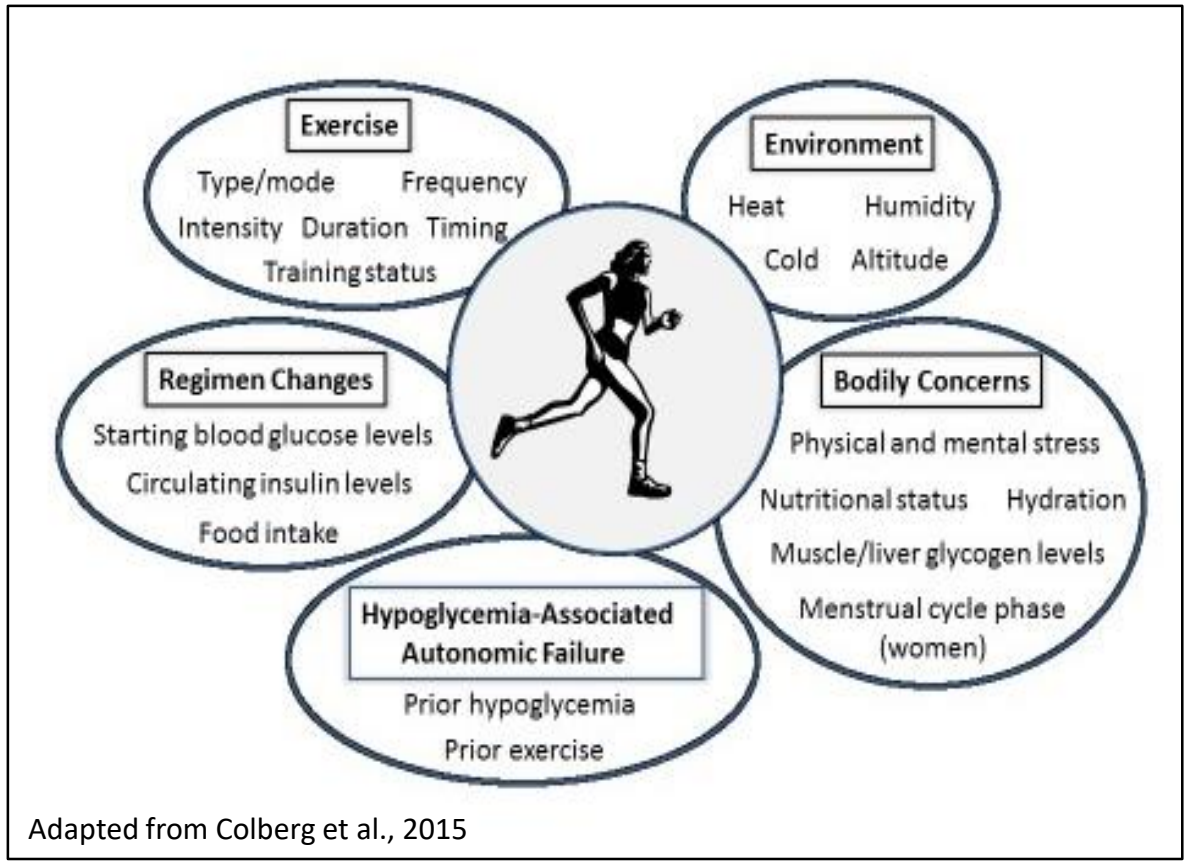


Adapted from Colberg et al., 2015

Advanced Exercise: Tweaks and Tips

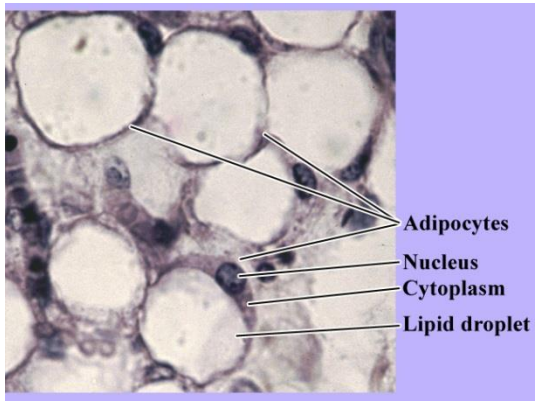
Jane Yardley, PhD

Objectives

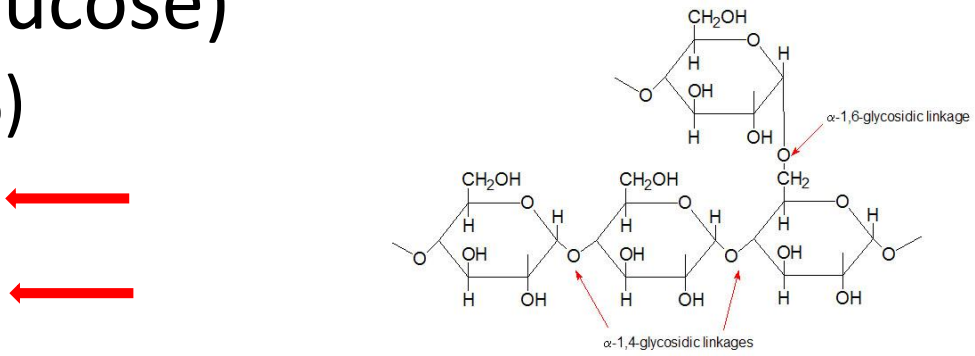
- By the end of this session you should be able to:
  - Describe the differences between aerobic and anaerobic exercise with respect to blood glucose changes and insulin adjustments
  - Explain some exercise-based options for hypoglycemia prevention
  - Discuss the potential impact of environmental conditions on blood glucose levels during exercise
  - Describe “additional considerations” for exercise and physical activity

Where is your Energy Stored?

- Lipids (fat)
  - Adipose tissue (97.53%)
  - Muscle (2.43%)
  - Blood (0.04%)
- Carbohydrate (glucose)
  - Muscle (79.52%)
  - Liver (19.88%)
  - Blood (0.60%)



www.linkpublishing.com



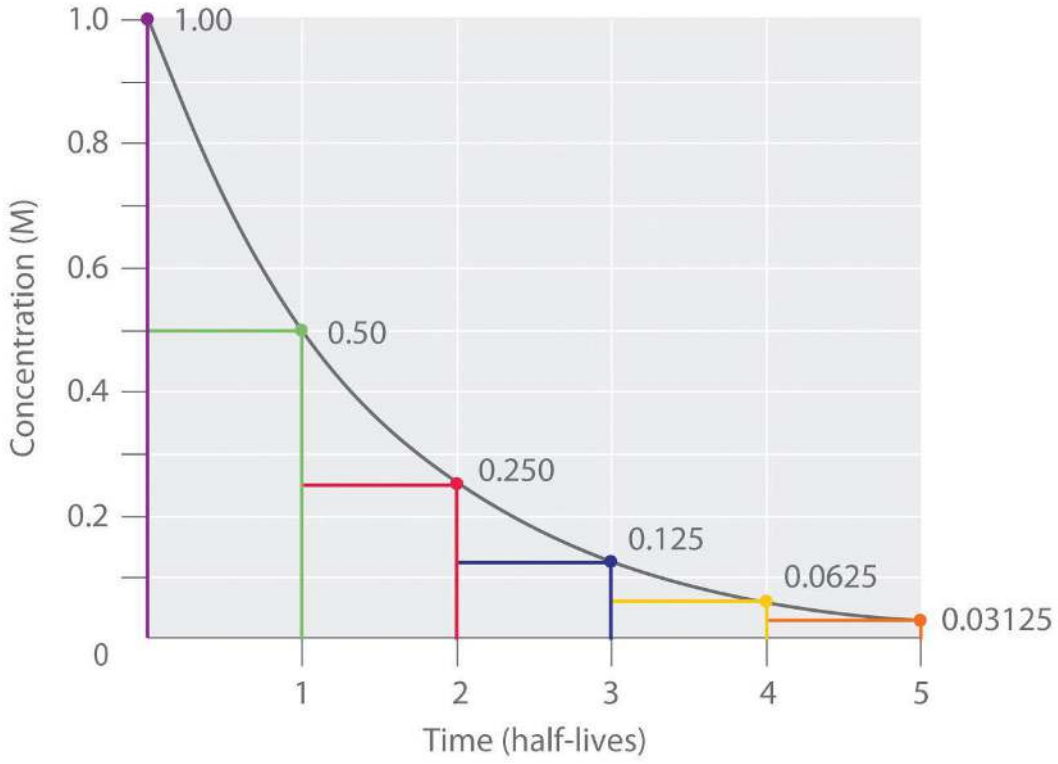
http://themedicalbiochemistrypage.org/carbohydrates.html

Storing and Accessing Energy

- Insulin: helps store glucose (muscle, liver, fat cells)
  - Glucose stored in muscle is burned in muscle
  - Glucose stored in liver can be released into the blood
- Glucagon: helps release energy from storage (liver) on demand (fasting or exercise)
- Both are released by the pancreas
- Circulating insulin prevents release of glucagon

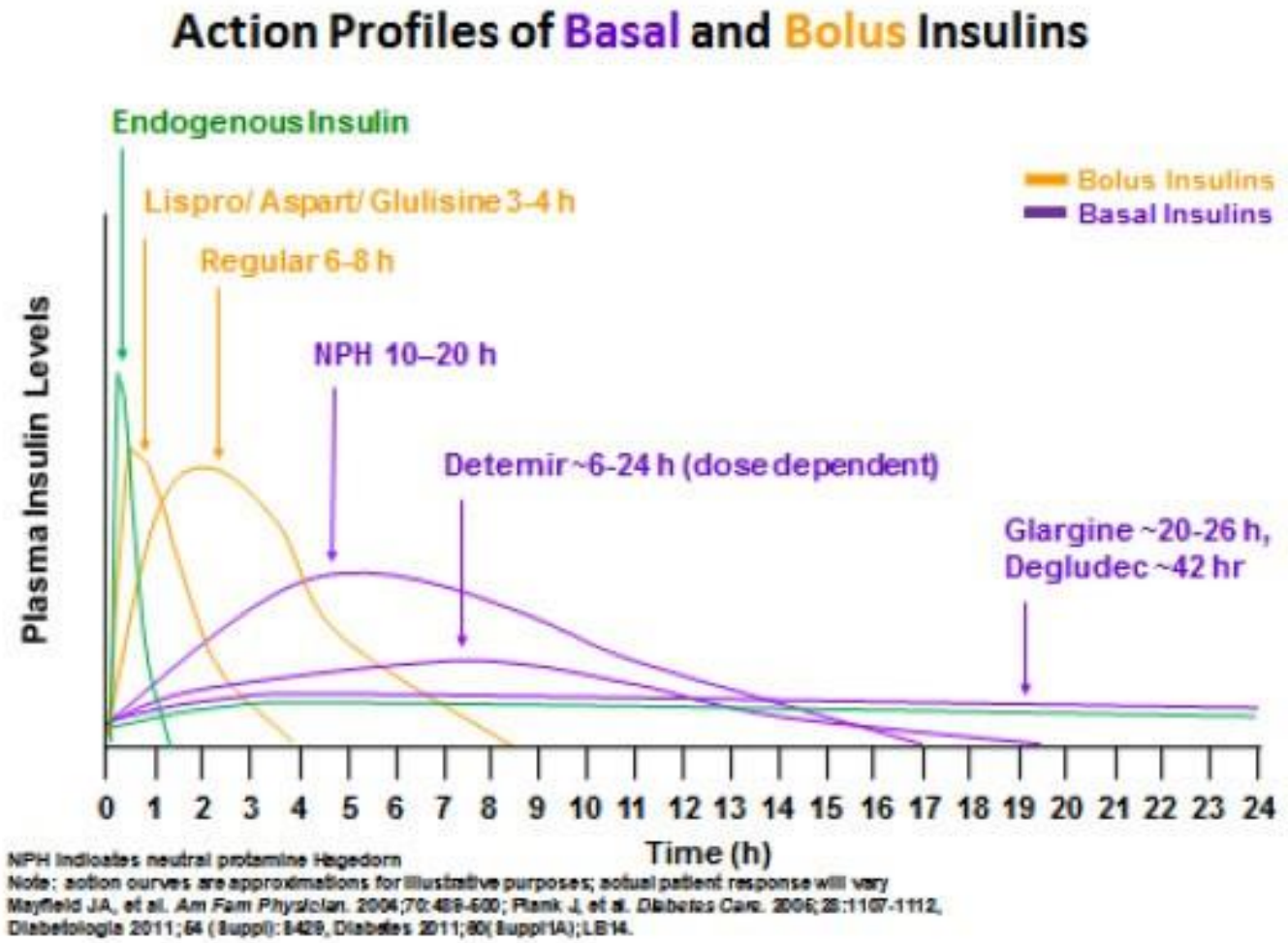
Insulin

- Naturally produced (endogenous) insulin
  - Made by beta cells of the pancreas
  - Half-life ~ 5-7 minutes
- Synthetic insulin
  - Delivered by pump/injection
  - Different durations
    - Very short acting (0.2 to 2 hours)
    - Long acting (up to 36 hours)

