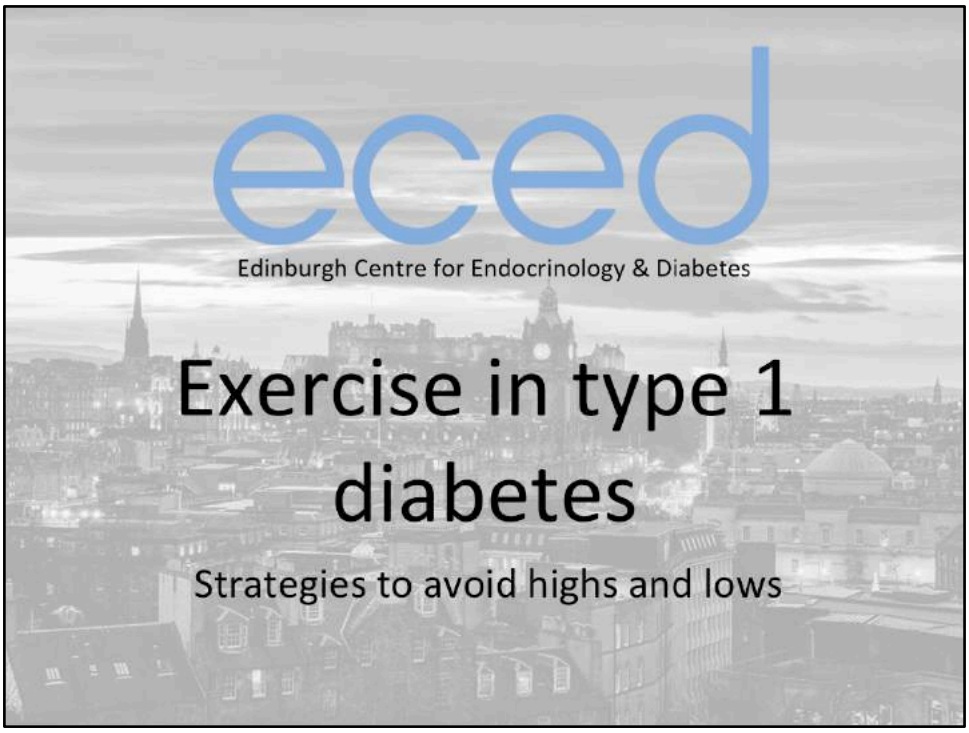
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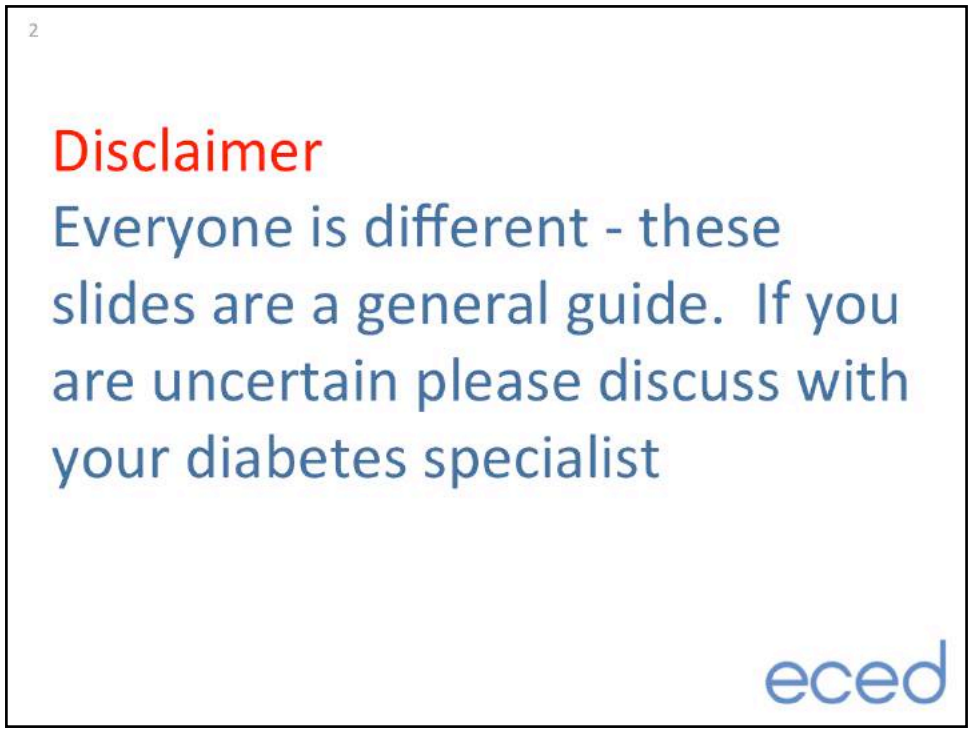
