# Type 1 and exercise
# Physiological Changes and glycaemic control

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# What we will cover

- Exercise types
- What are the normal endocrine responses to exercise
- How do different intensity of exercises alter these responses
- Impact of T1DM on these response
- Significance for glycaemic control and hypoglycaemia

# Aerobic exercise

- Aerobic exercise (cardio) is physical exercise which depends primarily on the aerobic energy-generating process, and refers to the use of oxygen to adequately meet energy demands during exercise via aerobic metabolism.

- Moderate intensity activities that are supported by aerobic metabolism can be performed for extended periods of time.
  - People with low aerobic capacity can become anaerobic at low workloads
  - Conversely, people with high aerobic capacity can perform high workloads for extended time
  - Some muscle groups may be anaerobic if overall lactate produced can be metabolized

# Anaerobic exercise

- Anaerobic exercise is a physical exercise intense enough to cause lactate to form.
- It promotes strength, speed and power and to build muscle mass.
- Muscle energy systems trained using anaerobic exercise develop differently compared to aerobic exercise, leading to greater performance in short duration, high intensity activities.
- Many mixed activities have periods of anaerobic exercise.

# Borg scale



| # | Level of Exertion |
|---|---|
| 6 | No exertion at all |
| 7 | |
| 7.5 | Extremely light (7.5) |
| 8 | |
| 9 | Very light |
| 10 | |
| 11 | Light |
| 12 | |
| 13 | Somewhat hard |
| 14 | |
| 15 | Hard (heavy) |
| 16 | |
| 17 | Very hard |
| 18 | |
| 19 | Extremely hard |
| 20 | Maximal exertion |

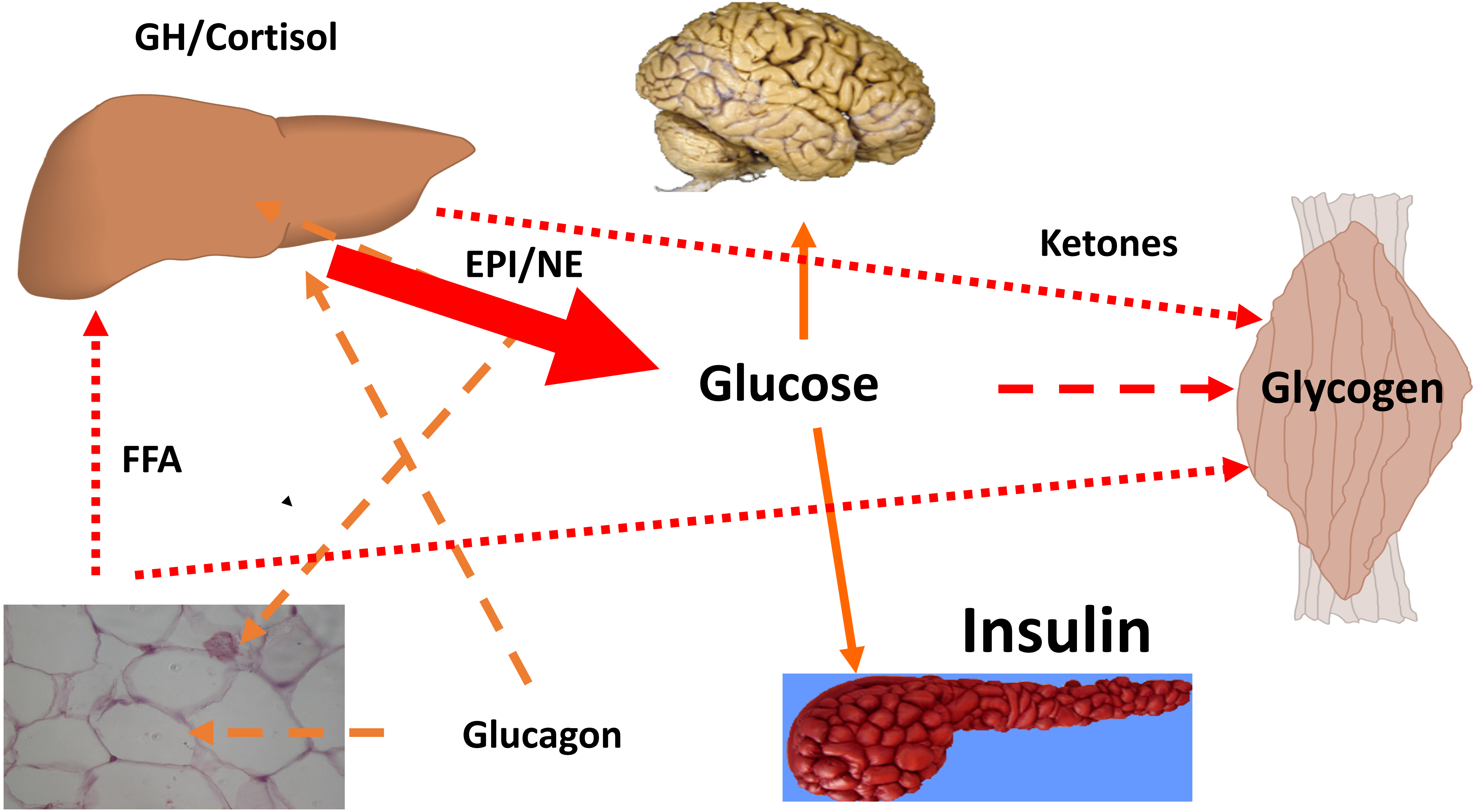
9 corresponds to “very light” exercise. For a Healthy person it is like walking slowly at his or her own pace for some minutes.

13 on the scale is “somewhat hard” exercise, But it still feels OK to continue.

17 “very hard” is very strenuous. A healthy Person can still go on but he or she really has to push him or herself. It feels very heavy, and the person is very tired

19 on the scale is an extremely strenuous exercise level. For most people this is the Most strenuous exercise they have ever Experienced.