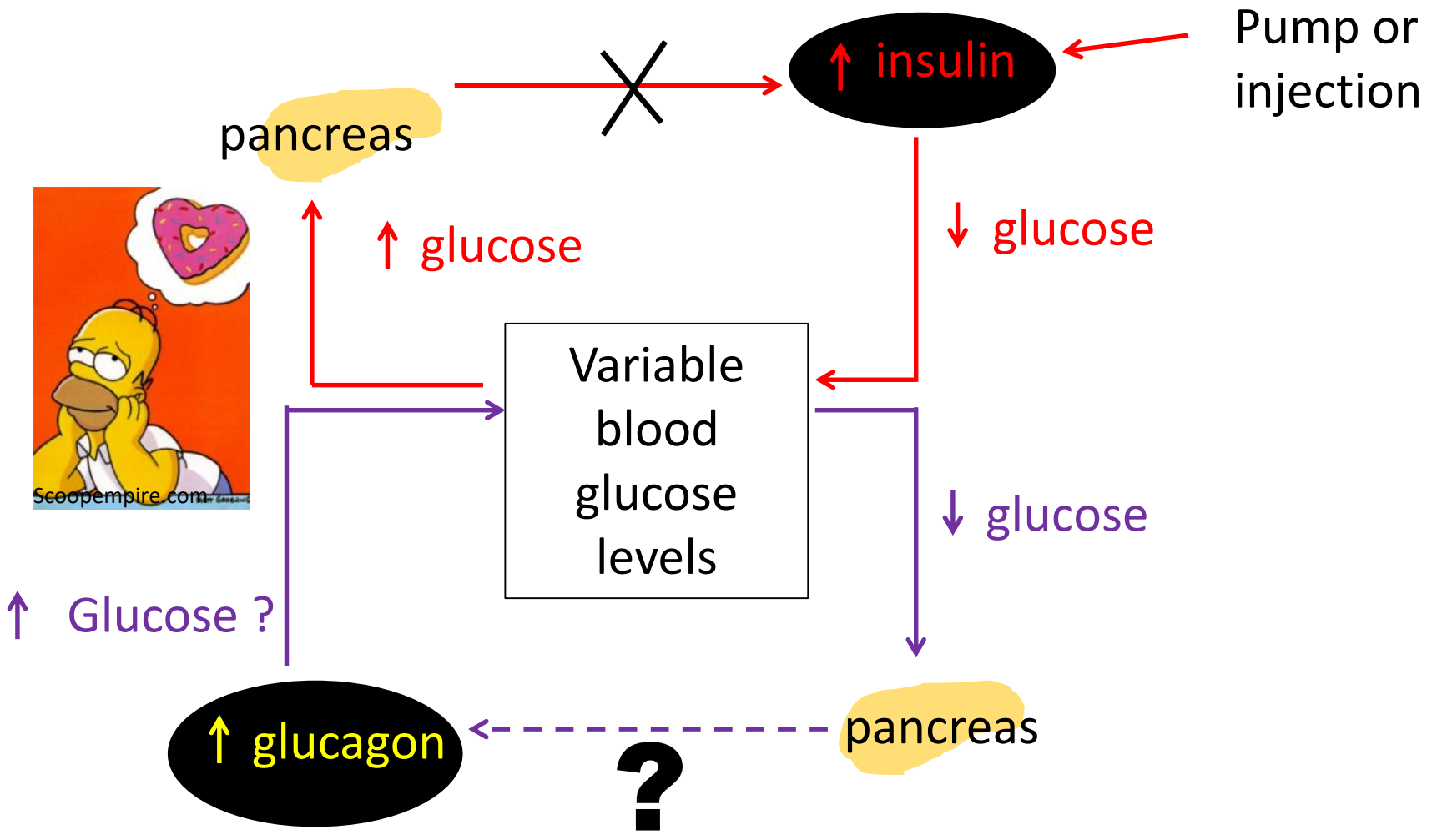


chem.libretexts.org

Insulin


Action Profiles of Basal and Bolus Insulins
Endogenous Insulin
Lispro/ Aspart/ Glulisine 3-4 h
Regular 6-8 h
NPH 10–20 h
Detemir ~6-24 h (dose dependent)
Glargine ~20-26 h,
Degludec ~42 hr
Bolus Insulins
Basal Insulins
Plasma Insulin Levels
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Time (h)
NPH indicates neutral protamine Hagedorn
Note: action curves are approximations for illustrative purposes; actual patient response will vary
Mayfield JA, et al. Am Fam Physician. 2004;70:489-500; Plank J, et al. Diabetes Care. 2006;29:1107-1112,
Diabetologia 2011;54 (Suppl):S429, Diabetes 2011;60(SupplA);LB14.

Keeping the Balance with Type 1 Diabetes



Fuel Sources for Aerobic Exercise

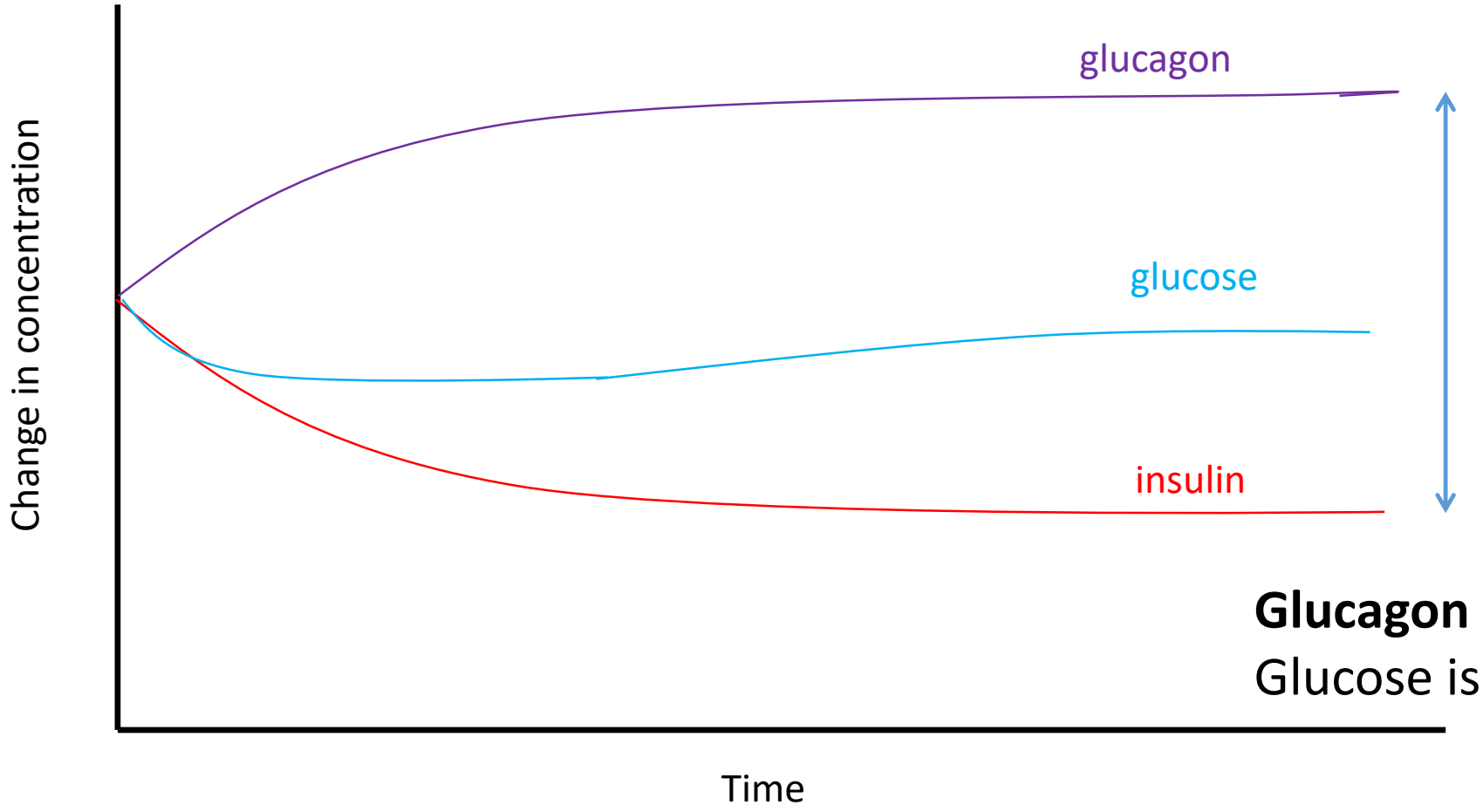
Type of Fuel	Storage Area
#1: Fat	Adipose Tissue
#2: Glucose	Blood Glucose
#3: Amino acids	Muscle

4 – 10 mmol/L
(~ 1 tsp)

Key hormones: Insulin and glucagon

"Aerobic" exercise – body can supply enough oxygen to fully convert glucose/fat to ATP

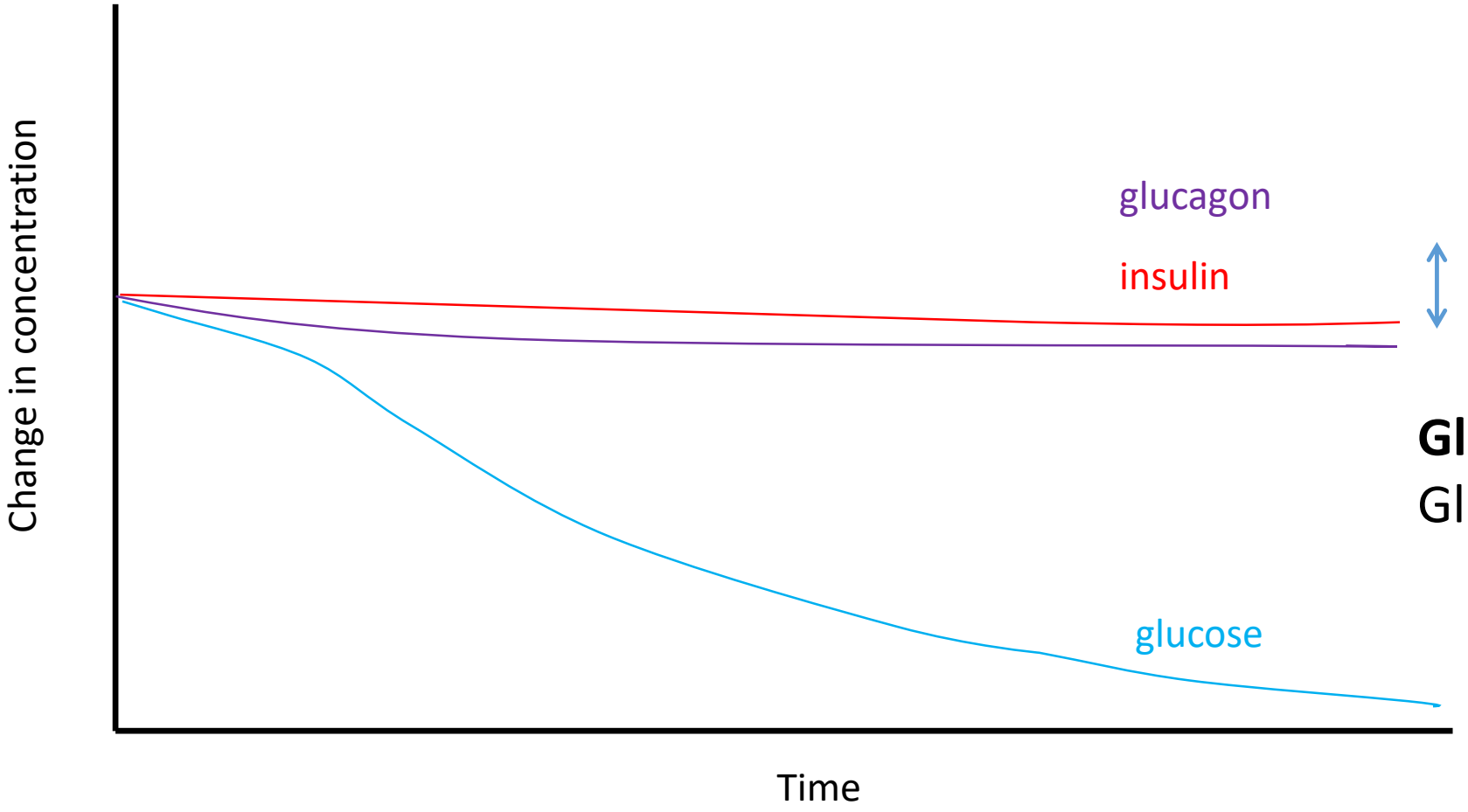
Aerobic Exercise without Type 1 Diabetes



