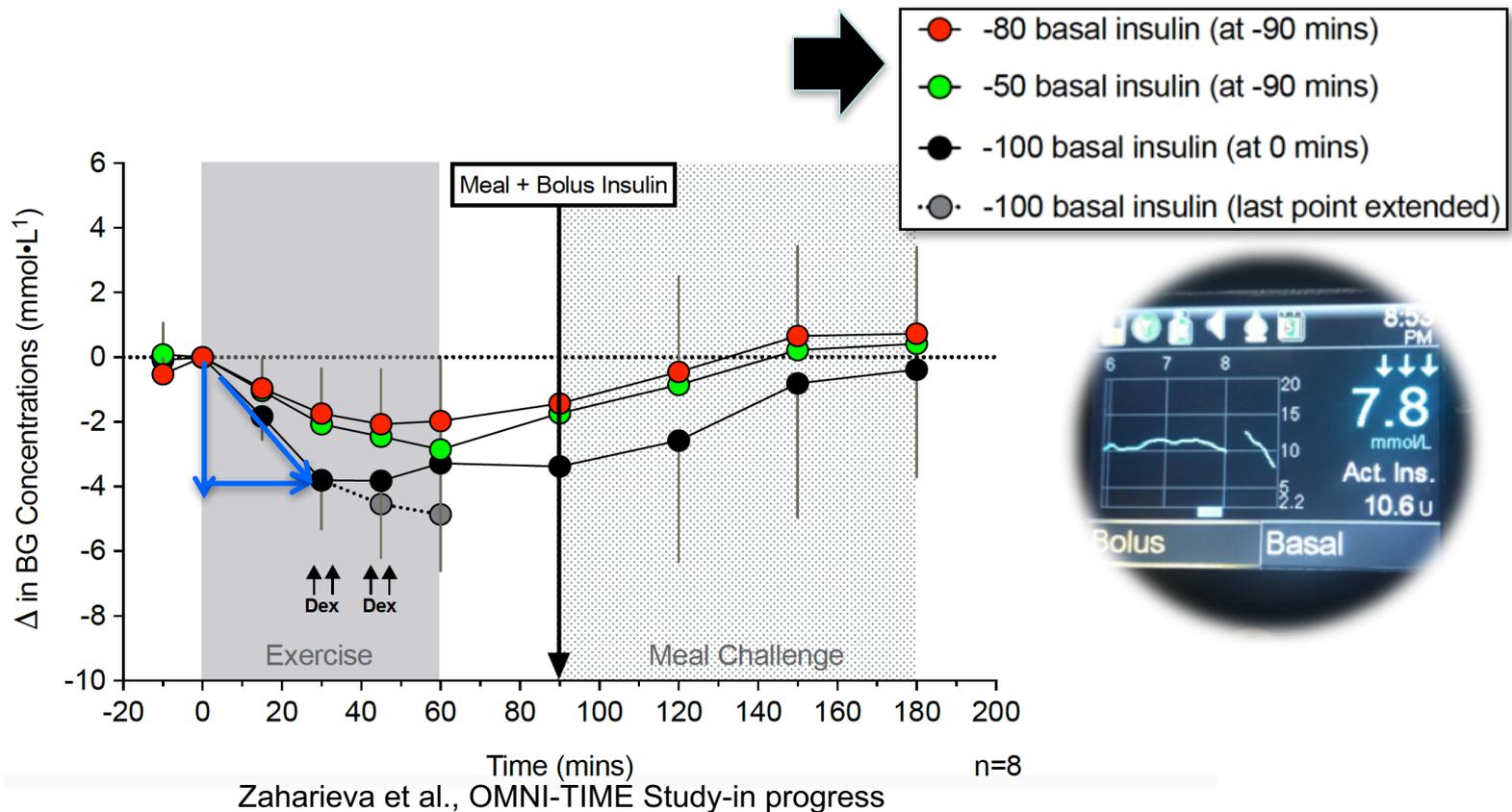


16 T1D “pumpers”  
exercising 120  
minutes after a  
meal (75g CHO)  
with usual  
basal/bolus insulin