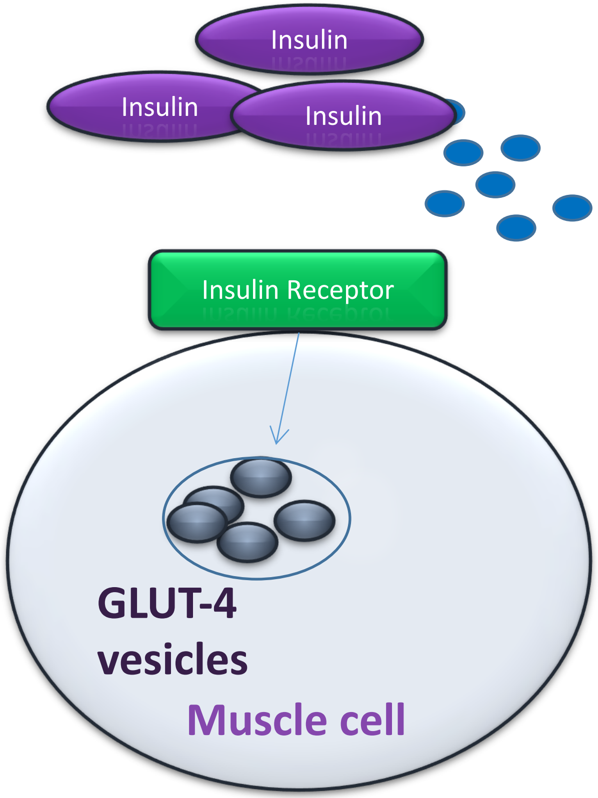
Borg RPE scale

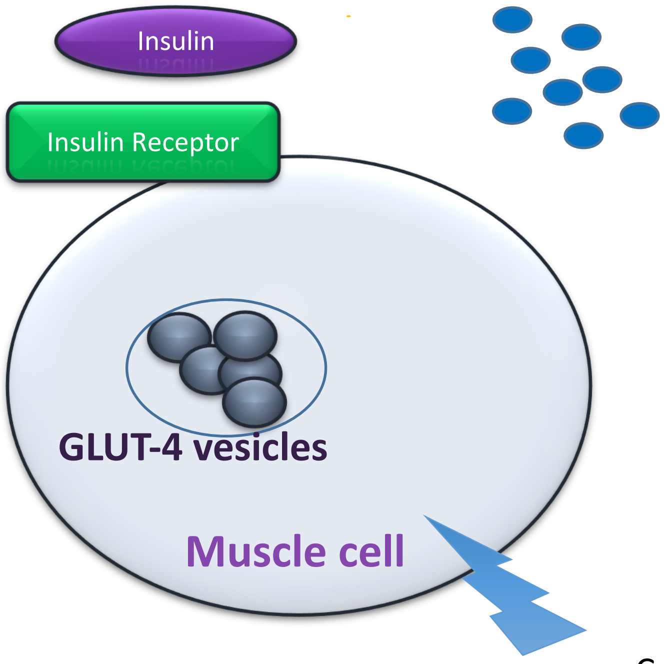

GH/Cortisol
EPI/NE
Ketones
Glucose
Glycogen
FFA
Insulin
Glucagon

# Both Insulin and Contraction Increase Glucose Uptake Into Skeletal Muscle Via Distinct Mechanisms





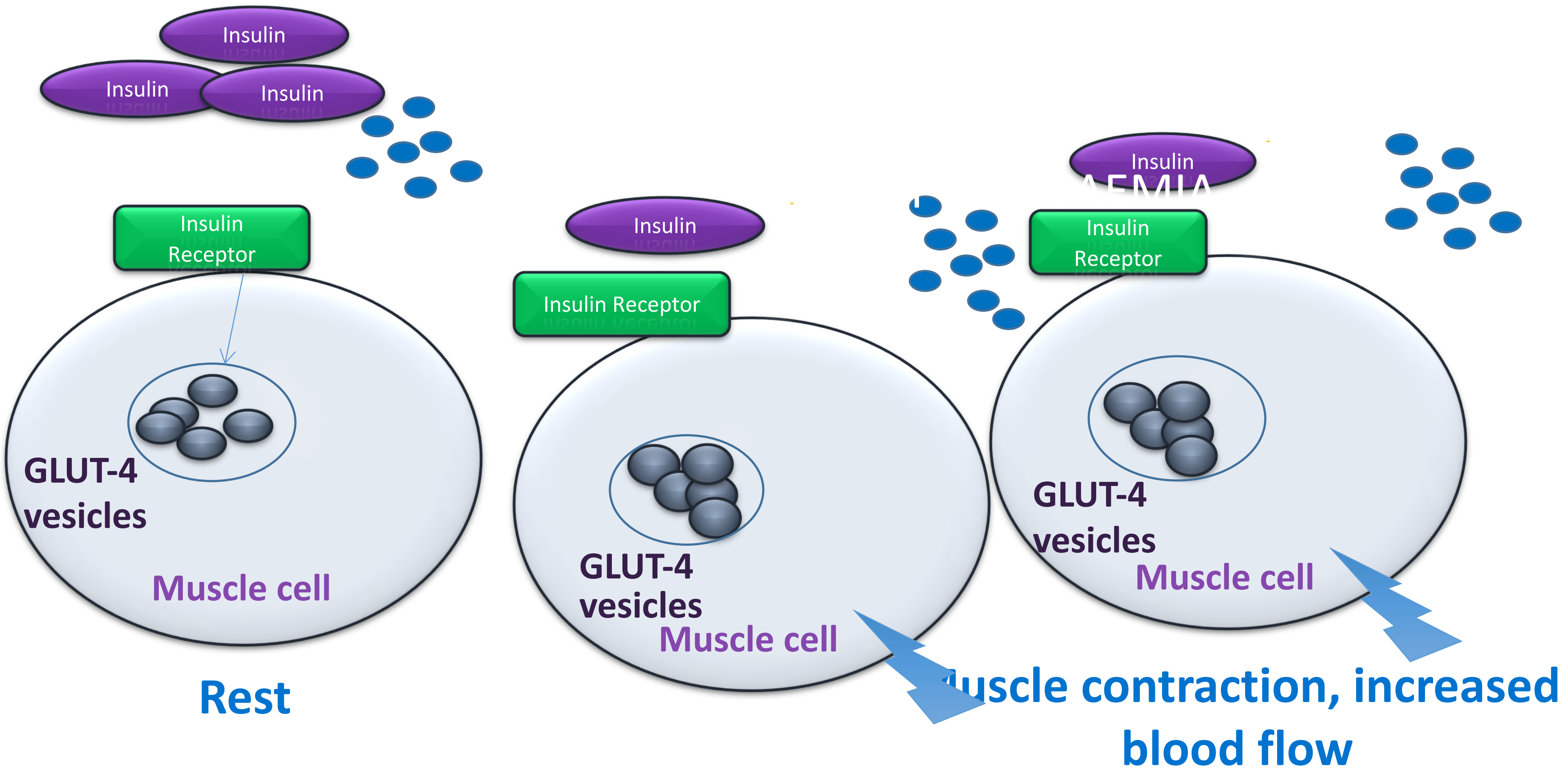



Courtesy M Riddell 2017

# Both Insulin and Contraction Increase Glucose uptake into muscle

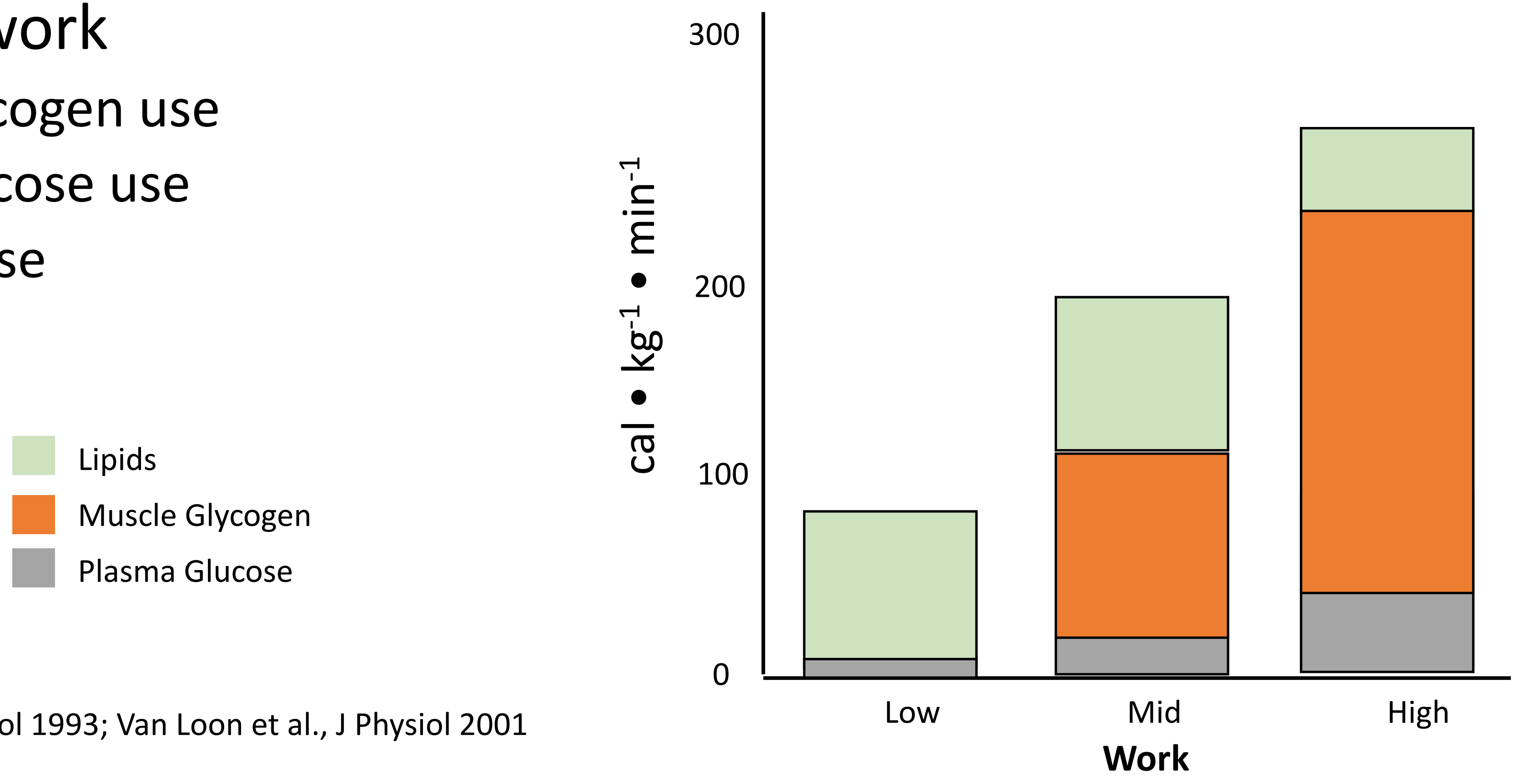





Courtesy M Riddell 2017

# Fuel Use changes with Intensity

- Increased work
  - More glycogen use
  - More glucose use
  - Less fat use



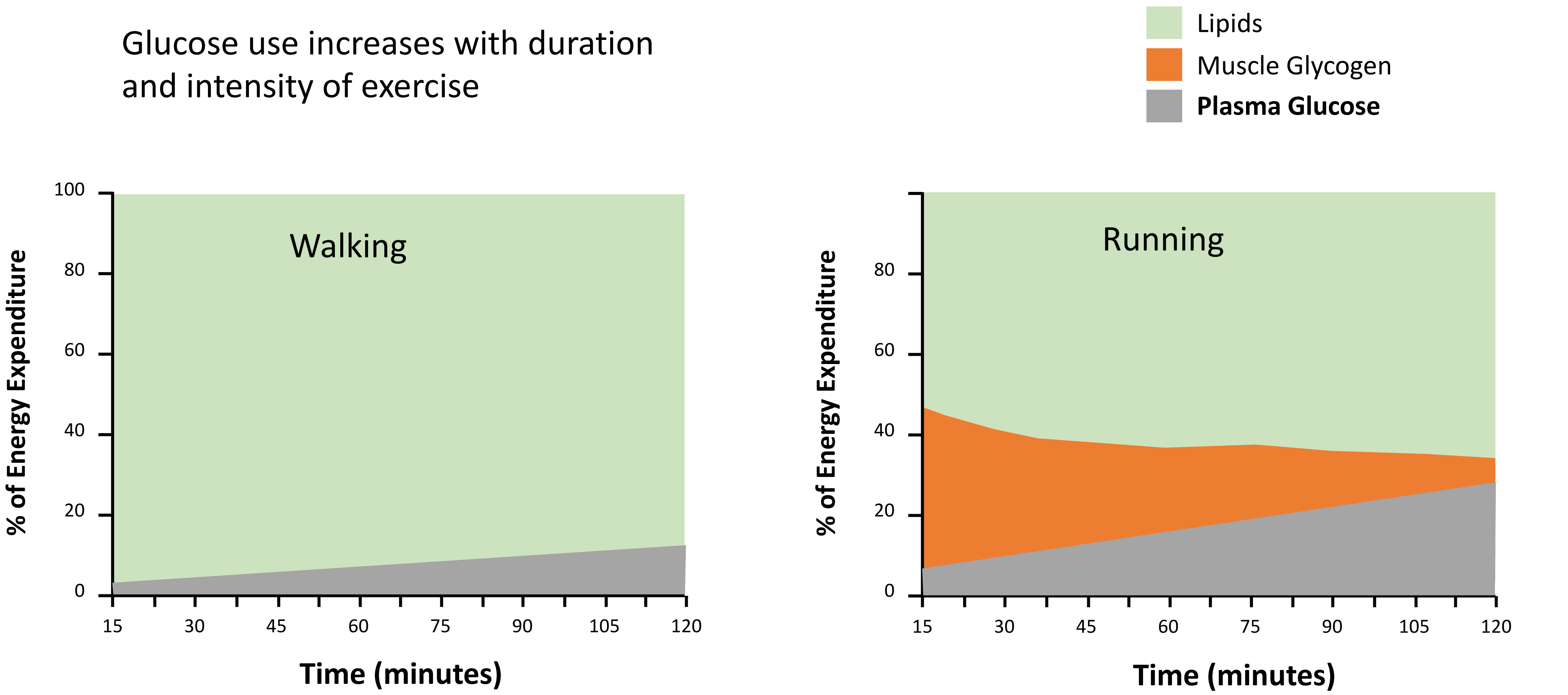

Romijn et al., Am J Physiol 1993; Van Loon et al., J Physiol 2001

# Prolonged exercise increases glucose use





Glucose use increases with duration and intensity of exercise

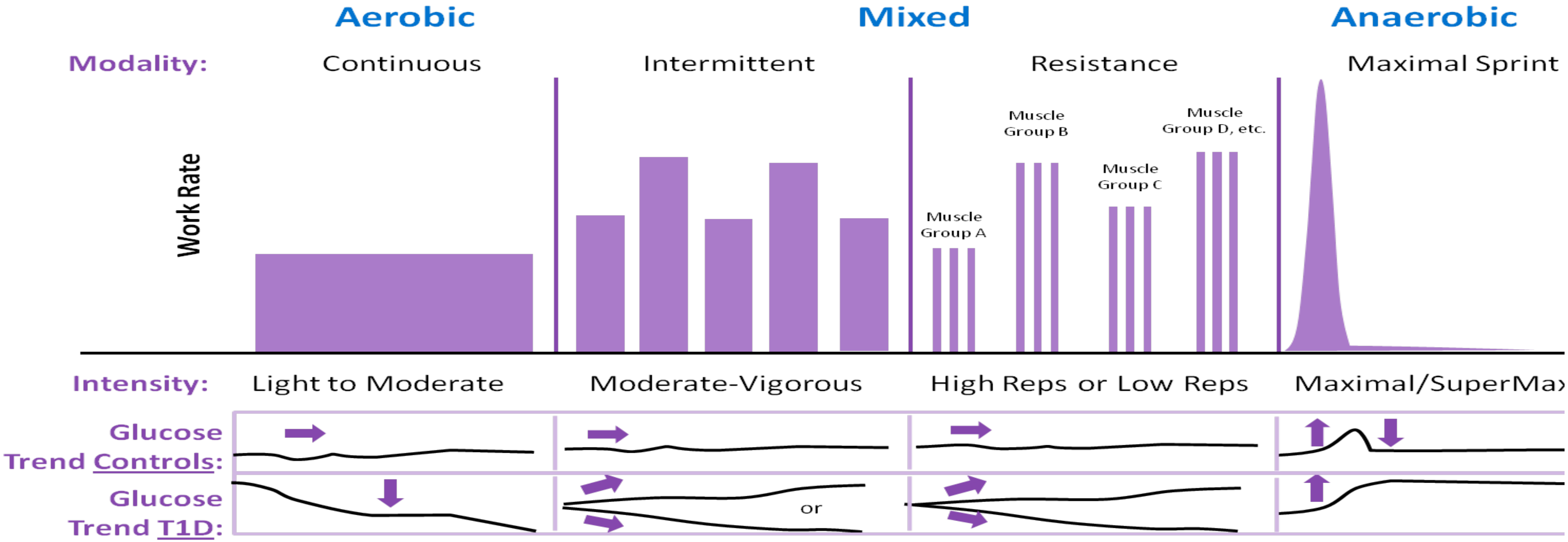



Romijn et al., Am J Physiol 1993; Van Loon et al., J Physiol 2001