Glucagon > insulin

Glucose is released from storage

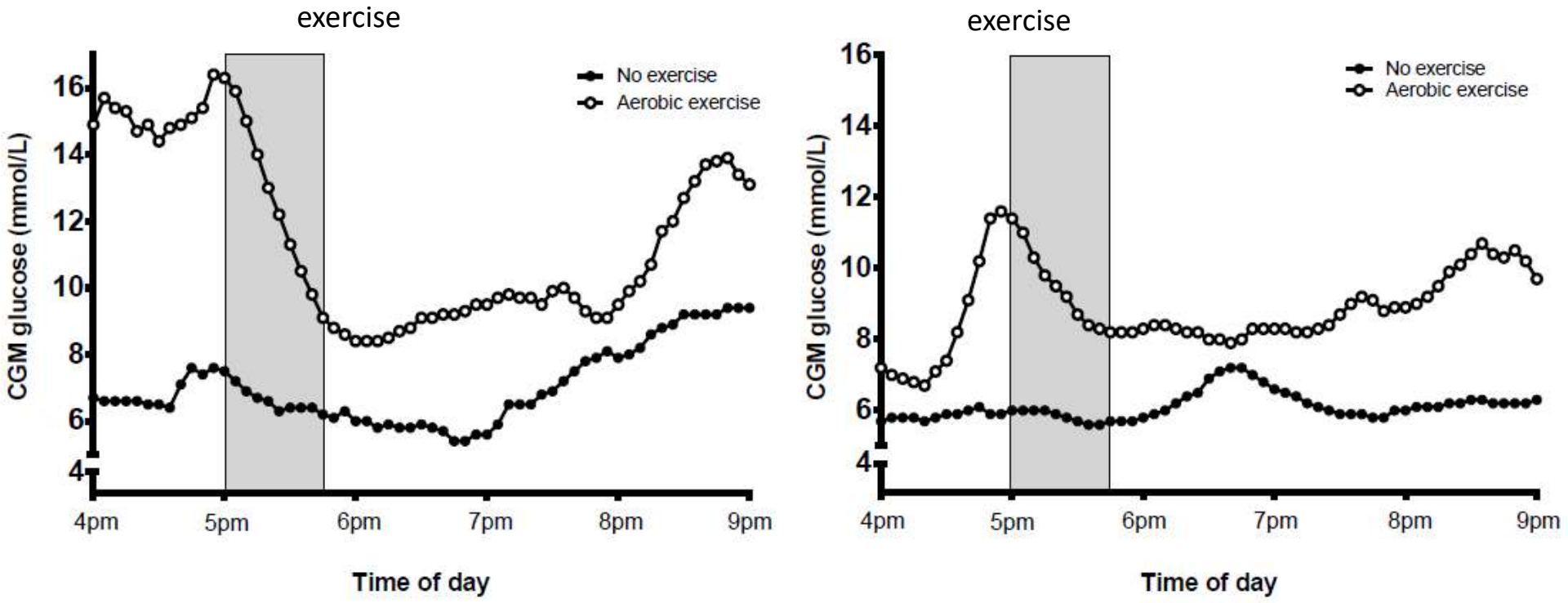
Aerobic Exercise in Type 1 Diabetes



Glucagon ~ insulin

Glucose is kept in storage

Finding the Sweet Spot



Reducing it just enough and at just the right time, otherwise….

Yardley et al. (2013) Can J Diabetes 37:427-32

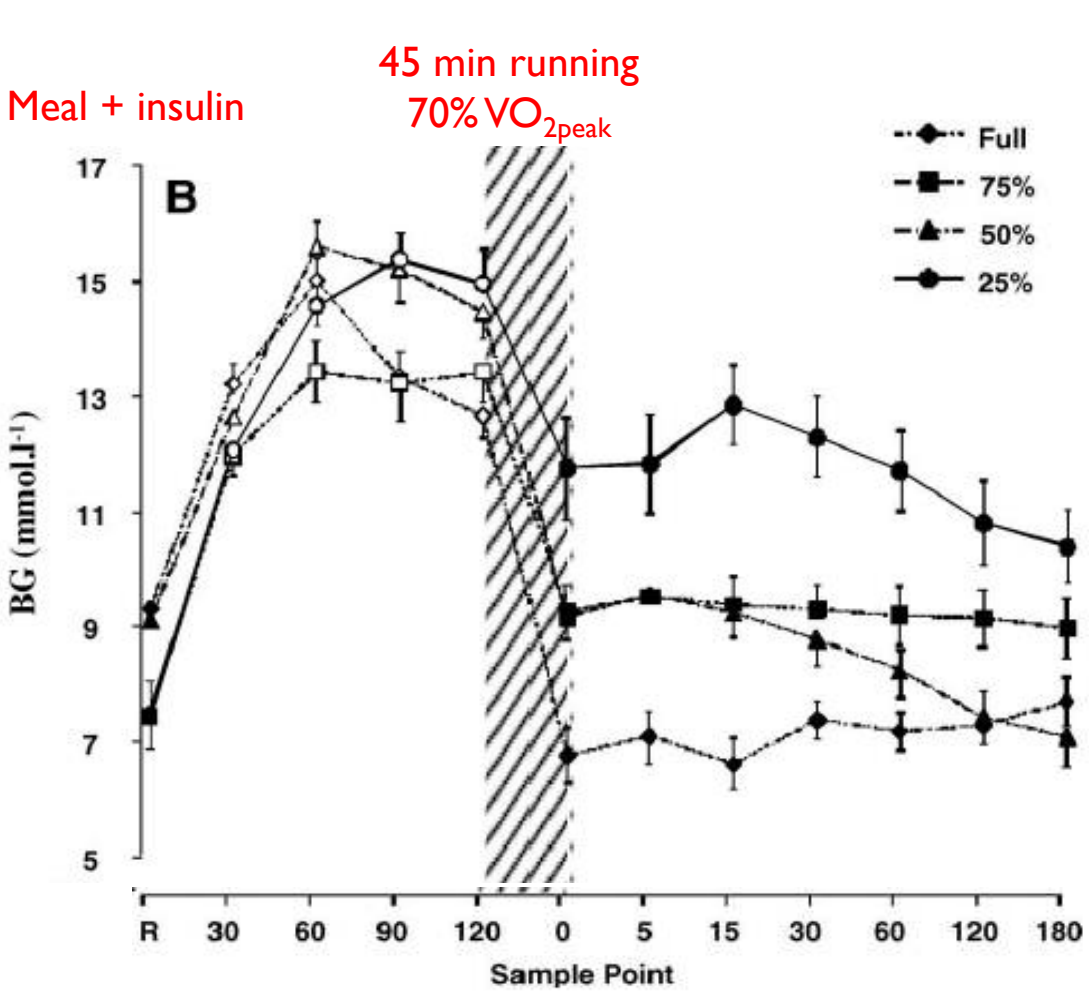
How Much is Just Right?

- It depends on exercise intensity, duration and timing
- General basal insulin recommendations **before** aerobic exercise:
  - Pump: at least 90 minutes before exercise decrease basal rate 50 to 100%
  - Injections: reduce pre-exercise basal dose by 20%
- General basal insulin recommendations **after** aerobic exercise:
  - Pump: decrease nocturnal basal rate post-exercise (especially if exercise is in the afternoon/evening)
  - Injections: consider decreasing post-exercise basal dose (depending on type of insulin)

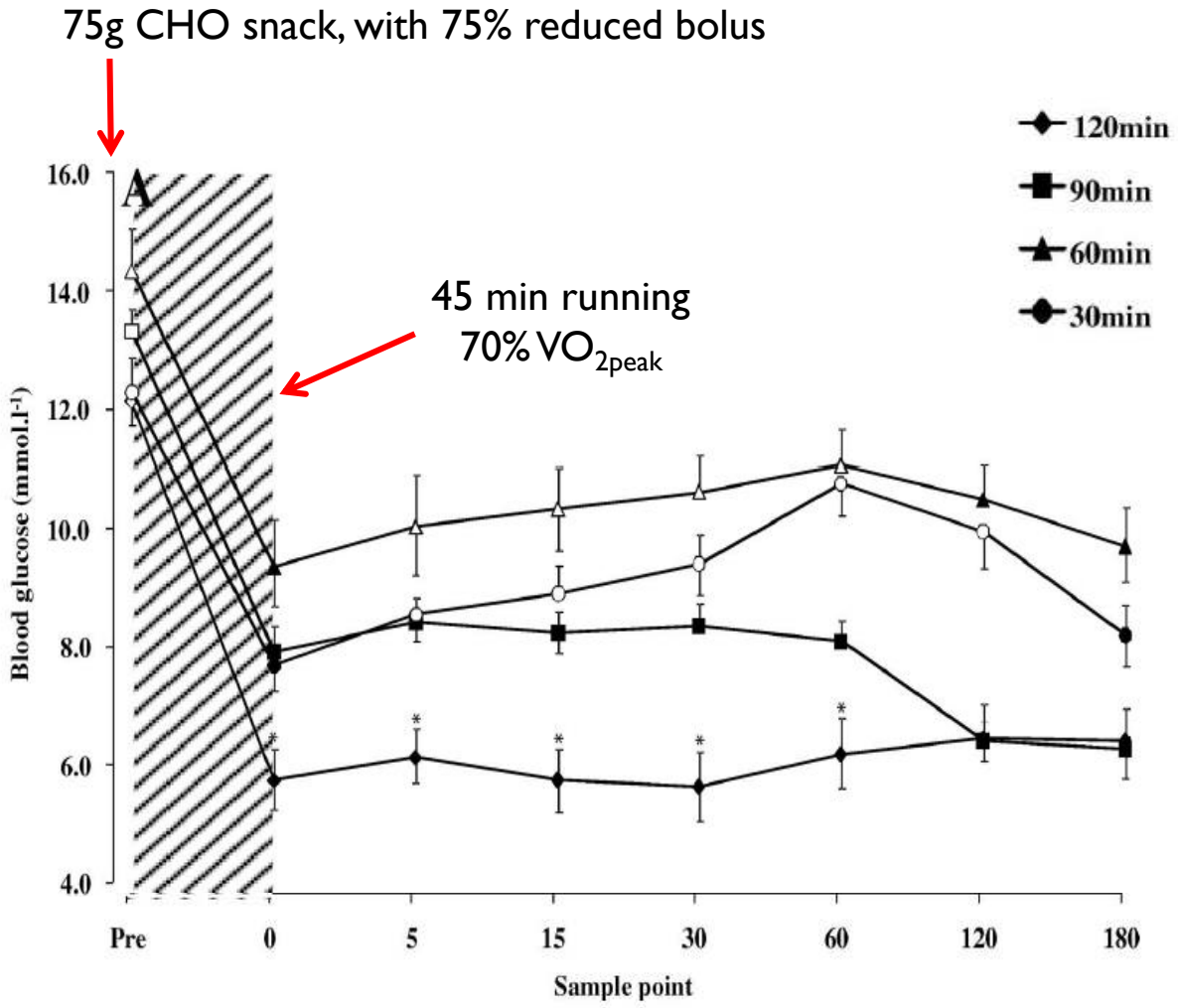
How Much is Just Right?

- Pre-exercise snacks (same advice for pump and injections)
- Reduce bolus insulin depending on timing
  - 25-50% reduction for snack 30 minutes before exercise
  - 50-75% reduction for snack 60 minutes before exercise
- Ideal starting blood glucose is in 8-10 mmol/L range

What is the Evidence for this?



West et al (2010) Journal of Sports Sciences 28(7):781-788



West et al (2011) J Sports Sci 29(3):279

Bottom line….

- Ideally insulin should be adjusted BEFORE exercise
- Try to mimic what the pancreas would normally do
- Without insulin adjustments, carbohydrate intake is usually needed
- Are there any other options?

INTENSITY

Different Intensity = Different Fuels

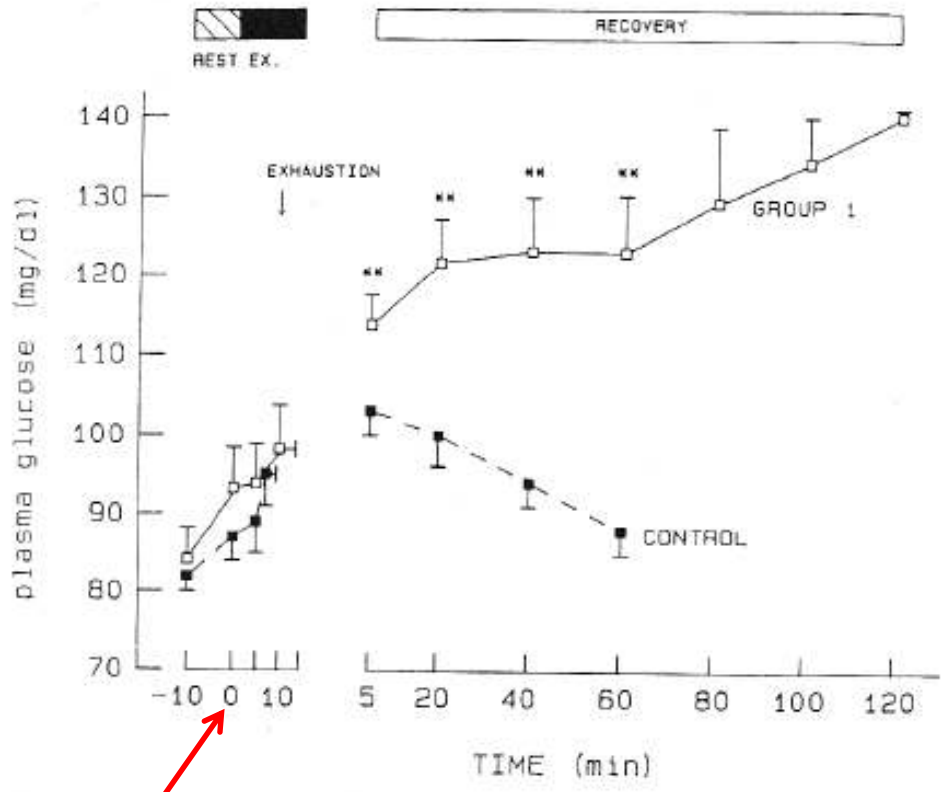
Aerobic (low to moderate intensity)

Type of Fuel	Storage Area
Fat	Adipose Tissue
Glucose	Blood Glucose
Amino acids	Muscle
Hormones	Insulin, glucagon

Anaerobic (high intensity)