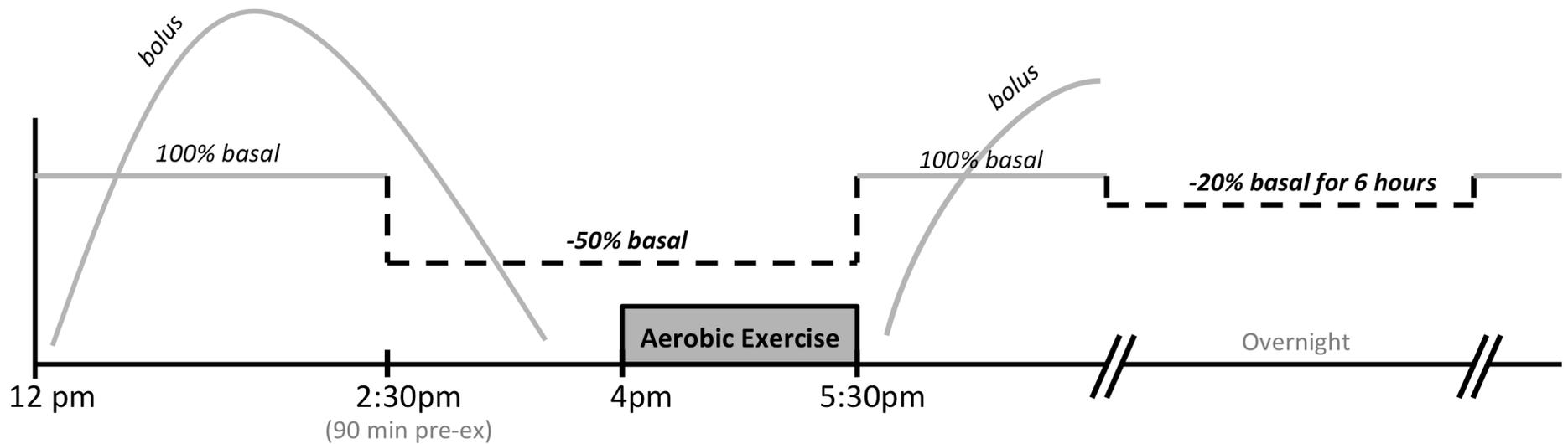
Basal insulin pump  
rates were not  
changed during the  
study duration

Glucagon response  
flat?