# Summary of normal metabolic response to exercise

- Muscle energy source
  - uses ATP from CP initially
  - Then Glucose from muscle Glycogen
  - Then glucose from liver glycogen
  - The glucose from gluconeogenesis
- With prolonged aerobic metabolism, FFA and Ketones are the main fuel
- With increasing intensity and duration, glucose use increase
- These are mediated by falling insulin, increasing glucagon, and for intense exercise increase catecholamines and later Growth hormone
- **This has significant implications for people with T1DM**

# Glycaemic response with types of exercise

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# Endocrine imbalance seen in T1DM during exercise





## A. Euglycaemia

- ↓ Insulin
- ↑ counterregulation (glucagon, growth hormone, cortisol, catecholamines)

## B. Hypoglycaemia

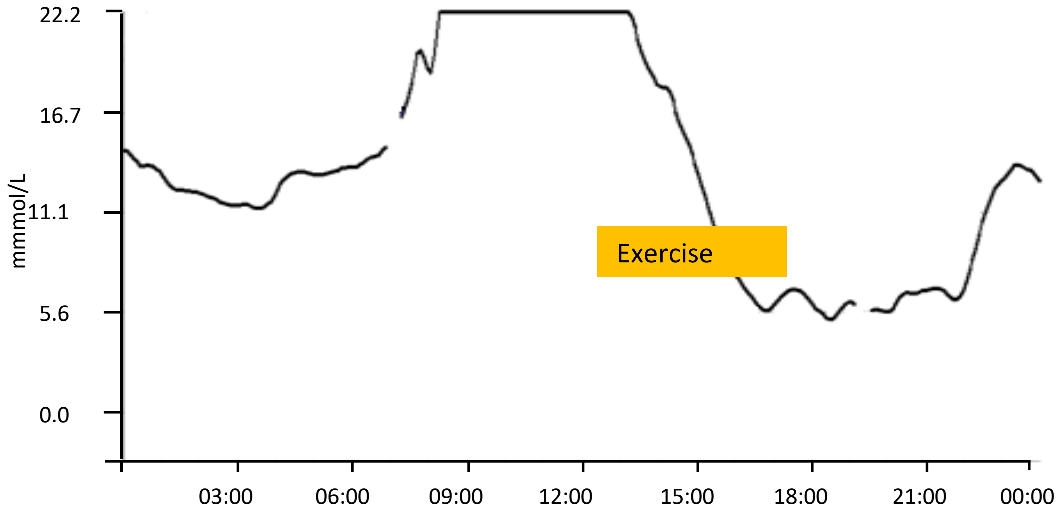
- Relative hyperinsulinaemia
- Impaired counterregulation