Type of Fuel	Storage Area
Glucose	Muscle glycogen
Glucose	Liver Glycogen
Hormones	Epinephrine, norepinephrine

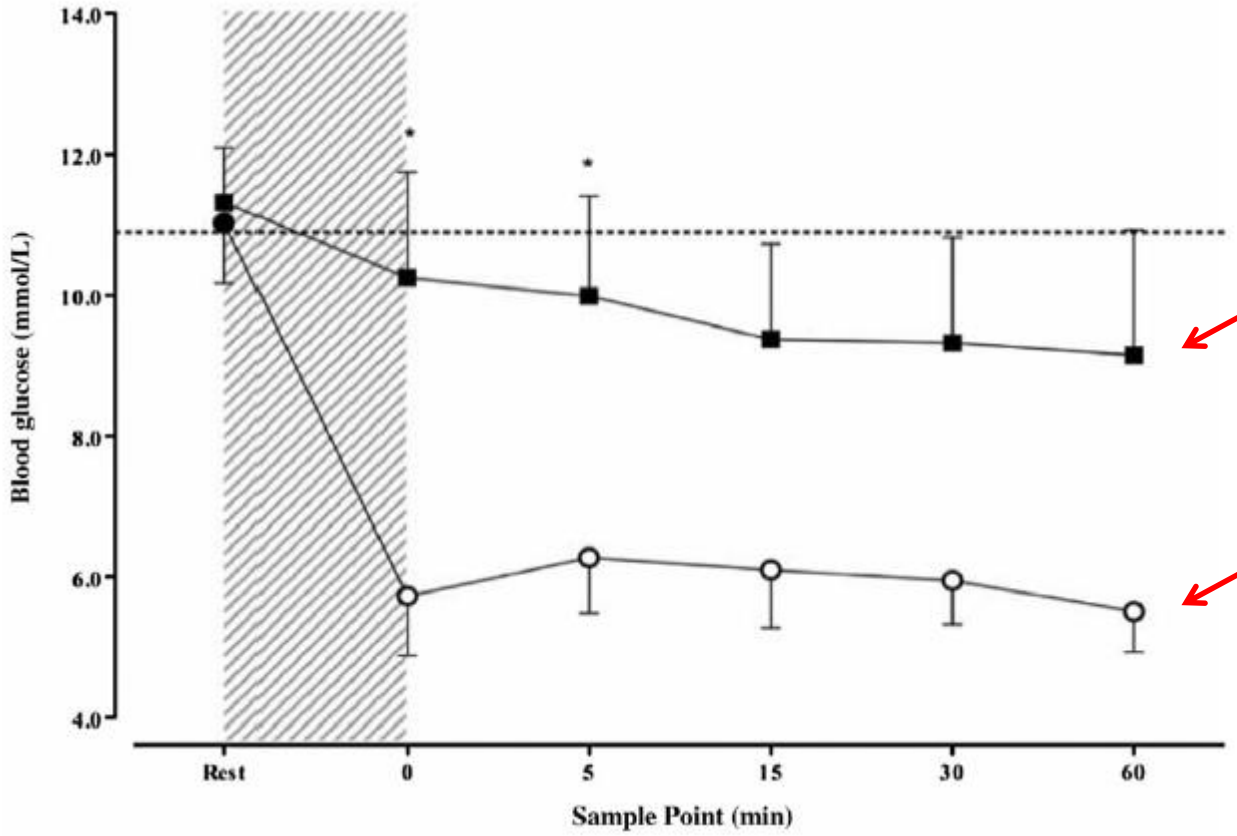
High intensity exercise increases BG



Cycling at >80% of max to exhaustion

Mitchell et al (1988) Diabetes Care 11(4):311-17

High Intensity Intermittent Exercise



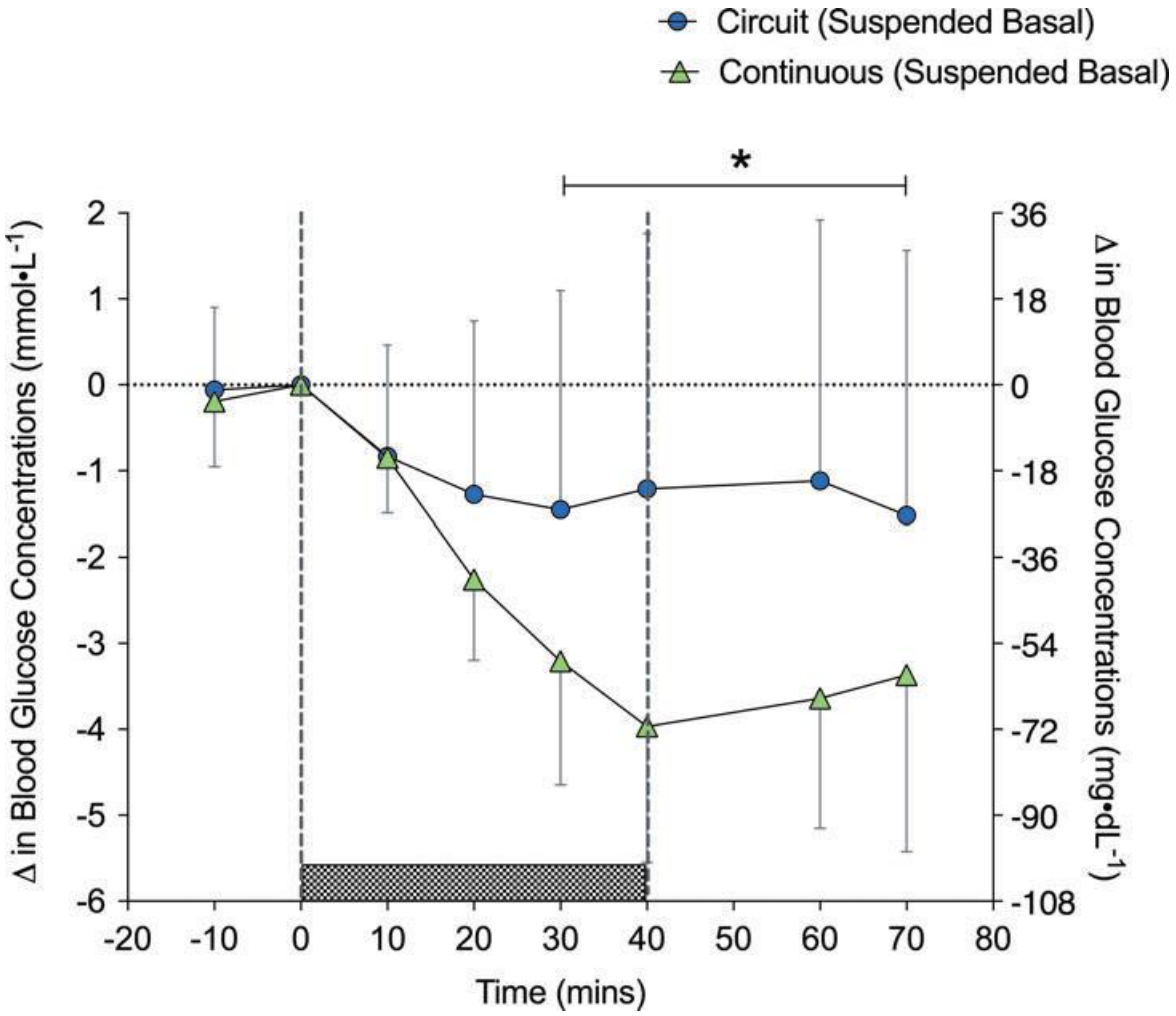
Loughborough Intermittent Shuttle Test

Treadmill running ~77% VO_2peak

Fig. 1. Time course changes in glycemia from rest. Data presented as mean ± SEM. Circles, **CON**; squares, **INT**. Transparent sample point within a condition indicates significant difference from resting concentrations ($P < 0.05$). *indicates significantly different from **CON** ($P < 0.05$). Thatched area indicates exercise.

Campbell et al (2015) Scand J Med Sci Sports. 25(2):216

Pump Adjustments Should be Made Before Exercise



- Pump turned off at the beginning of exercise
- Both types (moderate and interval circuit) of exercise resulted in average declines in blood glucose

Zaharieva et al (2017). Diabetes Technol Ther 19:370

Resistance Exercise

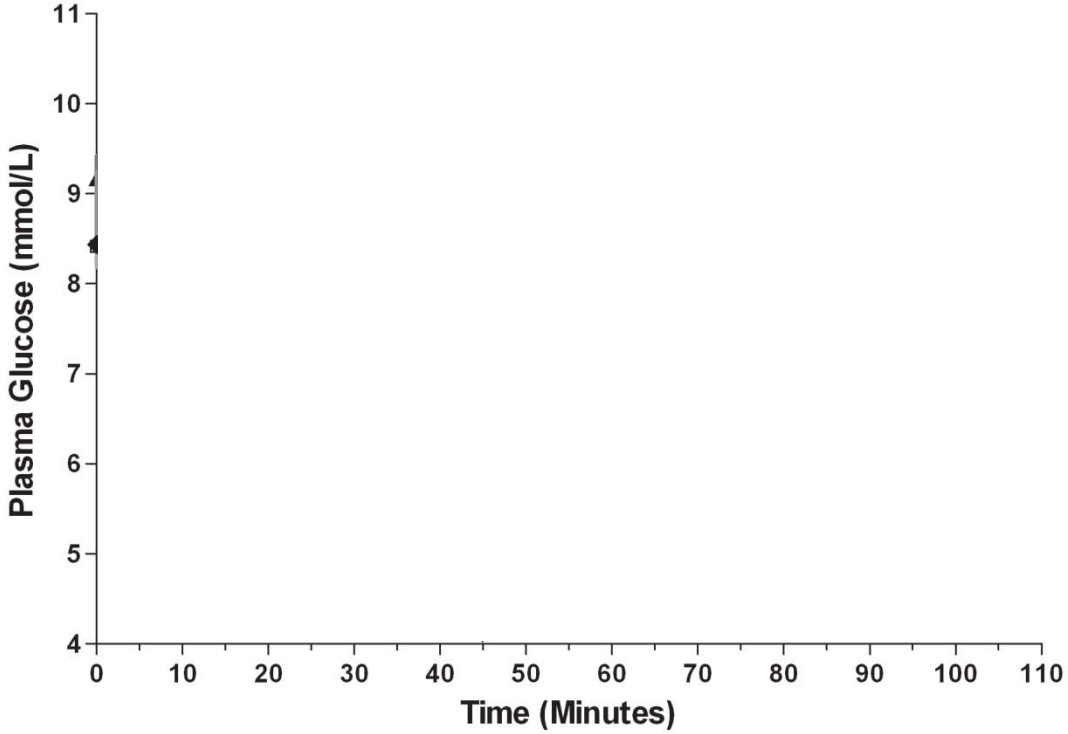
- Includes free weights, weight machines, body weight or elastic resistance bands
- Improves muscle mass, body composition, strength, physical function, bone mineral density, blood pressure, lipid profiles, cardiovascular health
- Unsure if it improves HbA1c
- Might be useful for preventing lows during exercise

Examples of beginner/intermediate programs

Main Goal of Training Program	Weight (% 1RM)	Reps per set	Sets per exercise	No. of weekly sessions	Velocity	Rest between sets
Build Muscular Endurance	Light to moderate (50-70%)	10 – 15 (or more)	2 – 7	2 – 4	Moderate	1 minute
Increase muscle mass	Moderate (60-80%)	8 – 12	1 – 3	2 – 4	Slow to Moderate	1 to 2 minutes
Increase strength	Moderate (60-80%)	6 – 12	1 – 3	2 – 4	Moderate	2 to 3 minutes
Increase power and/or explosiveness	Variable	3 – 6	1 – 3	2 – 4	Variable	3 to 5 minutes

*Adapted from McArdle et al. Eds (2010) *Exercise Physiology 7th Edition*

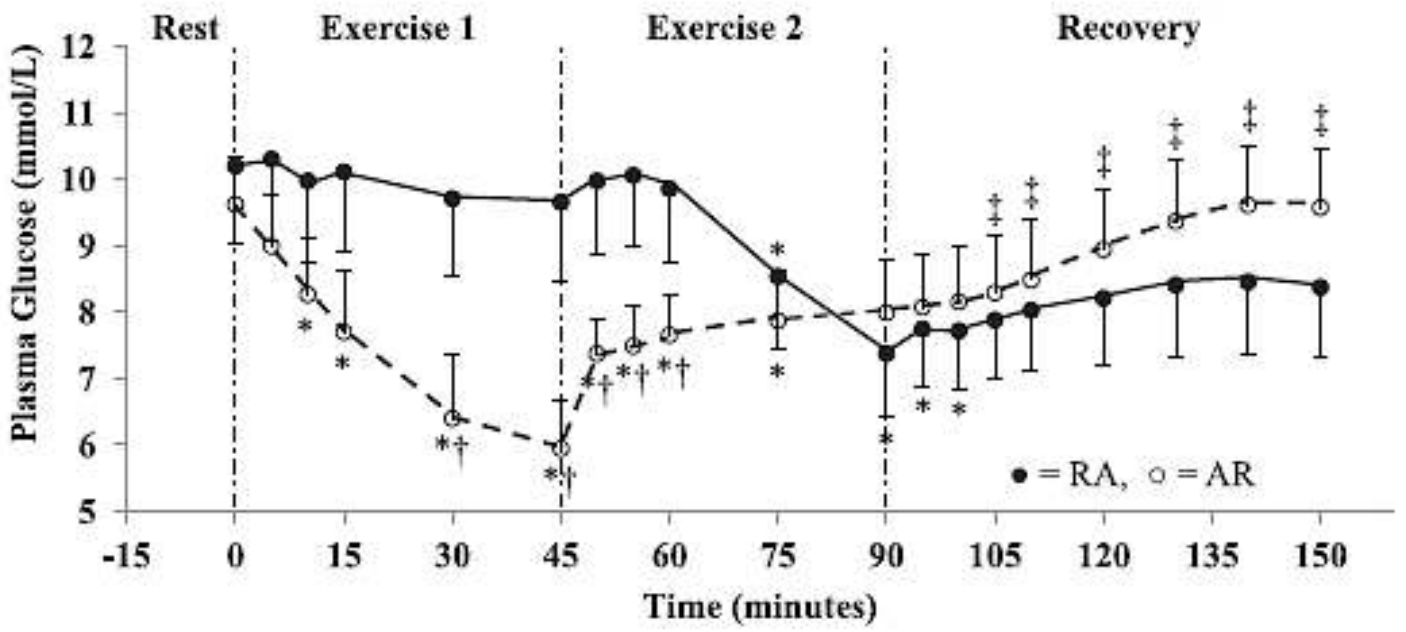
Aerobic vs. Resistance Exercise in T1D



a – significant change from baseline (aerobic)
b – significant change from baseline (resistance)
c – significant difference between aerobic & control
d – significant change throughout recovery (aerobic)