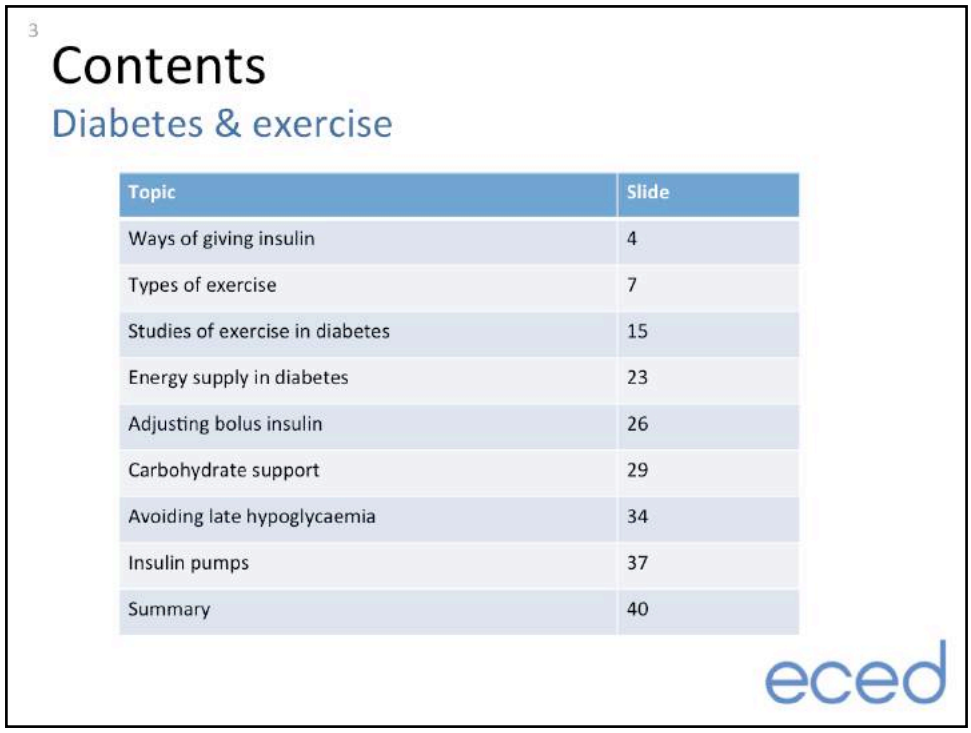
Edinburgh Centre for Endocrinology & Diabetes
Exercise in type 1 diabetes
Strategies to avoid highs and lows