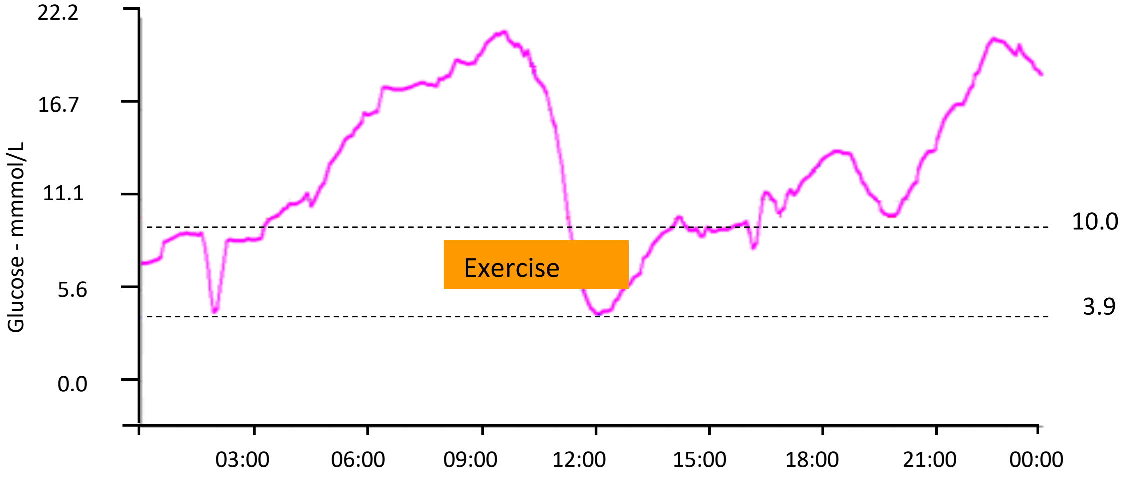
## C. Hyperglycaemia

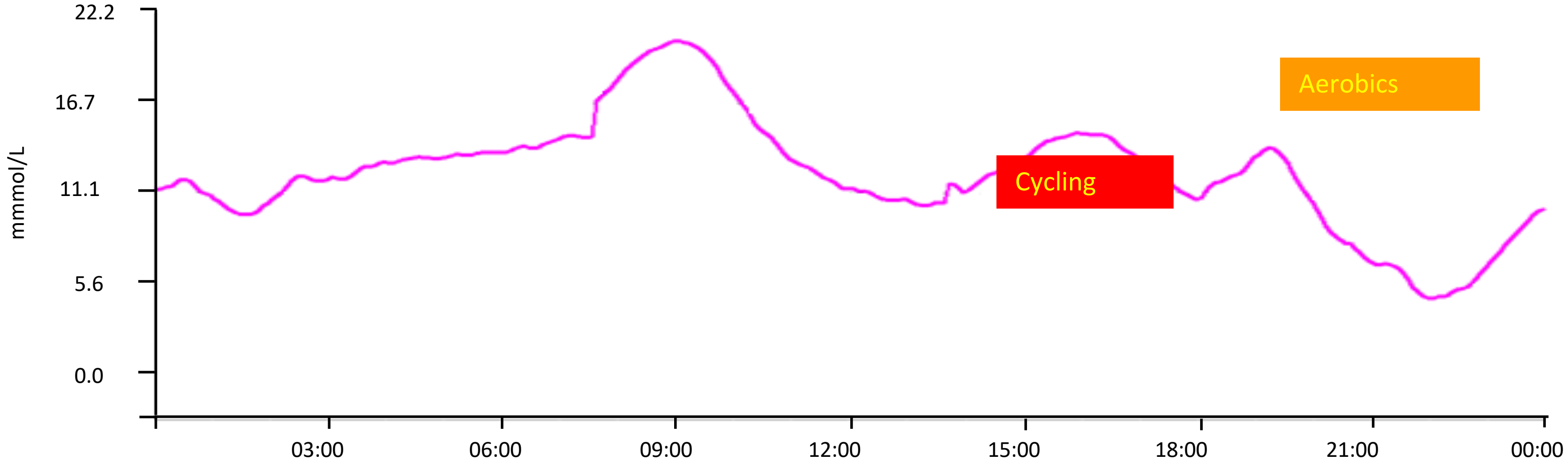
- Relative hypoinsulinaemia
- ↑Catecholamines
- Anaerobic metabolism (lactate production)

Courtesy M Riddell

# What Happens to Blood Glucose in Exercise in Type 1 Diabetes?




Data from Buckinghamshire Hospitals Diabetes Sports clinic



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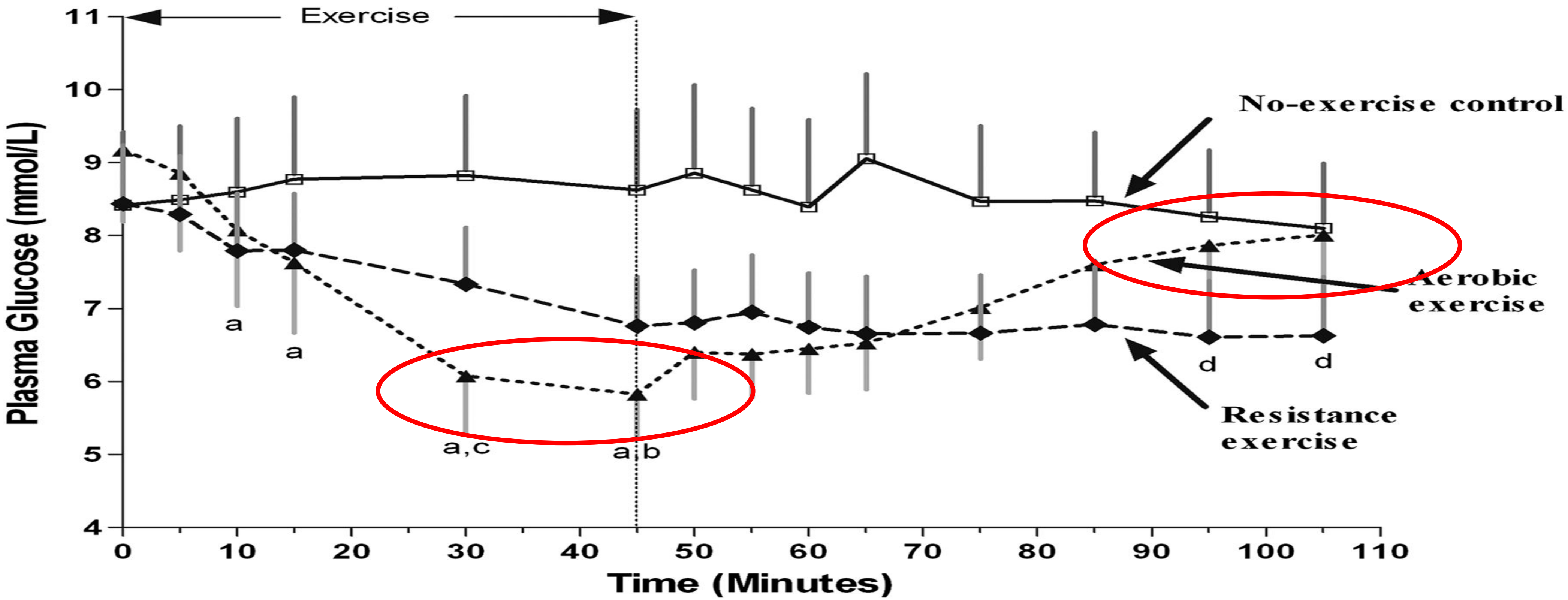
# Different forms of exercise cause different blood glucose responses





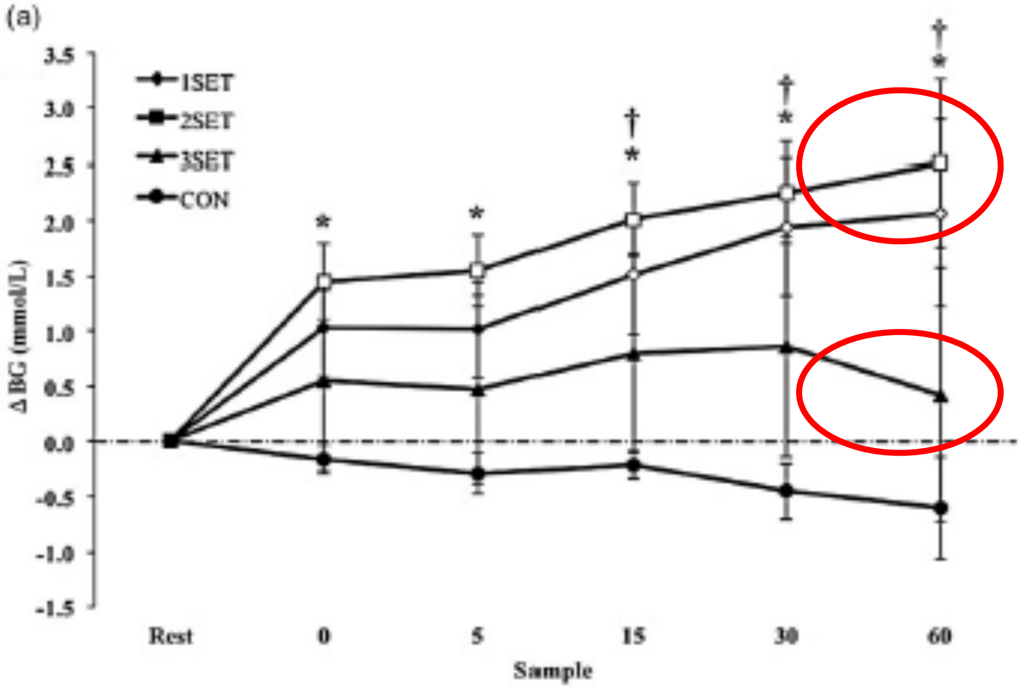


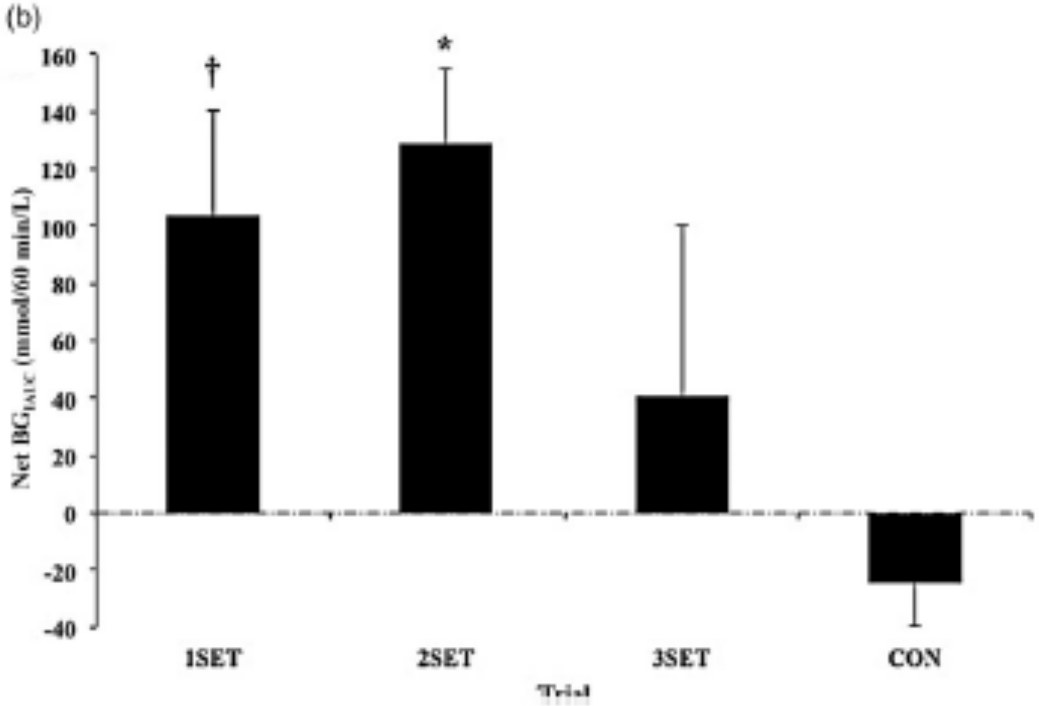

**Mean ± SE plasma glucose during the experimental sessions (represented by box) and 60 min of recovery (n = 12 for aerobic exercise and no-exercise control; n = 11 for resistance exercise). □, no-exercise control; , resistance exercise, ▲, aerobic exercise. A Statistically significant change from baseline in aerobic exercise. B Statistically significant change from baseline in resistance exercise. C Statistically significant difference between no-exercise control session and aerobic session.**