Yardley et al. Diabetes Care 2013; 36(3): 537-42

Exercise Order

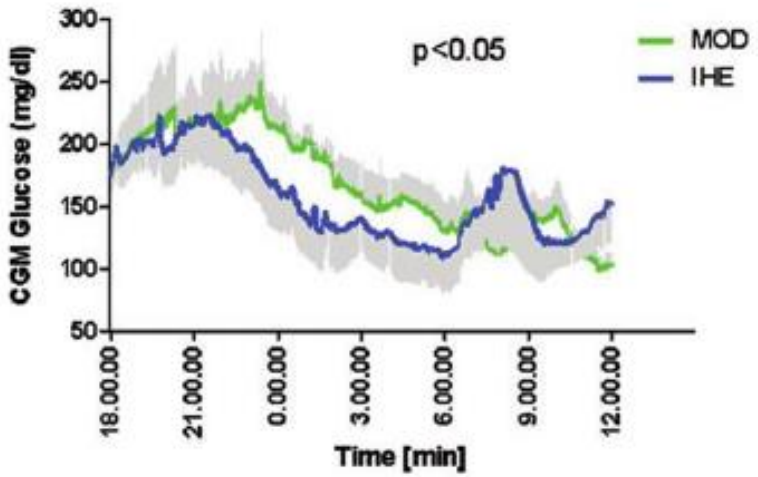


Yardley et al. Diabetes Care 35:669-75, 2012

Keep in Mind…

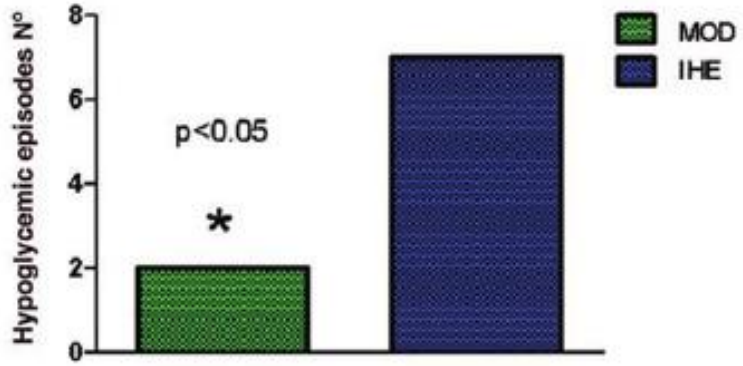
- You can only use what you have stored
  - Multiple training sessions or competitions in a day
  - Consecutive days of training or competition
  - Fasting (more than just overnight)
  - Very low carbohydrate diets?
- Eventually you have to pay back what you use
  - Glucose stores in muscle and liver need to build back up

Potential Problems with High Intensity Exercise



30 min moderate cycling (40%max)

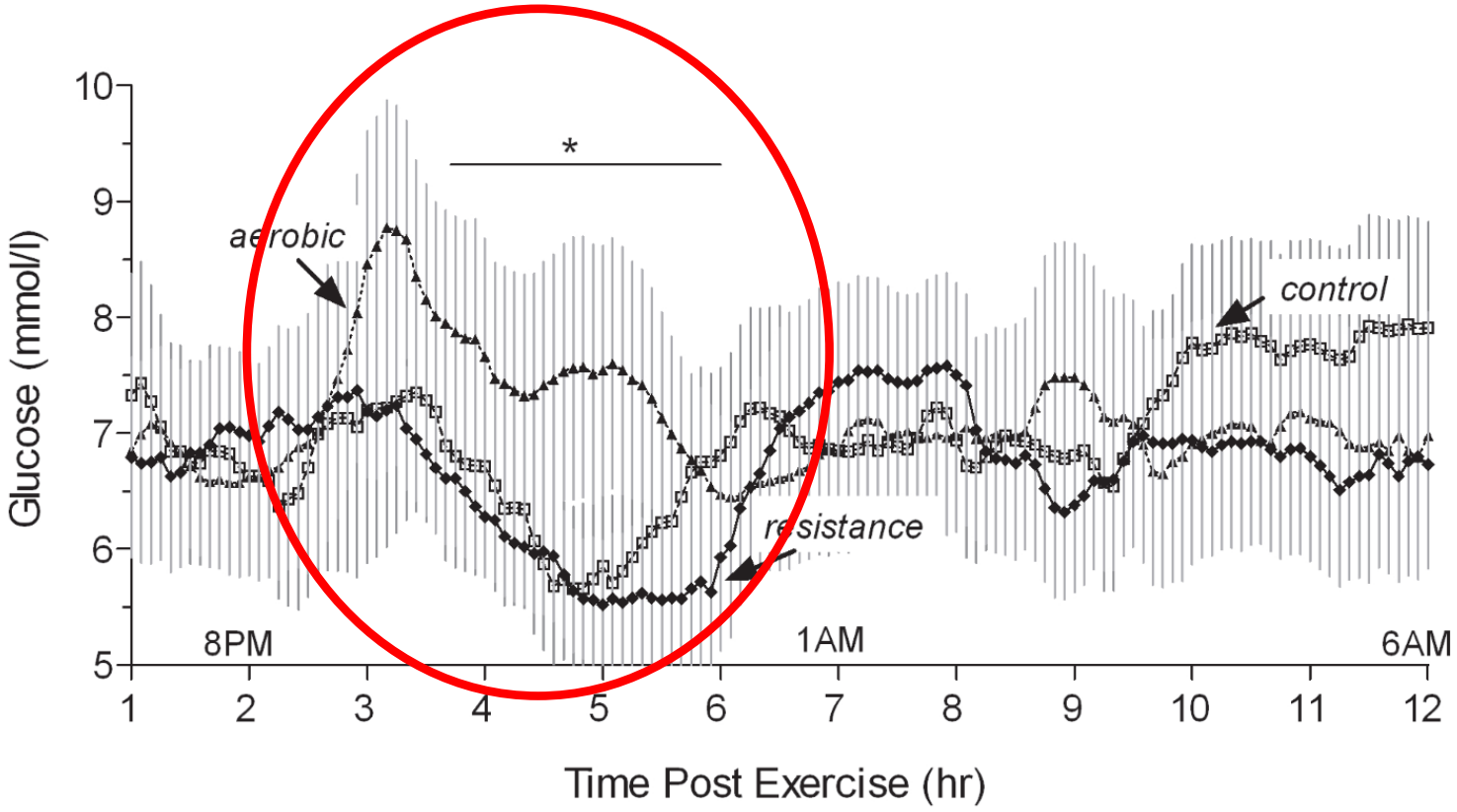
30 min moderate cycling (40%max) with 5 second bursts (85% max) every 2 minutes



The risk of late onset hypoglycemia might be increased with high intensity exercise

Maran et al. (2010) Diabet Sci Technol Ther 12: 763

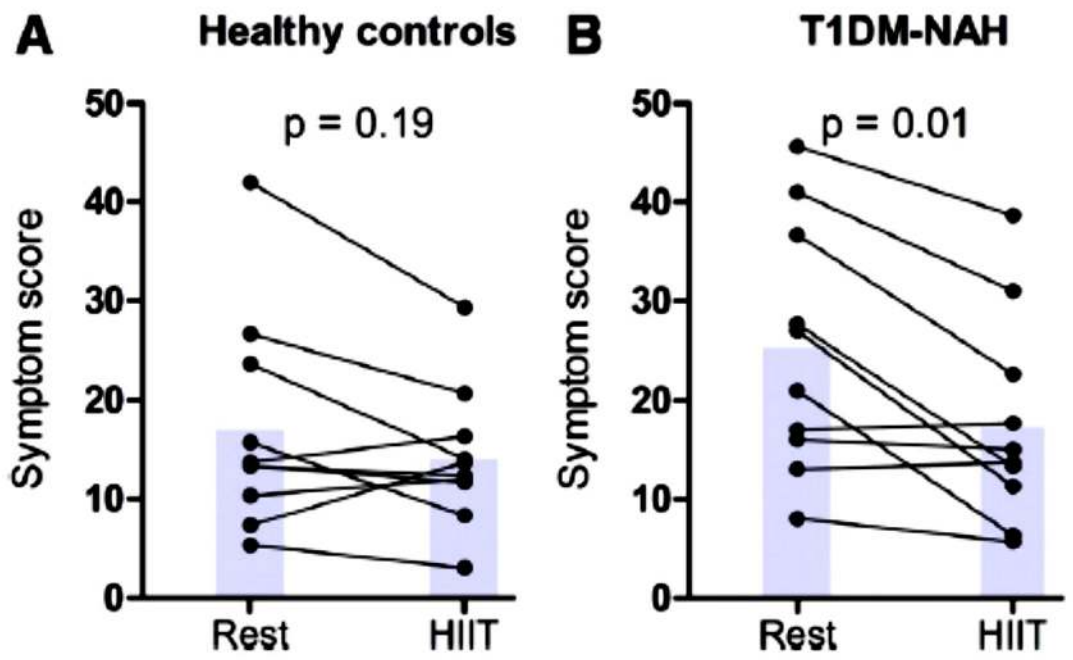
Potential Problems with High Intensity Exercise



Yardley et al. Diabetes Care 2013; 36(3): 537-42

Potential Problems with High Intensity Exercise

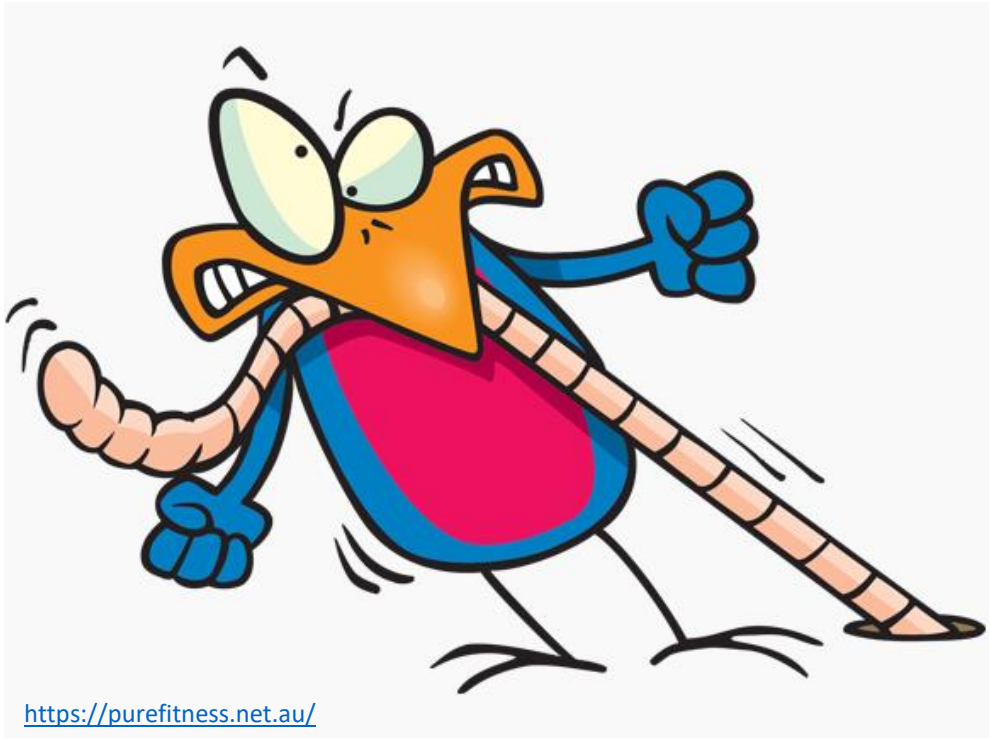
High intensity exercise may reduce hypoglycemia awareness



- Symptom score in response to hypoglycemic clamp (2.6 mmol/L) after 3 X 30 second maximal sprint with 4 minutes active recovery

Rooijackers et al (2017) Diabetes 66:1990

Is it Okay to Exercise Before Breakfast?