The advice in these slides is based on extensive experience and research but, at an individual level, response to exercise will vary. It is important to check blood glucose regularly, to establish what your own response is, and also to see which of the strategies discussed here are most suited to the exercise you are doing.



If there is a specific issue you would like to focus on, feel free to skip to the relevant slides.

4

Introduction

Ways of giving insulin

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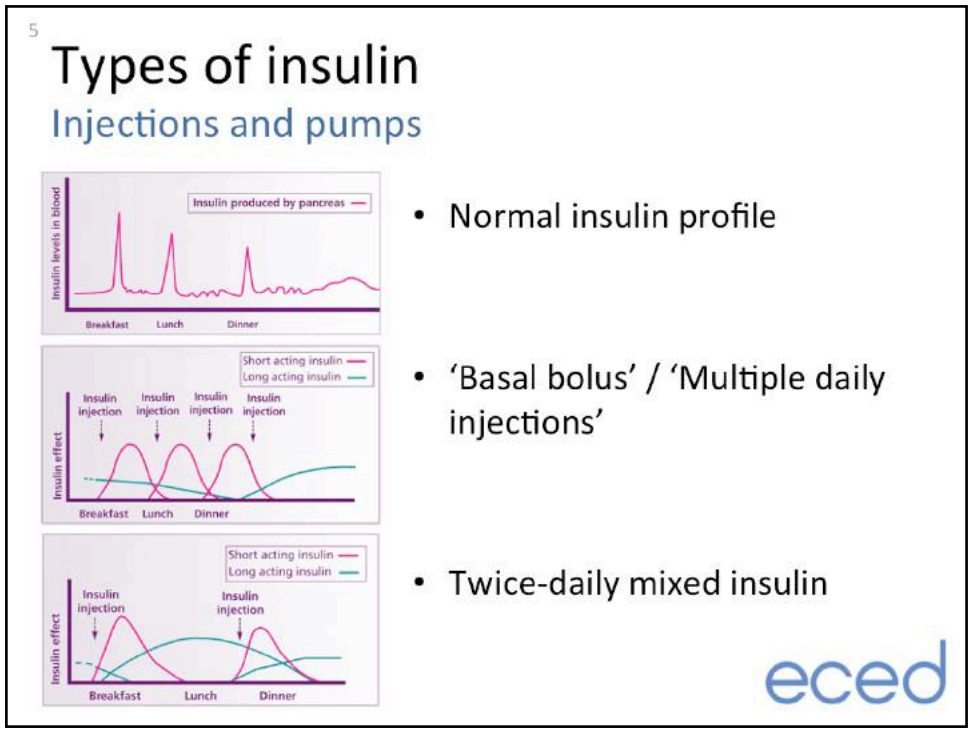


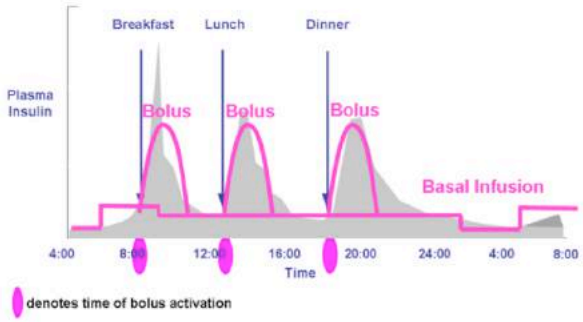
Most people with type 1 diabetes are on basal bolus insulin regimens, also known as multiple daily injections (MDI). These are designed to mimic, as closely as possible, the pattern of insulin which is present in people who do not have diabetes: a low background level of insulin, punctuated by peaks of insulin secretion when food is ingested. With basal bolus insulin, the background cover is provided by long acting insulins, like lantus or levemir, which can be given once or twice a day. Twice-daily background is often better as it results in less variability and also allows targeted reduction of the background insulin following prolonged exercise. People on insulin pumps have similar insulin profiles to 'basal bolus' but have the added advantage of more flexible adjustment of their basal (background) insulin levels as this is provided by a constant infusion of quick-acting insulin. Very few people with type 1 diabetes are on twice-daily mixed insulins anymore – this is because this type of insulin delivery is much less flexible than MDI and pumps.

6

Types of insulin

Injections and pumps

- Insulin profile of a pump (continuous subcutaneous insulin infusion [CSII])



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People on pumps have the ability to adjust the basal rate – in the example this person has five different basal insulin rates. The pump delivers boluses of quick acting insulin with meals based on their carbohydrate content and also the current blood glucose level. Most people using pumps are able to take part in contact sports and the pump can be removed for short spells (e.g. during swimming).