**dStatistically significant change throughout recovery after aerobic exercise.**

# Repeated resistance exercise has different effects on glucose

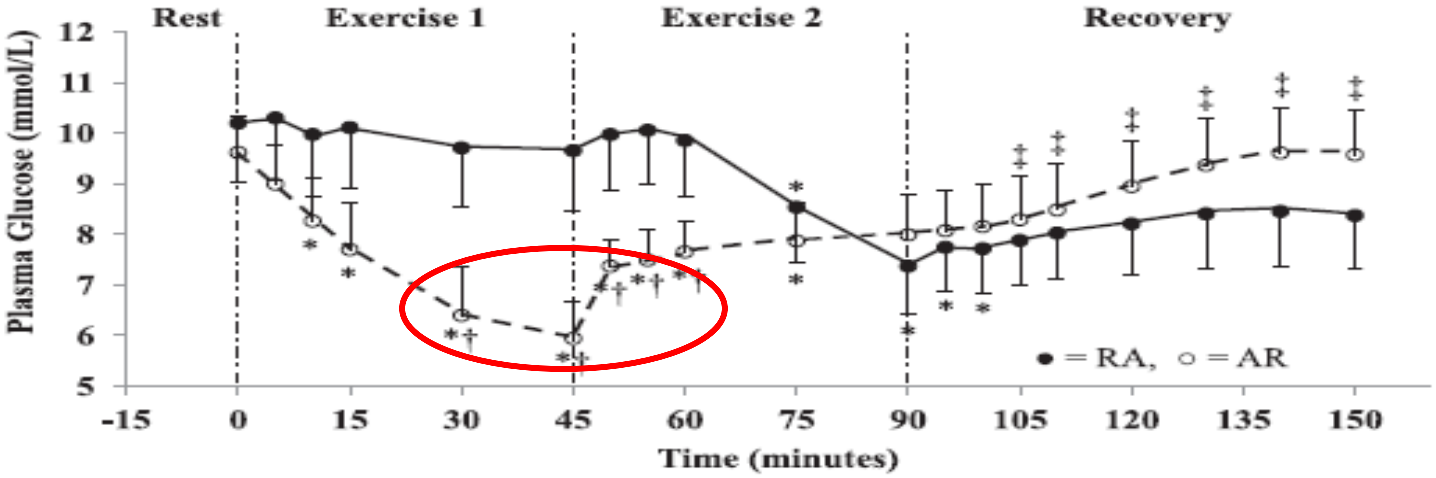




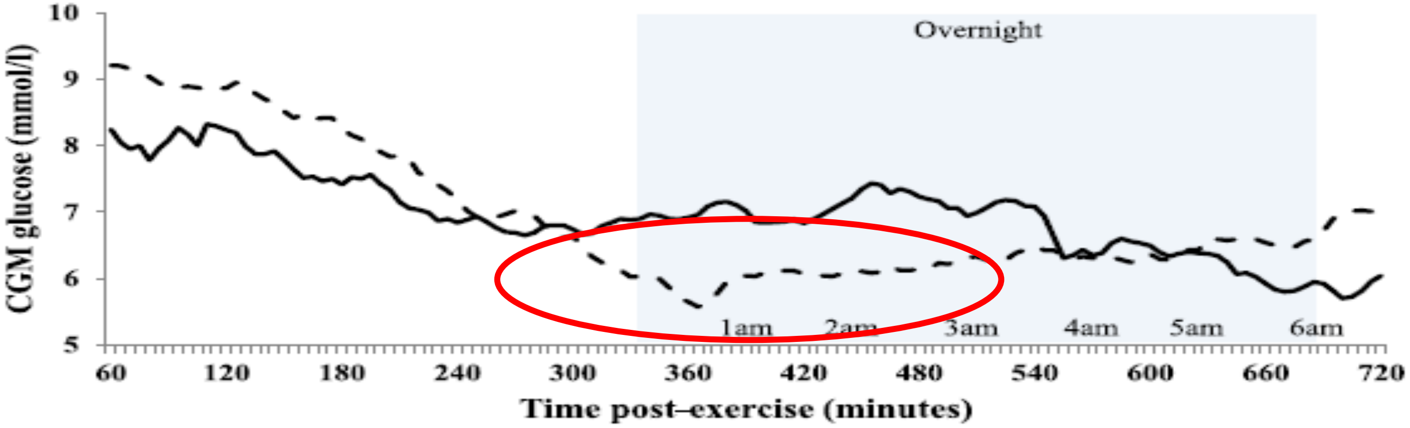

Tuner et al. Scan J. Med Sci 2014

# Glucose levels during and following different forms of exercise




Aerobic first

Resistance first




Aerobic first

Resistance first

*Diabetes Care* 35:669–675, 2012





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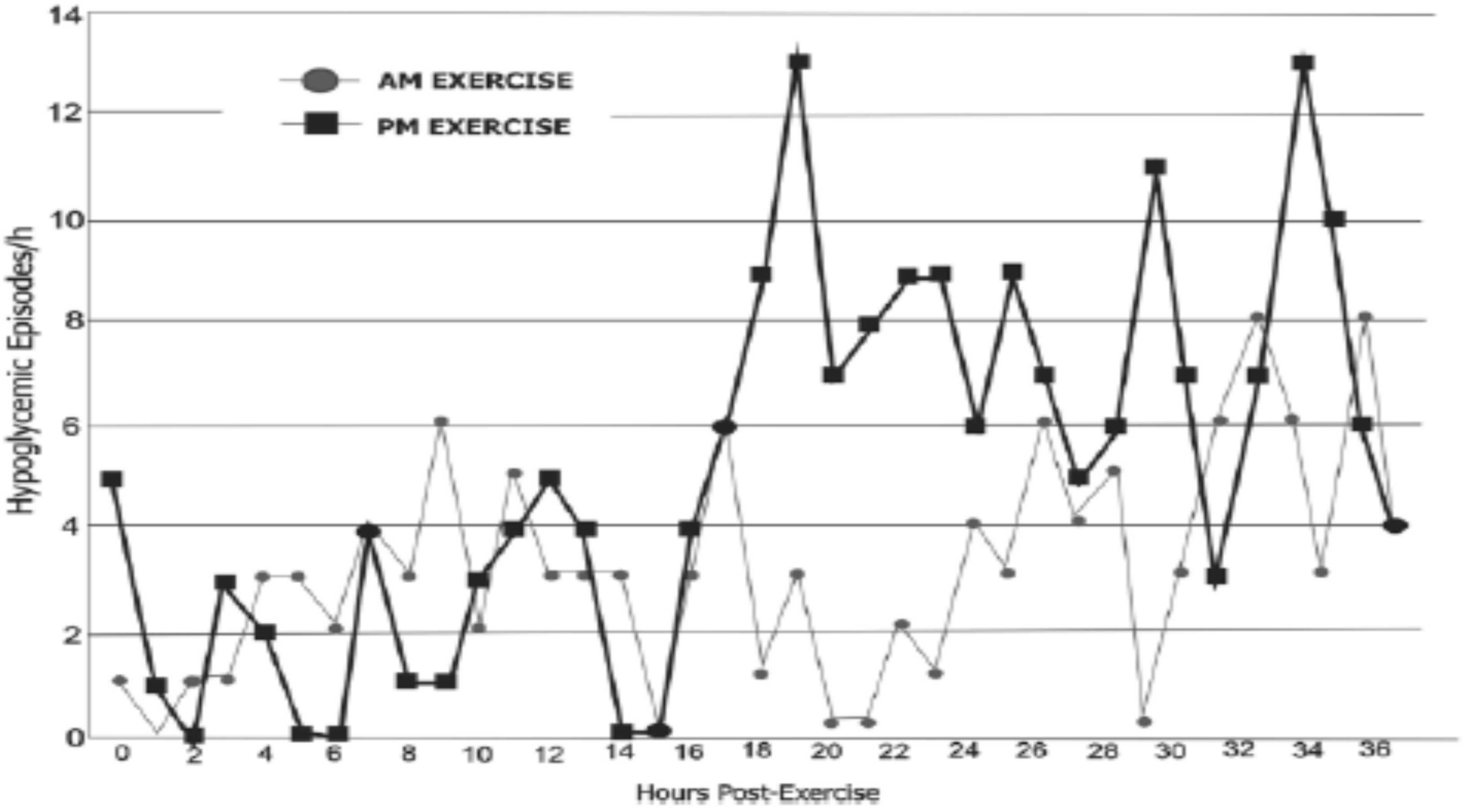
# Likelyhood of further hypoglycaemia following morning or afternoon exercise