https://purefitness.net.au/

- Depends on blood glucose levels and planned exercise duration
- Potential for early morning hyperglycemia (dawn phenomenon)
  - If glucose is > 16 mmol/L, exercise not recommended
- Higher levels of growth hormone and cortisol
  - Promotes fat as a fuel source
  - May cause increases in blood glucose with morning (fasting) exercise

Morning (Fasting) vs. Fed Exercise

- Aerobic exercise (30 minutes of cycling at ~60% VO_{2peak})
- Morning exercise fasting at 7am
- Afternoon exercise at 4pm
- Standardized meals

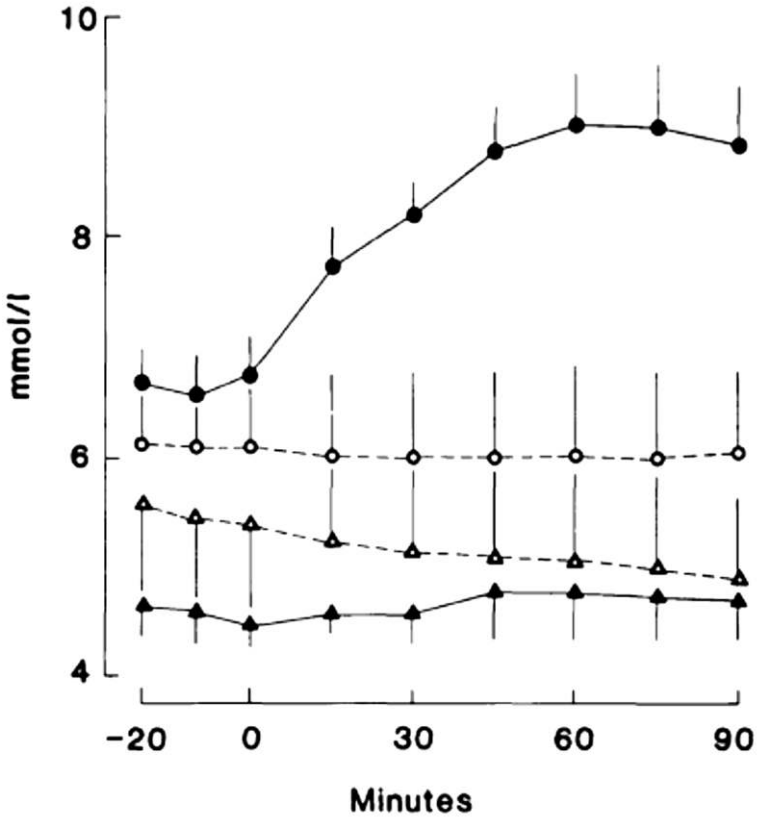
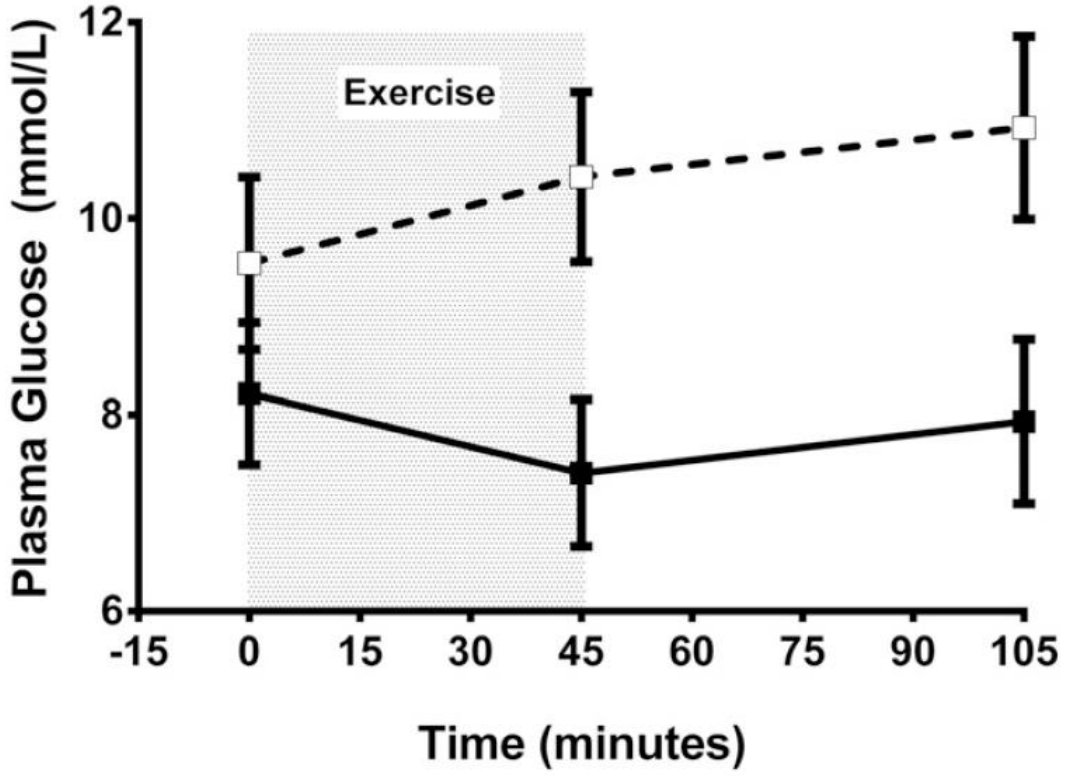


FIG. 1. Plasma glucose concentrations before, during, and after exercise. ●, Morning exercise; ○, morning control period; ▲, afternoon exercise; △, afternoon control period. Values are means ± SE; $n = 6$.

Ruegemer et al (1990) Diabetes Care 13:104

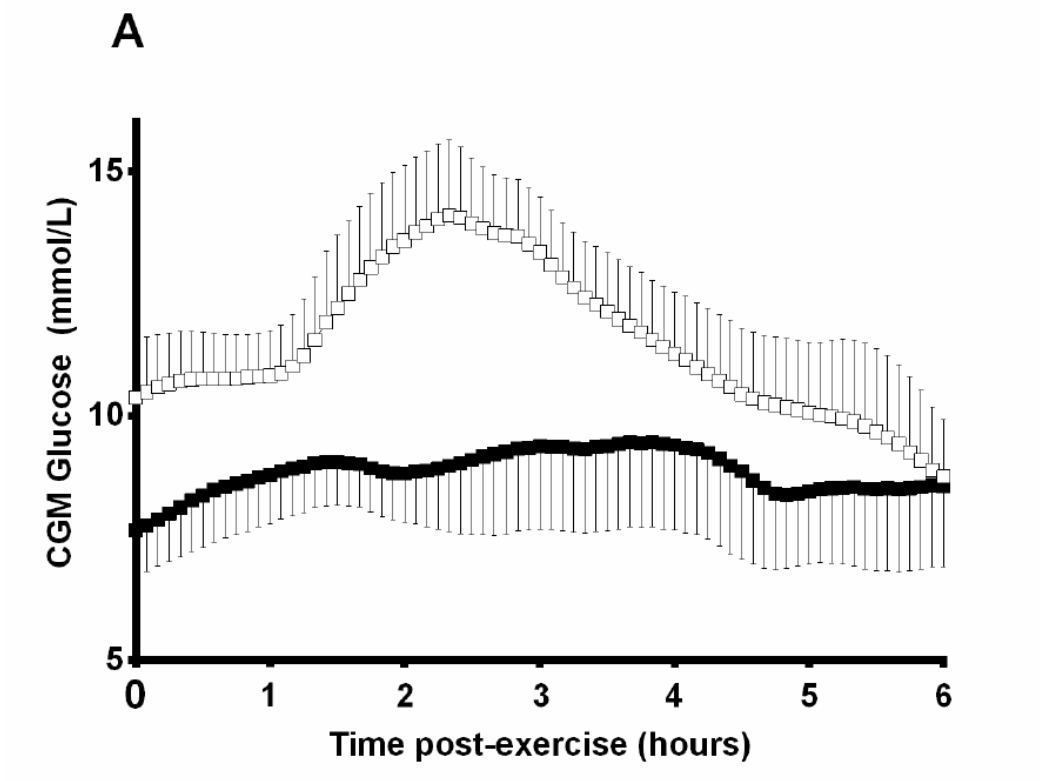
Morning (Fasting) vs. Fed Exercise

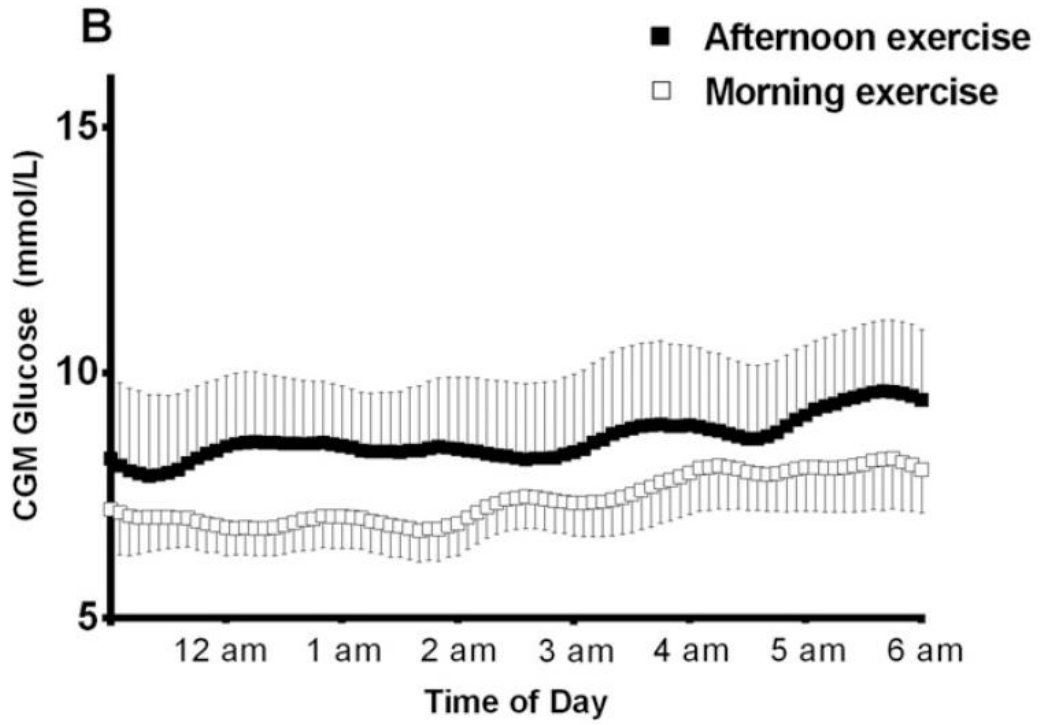


- Resistance exercise (3 X 8 reps)
- Morning exercise fasting at 7am
- Afternoon exercise at 5pm
- Post-exercise corrections likely required for fasting resistance exercise

Toghi-Eshghi & Yardley (2019). J Clin Endocrinol Metab 104:5217-5224

Morning (Fasting) vs. Fed Exercise

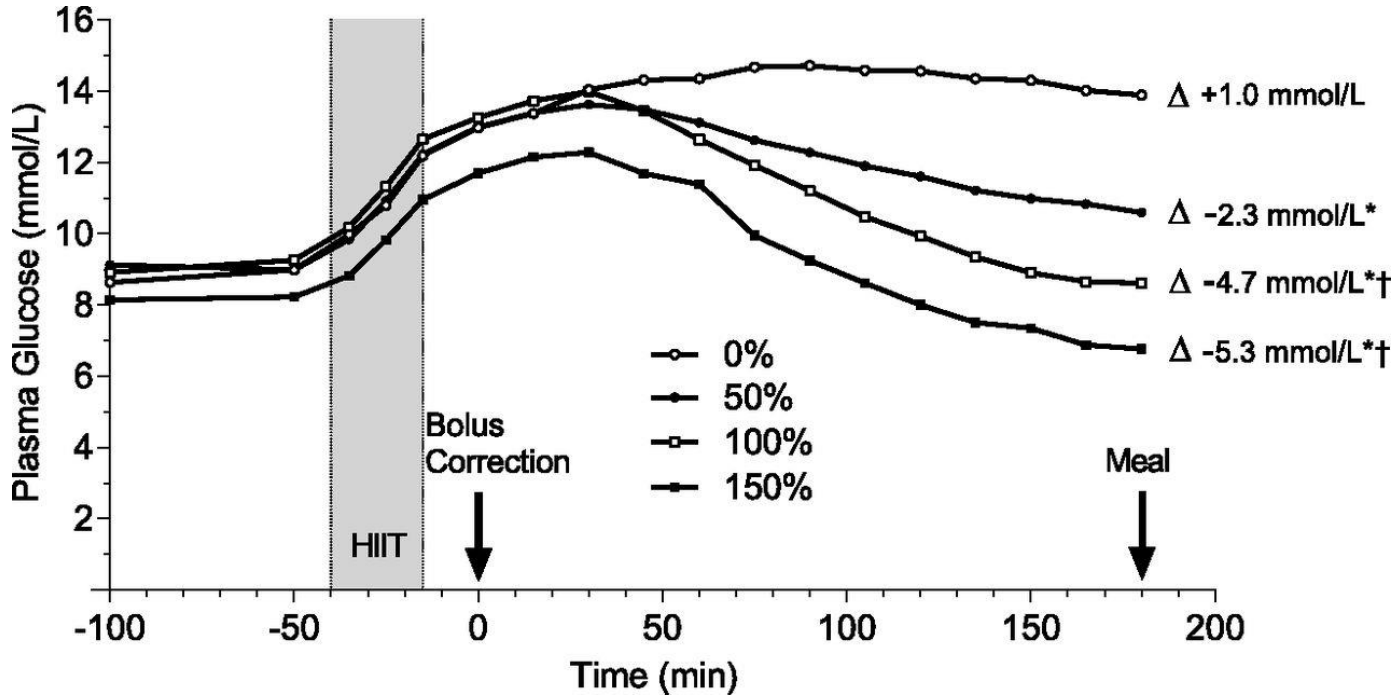




Toghi-Eshghi & Yardley (2019). J Clin Endocrinol Metab: 104:5217-5224

Take-Home Messages

- Exercising before breakfast can make glucose go up, regardless of exercise type or intensity
- Insulin adjustments will probably be smaller (if any are required)
- Hyperglycemia is more common after morning exercise
- A post-exercise bolus might be required