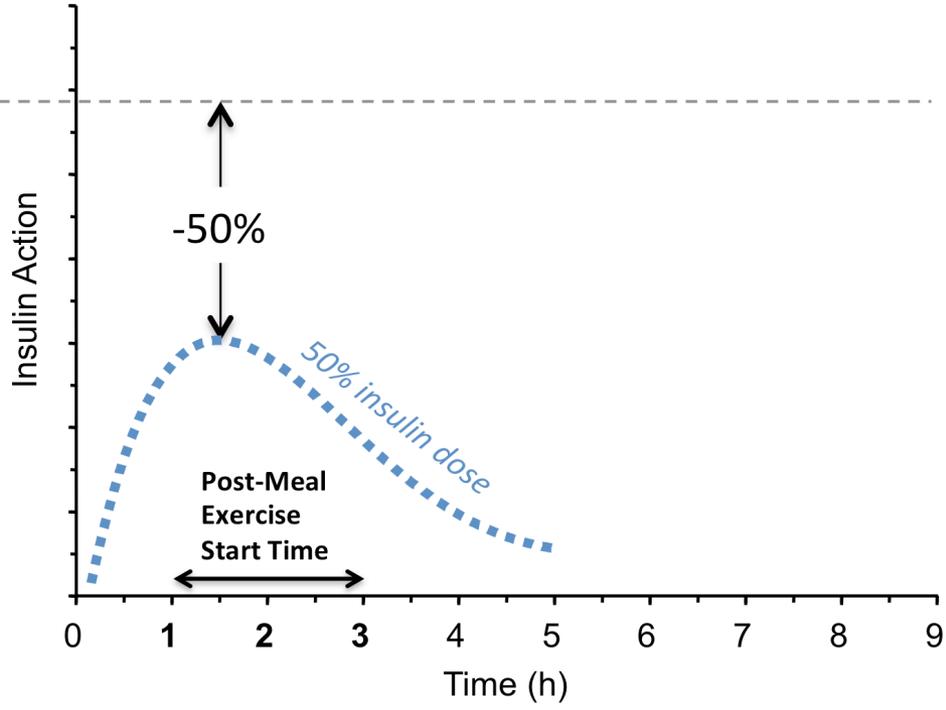
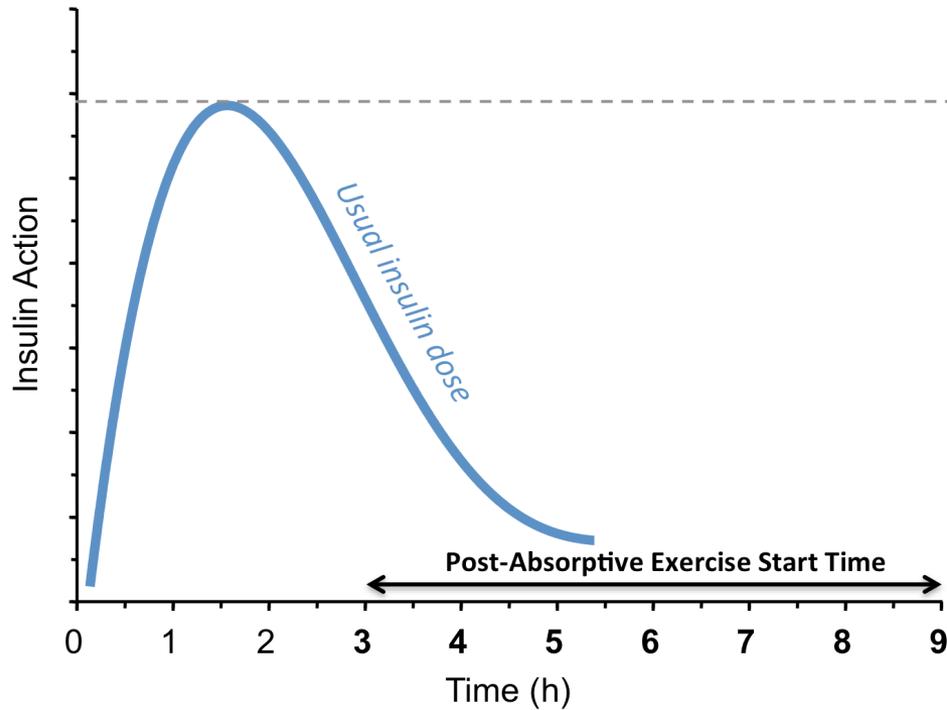
# Exercise and basal adjustments (CSII)



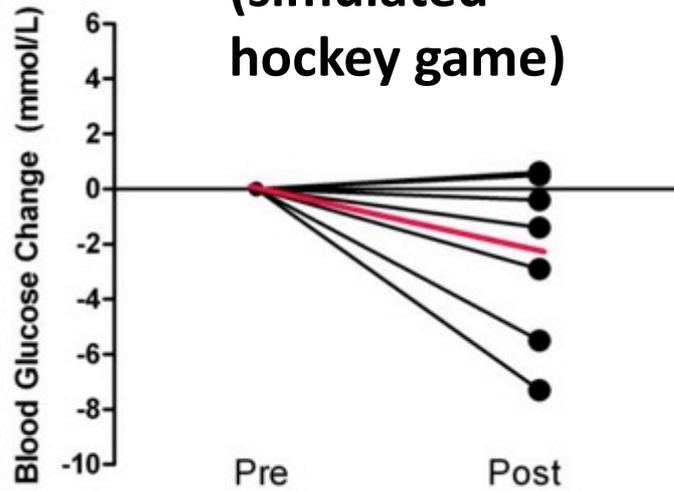
# When to try basal rate reductions (pump)