Journal of Diabetes Science and Technology
2015, Vol. 9(3) 619–624

# Effect of high or low intensity exercise on blood glucose in T1DM



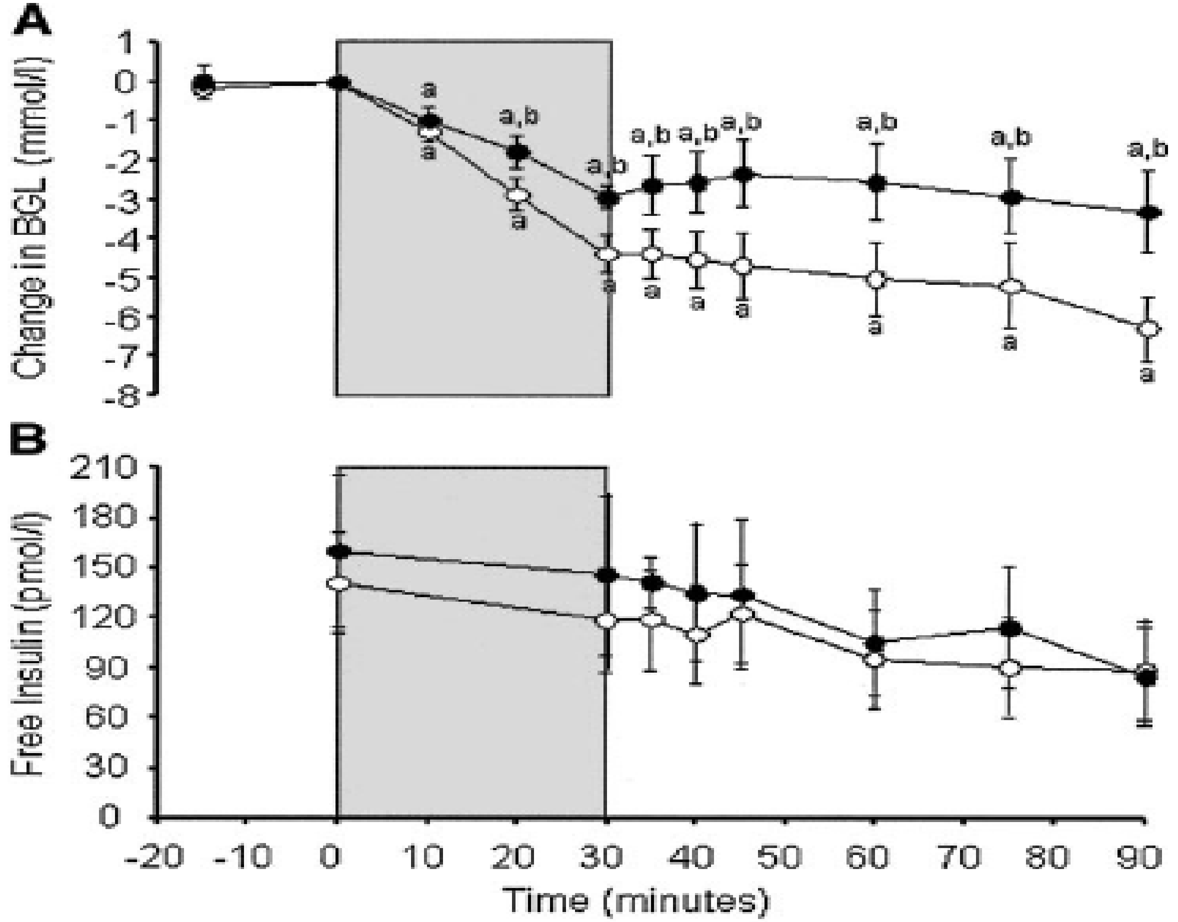



**Figure 1**—*Effect of 30 min (represented by box) of IHE (■) or MOD (□) on normalized blood glucose levels (A) and free insulin levels (B). Results are expressed as means ± SE.* [a]*Statistically significant difference (P < 0.05) from resting.* [b]*Statistically significant difference (P < 0.05) between IHE and MOD.*

Diabetes care
Vol 28:6 June 2005



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# Delayed hypoglycaemia CGMS following exercise in T1DM

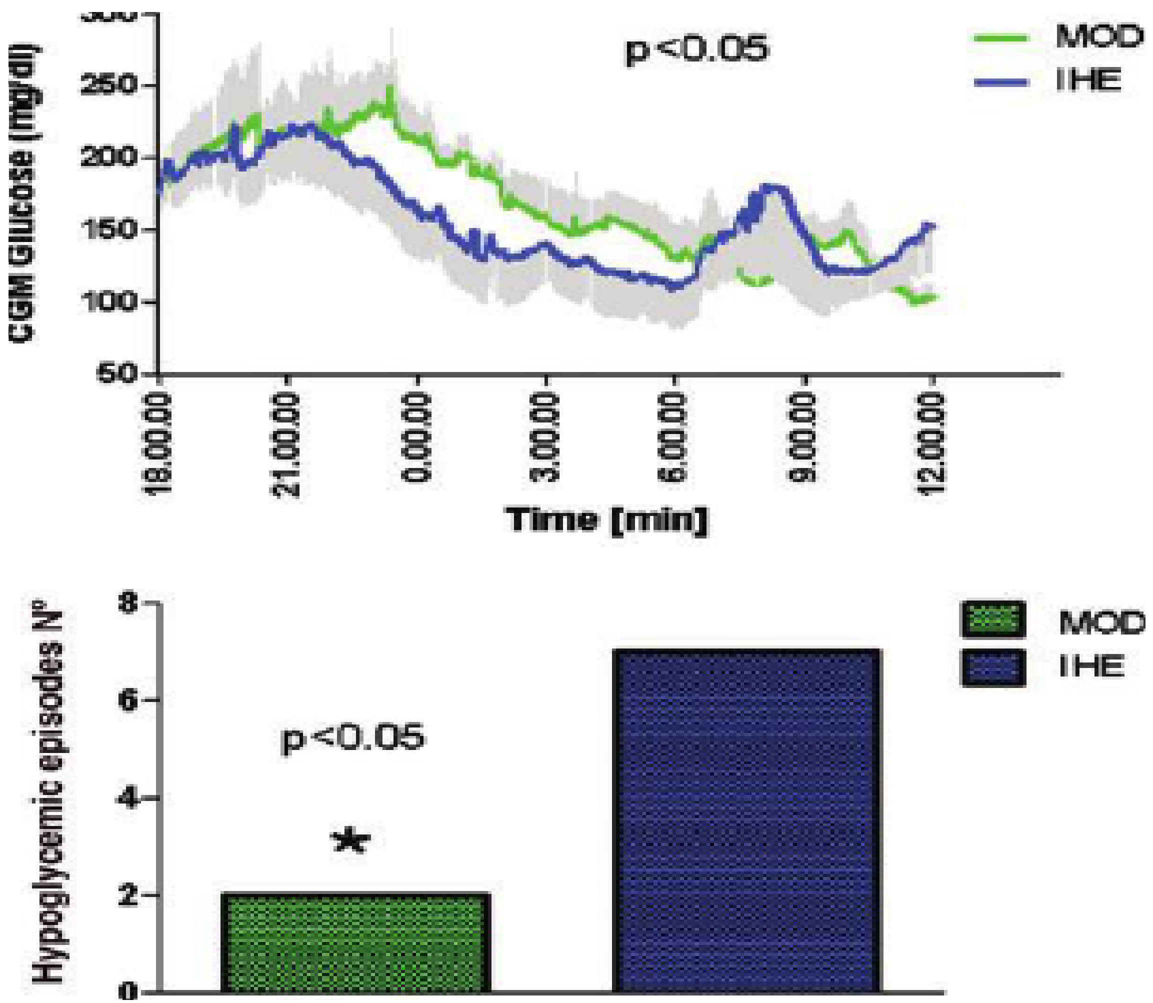
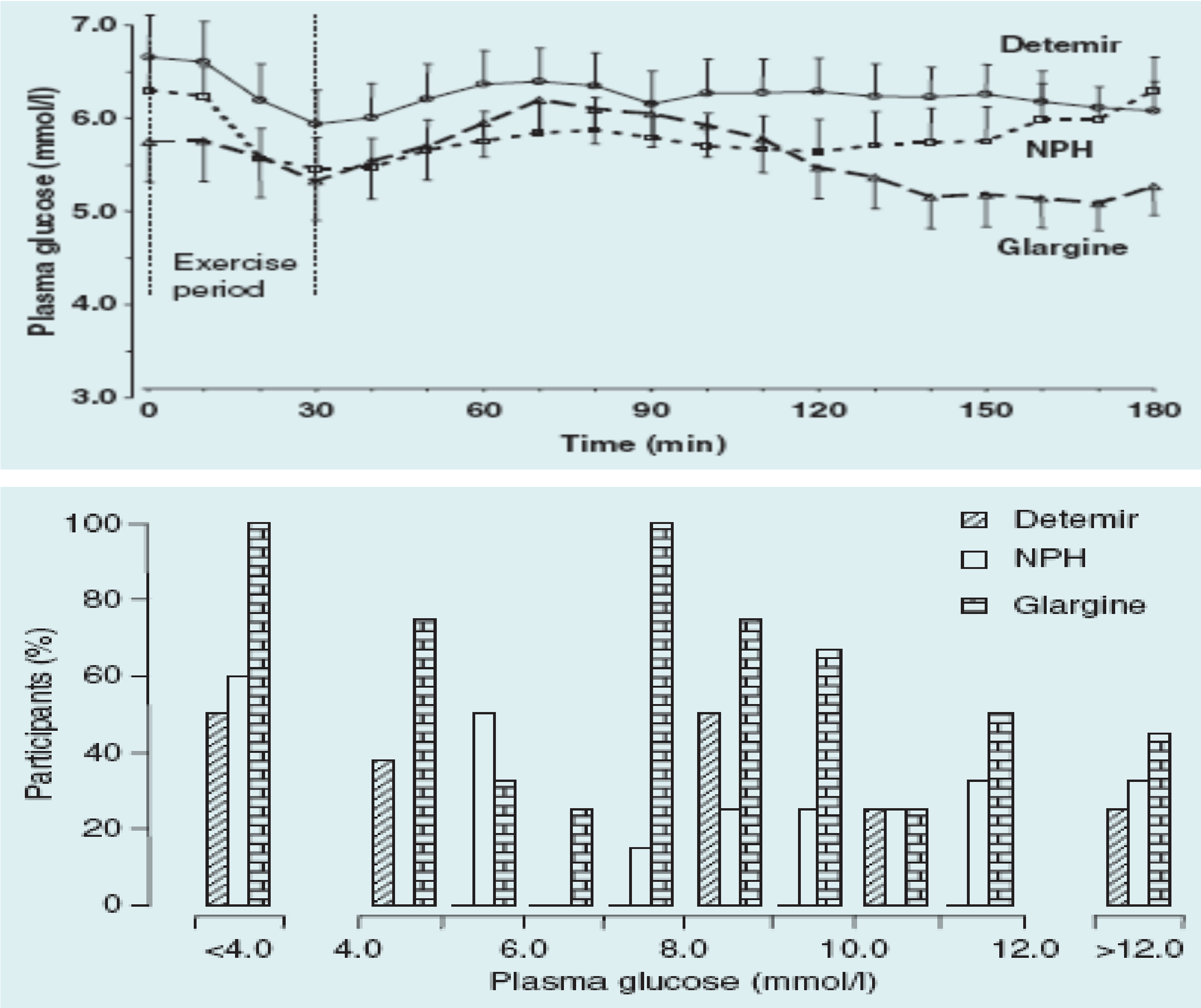