Aronson et al. Diabetes Care (2019). 42(1):10

Environmental Conditions: Heat

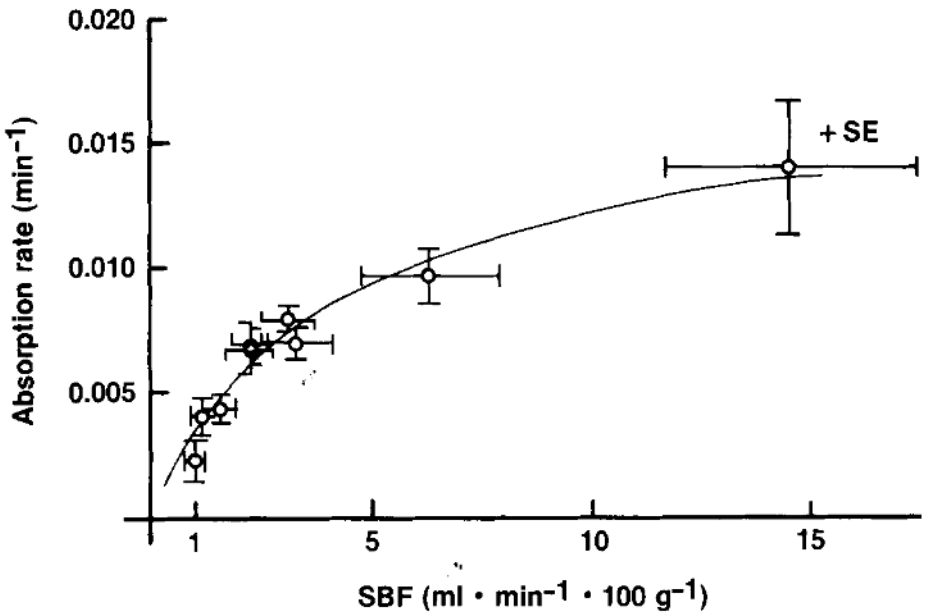


FIG. 1. The relationship between the insulin absorption rate (fraction·min^{-1}) and SBF (ml·(min·100 g)$^{-1}$). For each group of measurements, the figures are taken from Table I.

Hildebrandt et al (1985) Scand J Clin Lab Invest 45:685

- Skin blood flow increases as the body gets warmer
- Higher skin blood flow increases insulin absorption
- Higher insulin can lead to bigger glucose drop

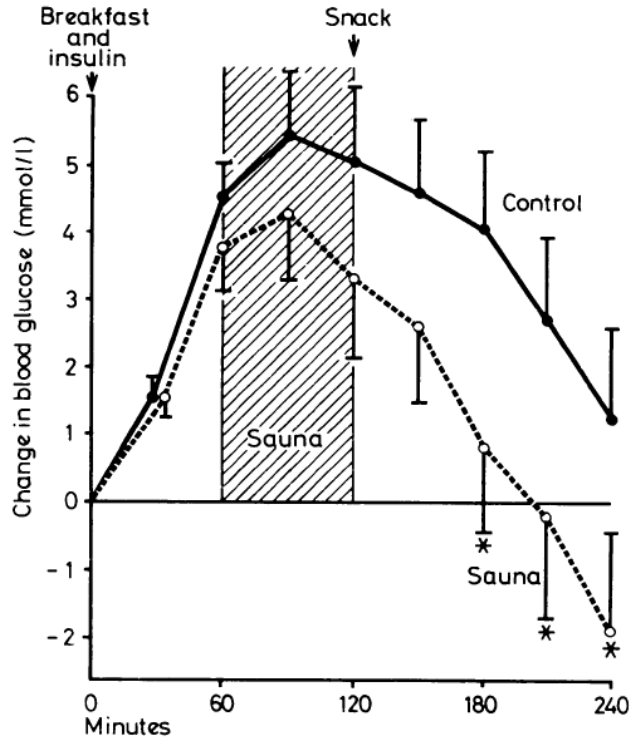
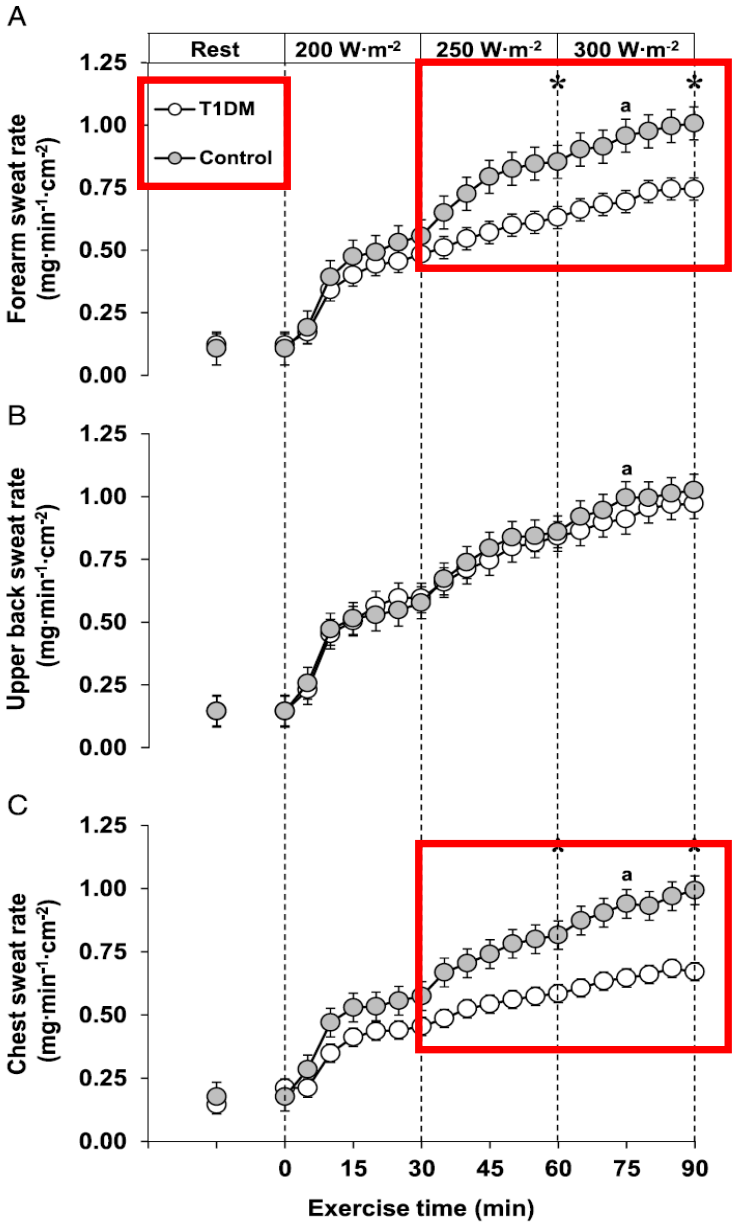


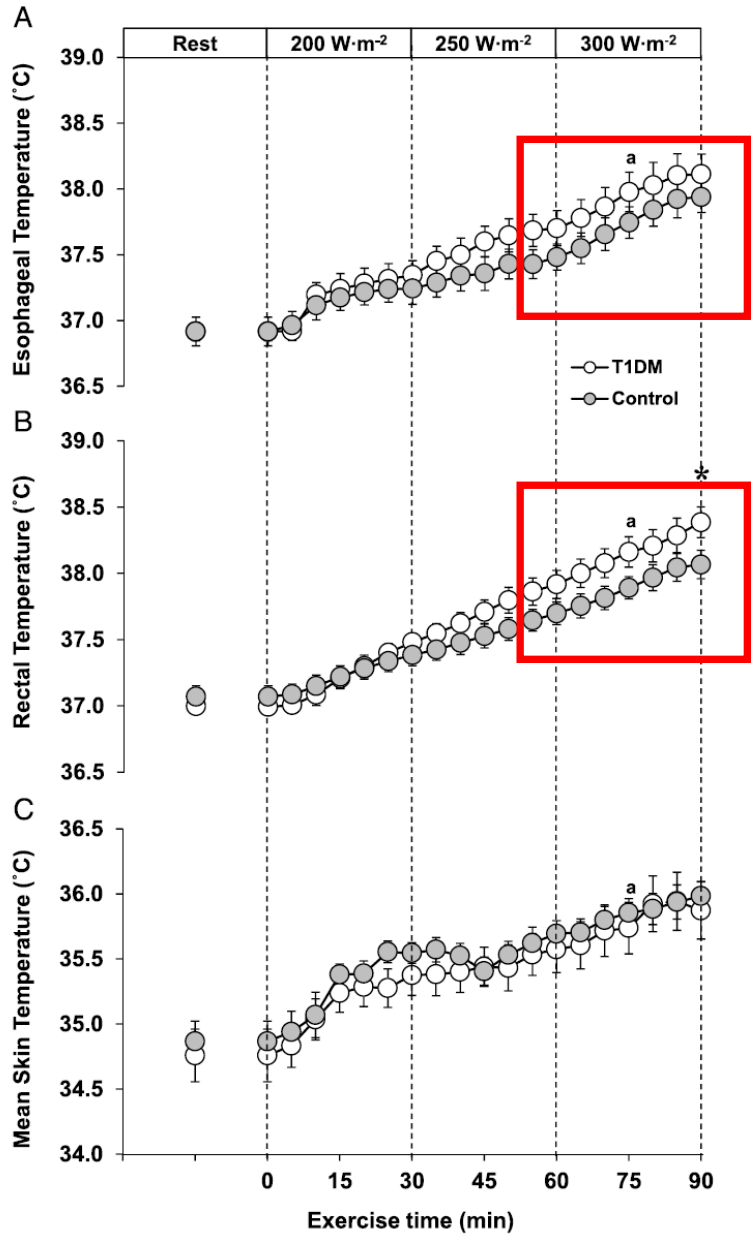
FIG 3—Postprandial changes in blood glucose concentration on control and sauna days (means ± SEM). At zero time subjects injected with insulin and given breakfast. Snack given 120 minutes after insulin. Sauna day *v* control day: *p < 0·05. (Blood glucose: 1 mmol/l ≈ 18 mg/100 ml.)

Koivisto (1980) Br Med J;280:1411



35C, 20% humidity

- Heat stroke risk might be higher with longer duration and/or higher intensity exercise in type 1 diabetes



Carter et al (2014) Med Sci Sports Exerc 46:2224

Environmental Conditions: Cold

- Cold: no studies to date but…
- Heat production uses energy
- Shivering = muscle contraction
- Muscle contraction uses fuel
- Changes in blood glucose with exercise in the cold?