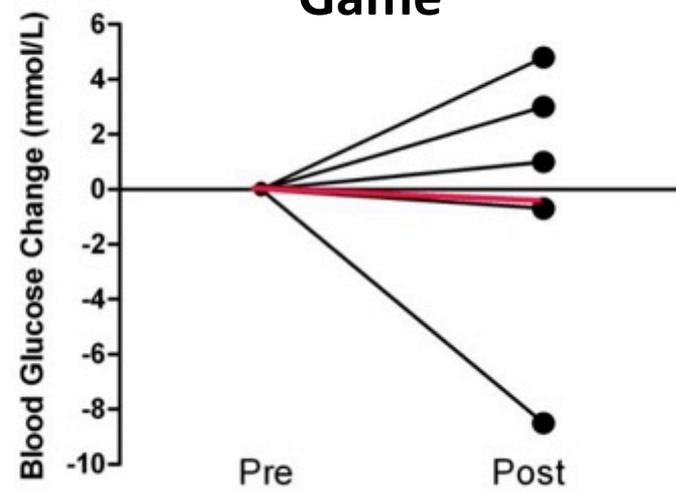
# When to try bolus reductions



## Lab Exercise (simulated hockey game)

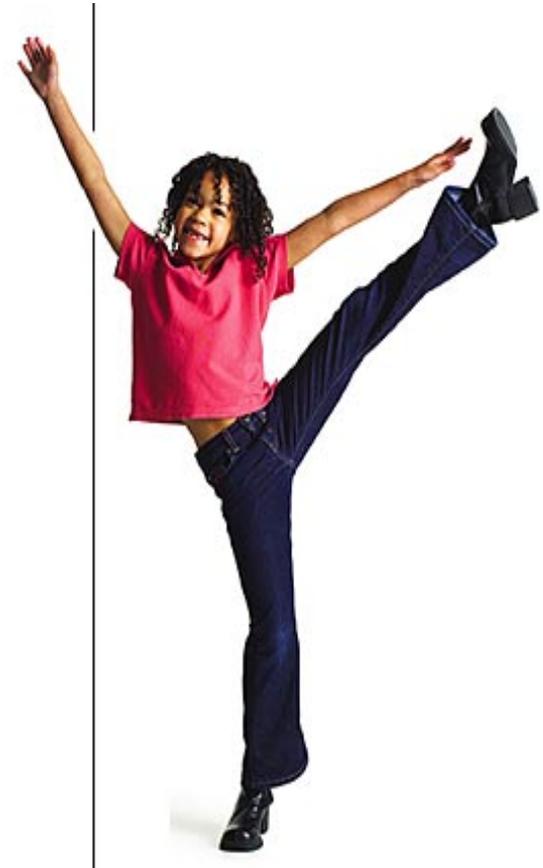


## True Hockey Game



# Managing exercise- key points

- Individual blood sugar responses to exercise
  - Aerobic activity= a drop typically occurs
  - Anaerobic activity= a rise typically occurs
- Monitoring glucose is key
  - Monitor glucose 60 minutes before activity, during the activity and about 15 min after the end of the activity
- Watch for overnight lows



## Managing exercise- key points (2)

- Basal insulin reductions need to occur about 90 min before aerobic exercise to be effective
- Intense anaerobic exercise may not require insulin reductions and may actually require more insulin in early recovery
- Treat low glucose with rapidly-absorbed glucose
- After prolonged activity, have an additional “free” snack of ~ 30 g slow acting carb with some protein and fat
- Keep accurate records of activity, food intake and glucose values