FIG. 4. Interstitial plasma glucose assessed by continuous glucose monitoring (CGM) (upper panel) and of hypoglycemic episodes during moderate intensity exercise (lower panel) after moderate-intensity exercise (MOD) (green line/bar) and during intermittent high-intensity exercise (IHE) (blue line/bar). Data are mean ± SEM values. Color images available online at www.liebertonline/dia.

DIABETES TECHNOLOGY & THERAPEUTICS
Volume 12, Number 10, 2010

# Hypoglycaemia seems to be more common with Glargine  than either NPH or Detemir

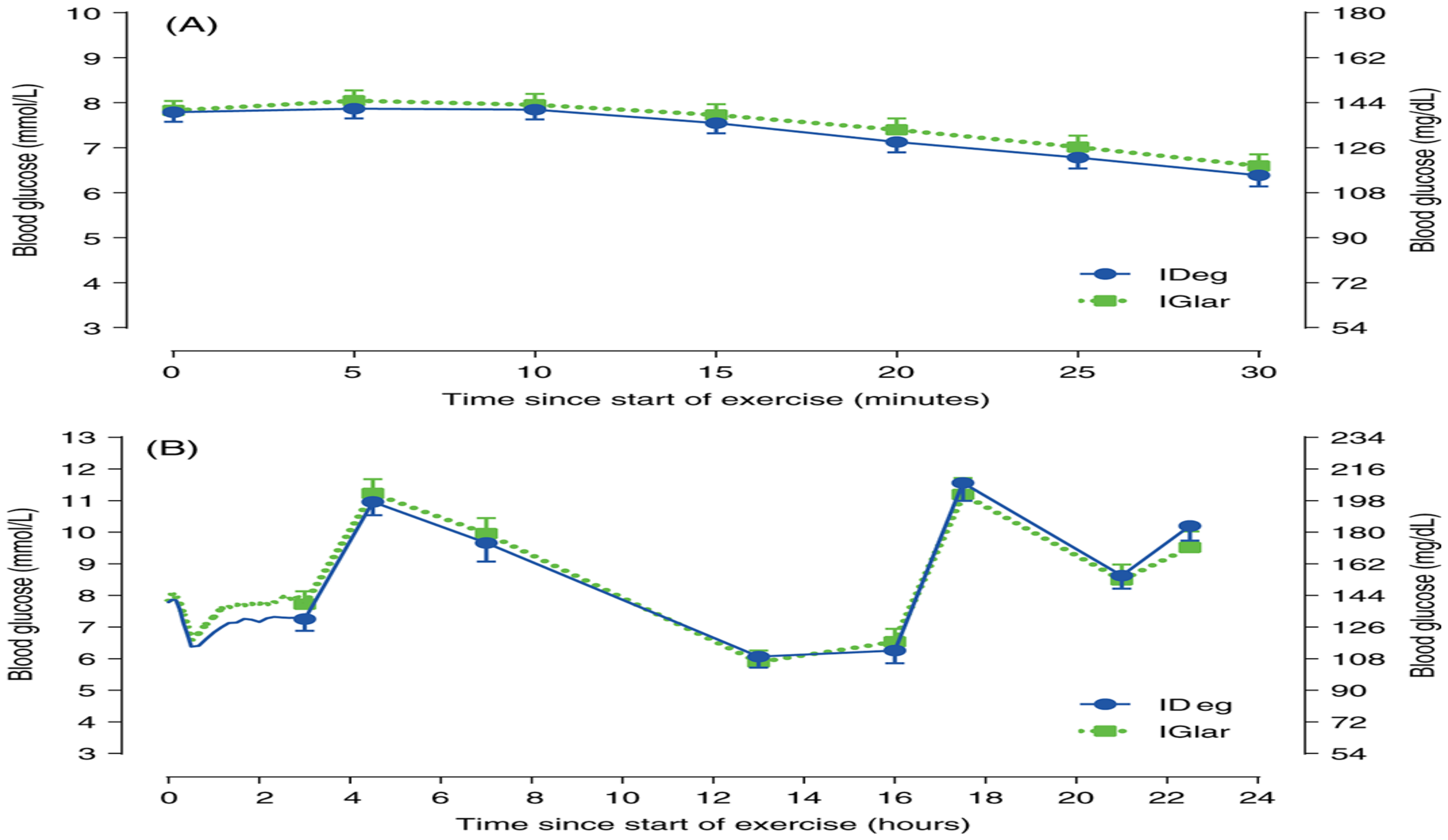





51 patients

**Diabetic Medicine** Volume 26, Issue 10, pages 1027-1032

# Hypoglycaemia with longer acting analogue basal insulin




Diabetes Obes Metab. 2016 Feb;18(2):196-9.

# Effects of exercise on blood glucose

- Aerobic/sub maximal exercise causes blood glucose to fall rapidly
- Intense exercise causes blood glucose to rise
- Aerobic/sub maximal exercise increases risk of nocturnal hypoglycaemia
- Repeated resistance exercise causes blood glucose to fall
- Intermittent high intensity exercise protects against hypoglycaemia during exercise, but is more likely to cause nocturnal hypoglycaemia
- Team sports have variable effect on glucose depending on position and intensity of play

# ?Macdonald's syndrome Late –onset hypoglycaemia following exercise





TABLE 1
Summary of characteristics of 48 patients who experienced late-onset hypoglycemia after play or exercise