Things to Keep in Mind: Sex-related differences

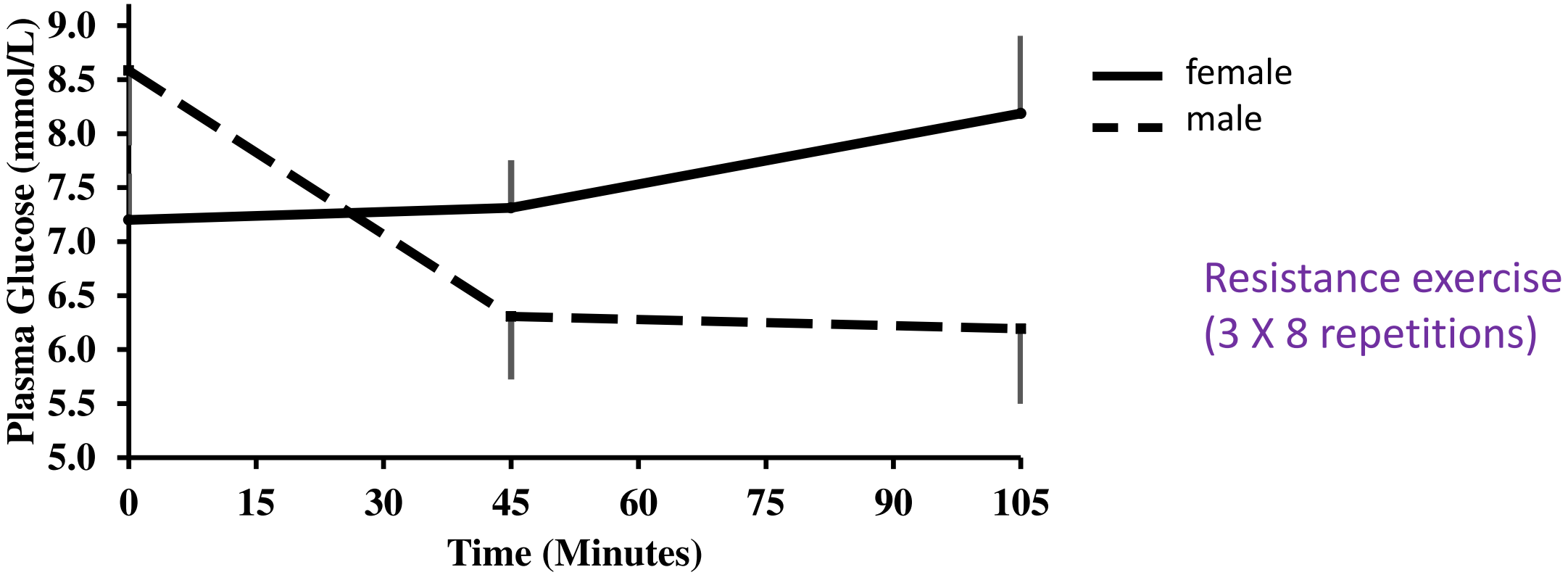
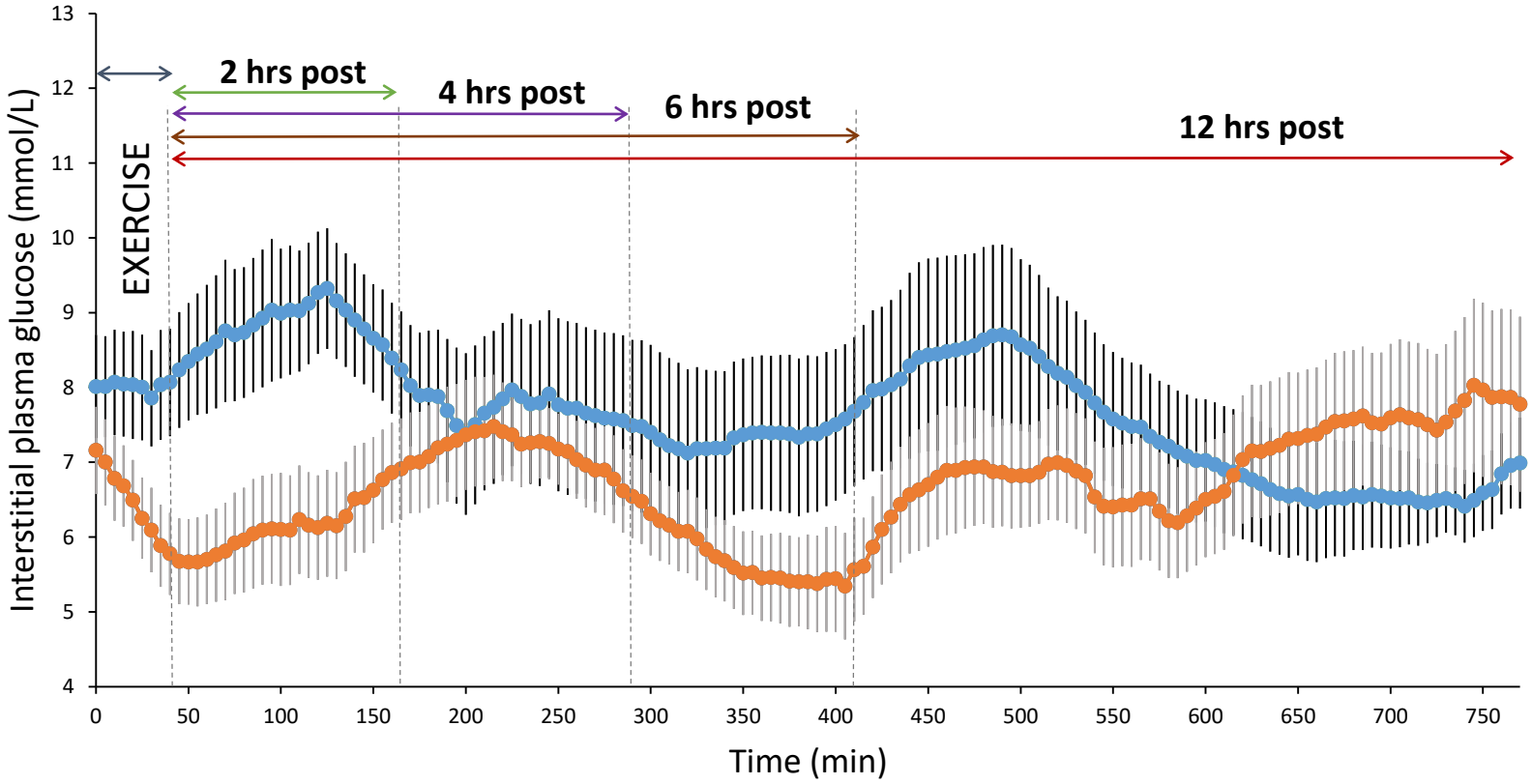


Figure 1. *Mean ± SE plasma glucose during the resistance exercise session and 1 hour of recovery (n= 9 females and 13 males).*

Brockman & Yardley, Canadian Journal of Diabetes (in press)

Things to Keep in Mind: Sex-related differences



-Be aware:

- Small sample size
- Fit individuals
- Secondary analysis

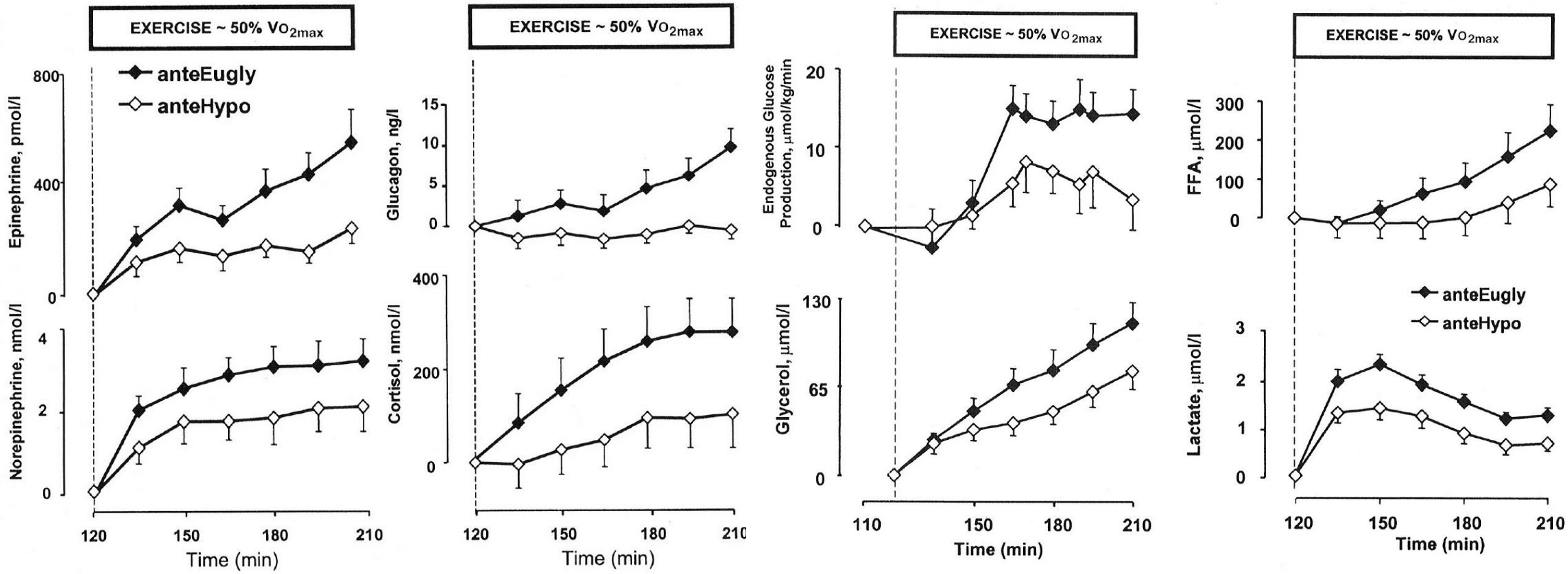
Females
Males

Brockman & Yardley, Canadian Journal of Diabetes (in press)

Things to Keep in Mind: Menstrual Cycle

- More hyperglycemia reported during luteal phase
- Higher insulin?
- Differences in fuel use?
- Impact on hypoglycemia risk?

Things to Keep in Mind: Antecedent Hypoglycemia

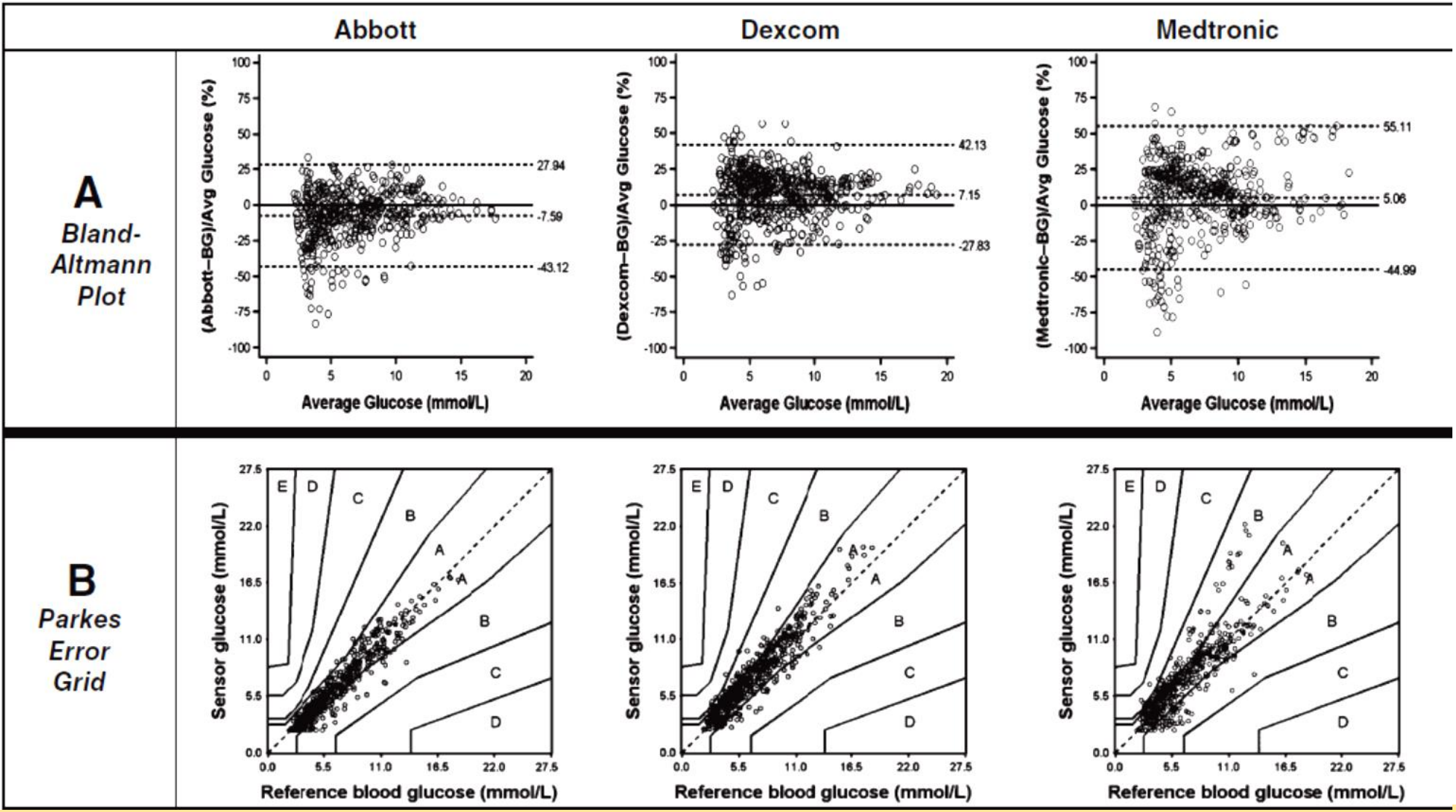


Galassetti et al (2003) Diabetes. 52(7):1761

CGM can Improve Knowledge/Confidence

- T1D Boot Camp 360 study (Dyck et al, 2018, Can J Diabetes)
- CGM, education, and experiential learning used to teach people with T1D about exercise
- Focus group data indicated that CGM use
  - Allowed a better understanding of blood glucose fluctuations
  - Permitted closer monitoring of blood glucose during exercise
  - Led to less over-correction before, during and after exercise
  - Acted as a safety net to be able to exercise with confidence

CGM Accuracy During Exercise has Improved



Aberer et al (2017) Diabetes Obes Metab 19:1051

Exercise = 2 X 15 min cycling @ 50% VO_{2peak} (12 participants)

Things we take for Granted

- Activities of daily living can be physical activity
  - Scrubbing floors
  - Gardening
  - Carrying laundry up and down stairs
  - Vacuuming
  - General tidying
- Anything involving repeated muscle contractions can cause declines in blood glucose
- If chores aren't pre-planned with an insulin adjustment, snacks might be required!

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Final Words of Wisdom

- Find the right routine for success
- Keep a diary to track the following things:
  - Type, timing, intensity, duration of exercise
  - Carbohydrate intake and insulin adjustments
  - Environmental conditions
  - General mood, overall health
- Be as consistent as possible and check glucose levels often
- Use a CGM to determine blood glucose trends
- Experiment with one variable at a time
- Make small adjustments to find what works

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Questions?

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