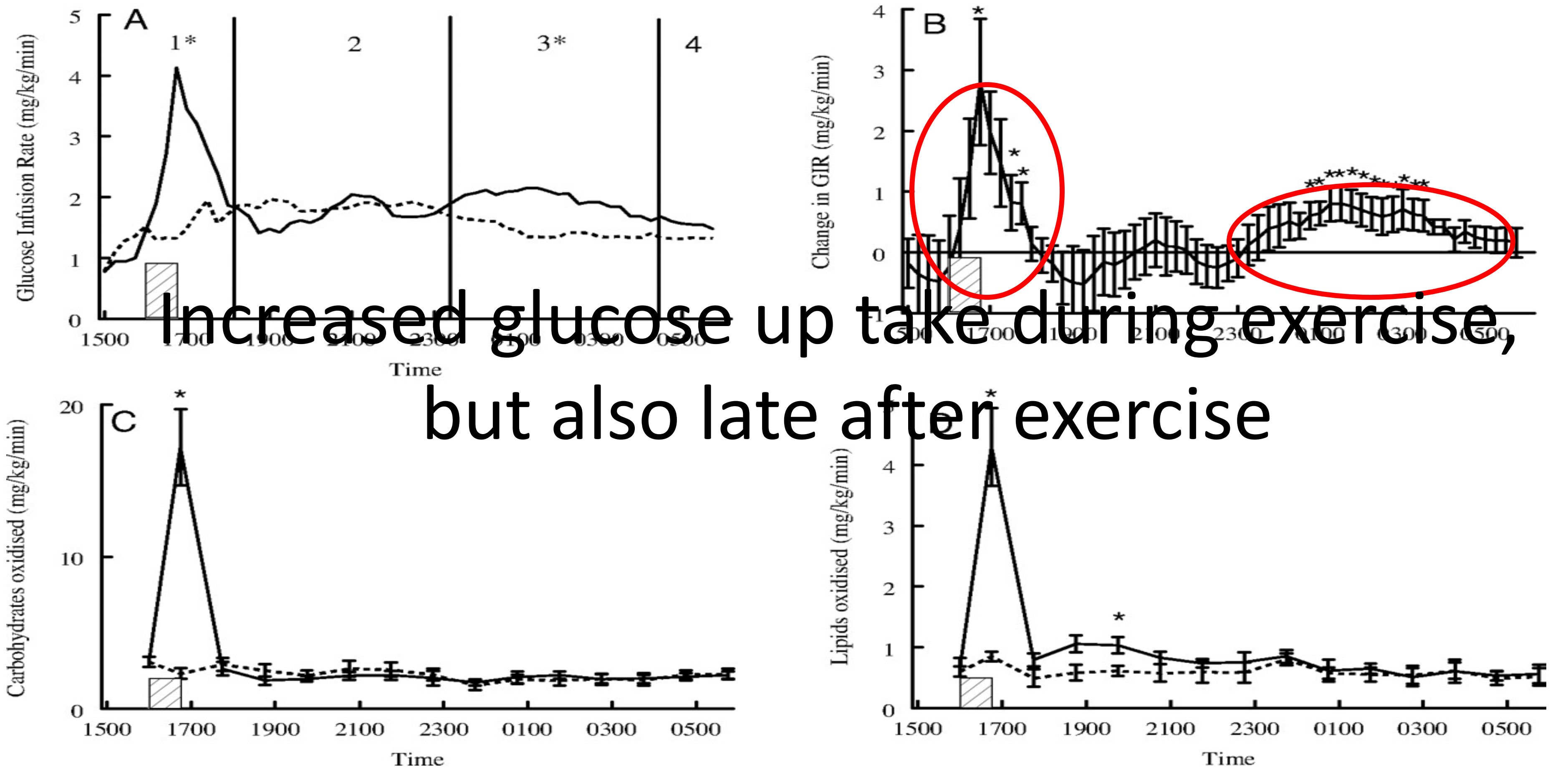
| Characteristic | Comments |
|---|---|
| Age (yr) | Mean ± SD 12.15 ± 4.67, median 13, range 4–24 |
| Duration of diabetes (yr) | Mean ± SD 5.1 ± 3.7, median 5, range 0.1–14. |
| Total daily insulin dose (U/kg body wt) | Mean ± SD 0.98 ± 0.37, median 0.9, range 0.2–2.0 |
| Interval between end of exercise and hypoglycemia (h) | Mean ± SD 9.9 ± 3.7, median 11, range 3–31 |
| $HbA_1$ at time of hypoglycemia (%) | Mean ± SD 9.9 ± 1.5 ($n$ = 46), median 9.9, range 6.9–14.2 |
| Sex distribution | 26 boys, 22 girls |
| Time of day exercise ended | Between 1500 and 2000 h ($n$ = 47) |
| Time of day of hypoglycemia | Between 2000 h and midnight in 10 patients, between 0100 and 0800 h in 36 patients, and after 0800 h in 2 patients |
| Severity of hypoglycemia | Moderate in 16 patients; stupor, coma, and/or seizure in 32 patients |
| Treatment | 22 patients received glucagon, 17 were treated in a hospital emergency room, and 11 received intravenous glucose |
| Types of exercise | Vigorous playing (15), basketball (6), swimming (6), running (5), bicycling (4), roller or ice skating (4), skiing (2), dancing (2), football (2), garden work (2), walking (2), hiking (2), sledding (1), baseball (1), cutting wood (1), ice fishing (1), jumping rope (1), shoveling snow (1), riding a horse (1), calisthenics (1), sailing (1), and tennis (1); many activities were combined with others |
| Insulin plans | 32 patients used morning and evening short- and intermediate-acting insulin, 11 patients used little or no evening and night insulin coverage, 3 patients used subcutaneous insulin infusion, and 2 patients used ≥3 injections/day |
| Metabolic control | Recent improvement in metabolic control or tight control did not explain hypoglycemia; $HbA_1$ was judged as excellent (<9.0%) in 13 patients, good (9.0–9.9%) in 13 patients, fair (10.0–10.9%) in 12 patients, and poor (≥11.0%) in 9 patients |

DIABETES CARE, VOL. 10 NO. 5, SEPTEMBER-OCTOBER 1987

# Biphasic response in glucose requirement with exercise





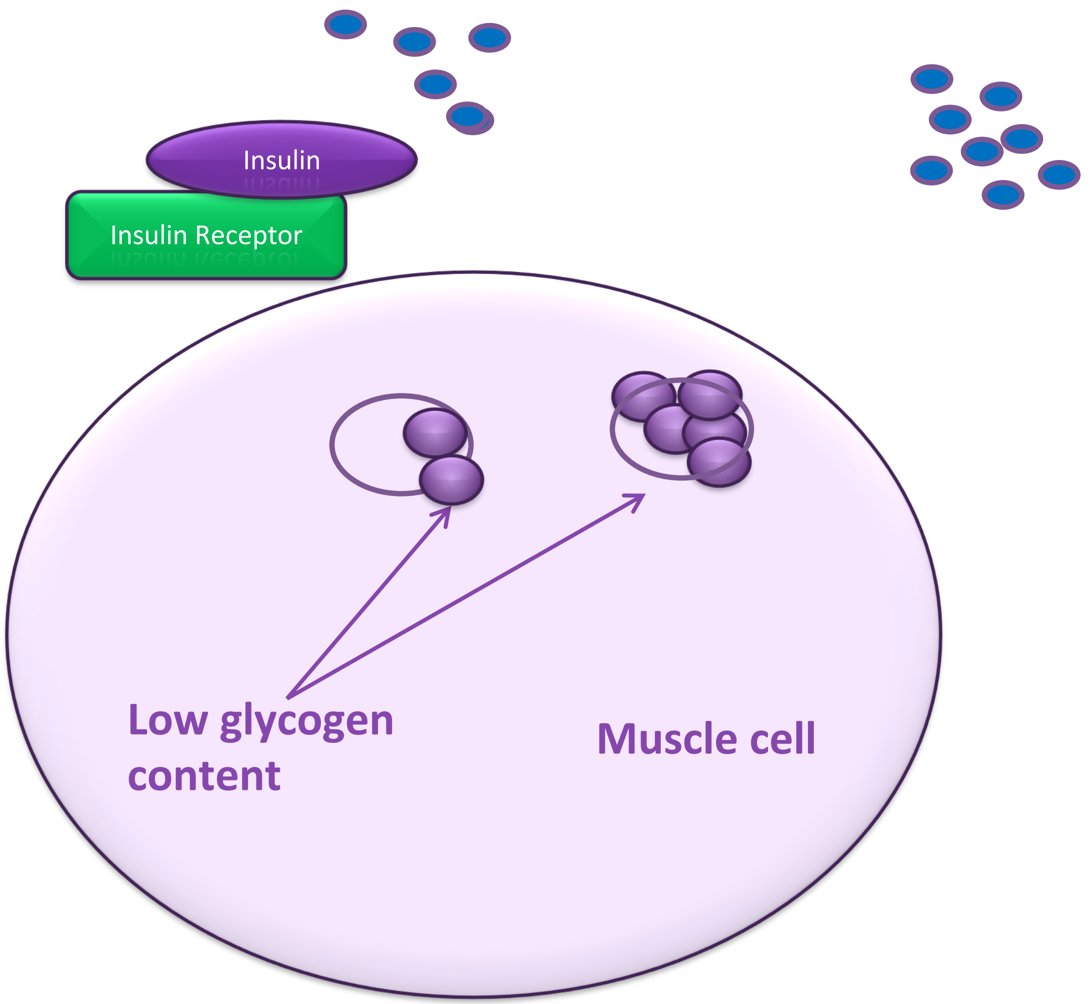



Increased glucose up take during exercise, but also late after exercise

Responses of glucose infusion rate (mg/kg{middle dot}min) (A), difference in glucose infusion rate (GIR) between exercise and rest studies (mg/kg{middle dot}min) (B), rate of carbohydrate oxidation (mg/kg{middle dot}min) (C), and rate of lipid oxidation (D) to exercise (solid lines) and rest (dashed lines) studies

# Increase glucose uptake after exercise increases risk of nocturnal hypoglycaemia





# Things to consider before exercise

- What type of exercise is it?
  - Will blood glucose go down or up?
  - Which order shall I do the exercise?
- How close is exercise to the last meal injection?
  - Will meal injection still be working?
- Does basal pump infusion rate need to change?
  - Is the rate too high for exercise?
- Has there been a hypo in the last 24 hours
  - Is it safe to exercise?
- What is the blood glucose value before exercise?
  - take extra glucose, or exercise less hard, or bolus insulin?