7

Types of exercise

Aerobic and anaerobic

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8

What type of exercise should I do?

Type 1 diabetes

- Something you enjoy!
- Exercise is divided into two main types:
  - Aerobic – where you can talk, but not sing! Walking, cycling, jogging, swimming etc
  - Anaerobic – maximal effort which you cannot sustain: Weight lifting, sprints
- Many sports are a mixture
- Important because your body responds to each type differently

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9

Types of exercise

By how they feel

- Aerobic / Moderate Intensity
  - Jogging, swimming
- Anaerobic / Intense
  - Sprint running or swimming
- Mixed
  - Football, rugby, tennis
- Intense Aerobic
  - Middle distance racing, cycle/running with hills

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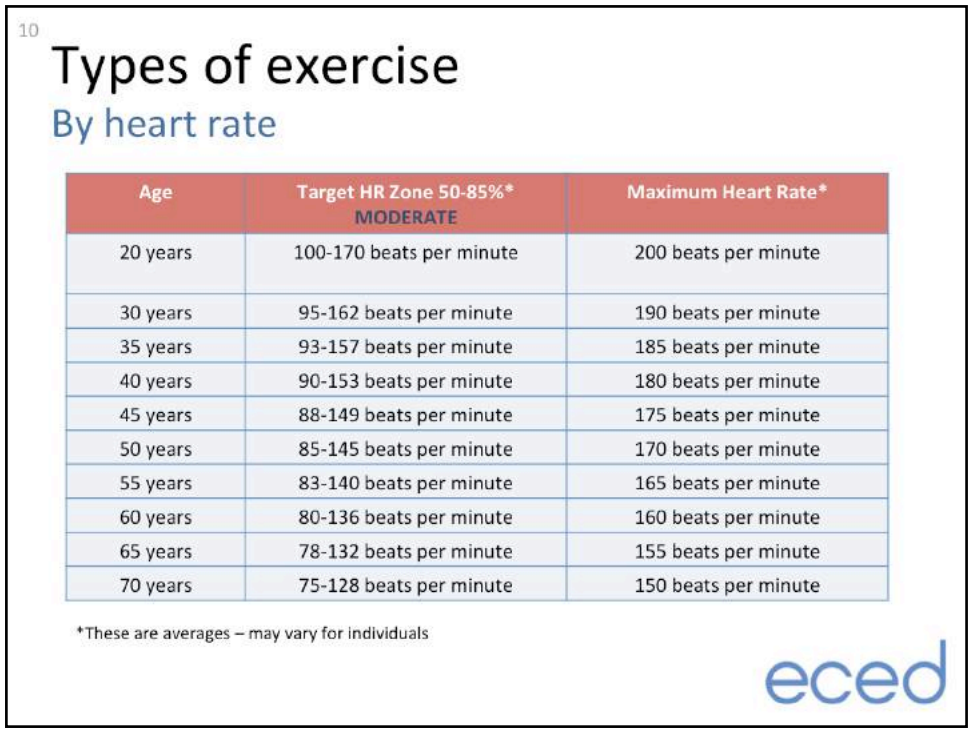

You can also classify types of exercise by the effect they have on your heart rate. The targets are different for each age bracket. Moderate intensity exercise is the type which raises your heart rate to between 50 – 85% of the maximum; so if you are 40 years old this is anywhere between 90 – 153 beats per minute.

11

Types of exercise

By %VO_2 max

- VO_2 max is the maximum capacity of an individual to consume oxygen and is a marker of aerobic physical fitness
- Target heart rates of 50 – 85% maximum are a level at which most people will be exercising aerobically
- Exercise more strenuous than this tips over the 'anaerobic threshold' – this is different for everyone and is higher in elite athletes

- Studies quoted later on exercise people to 40% of their maximum VO2 – this is aerobic

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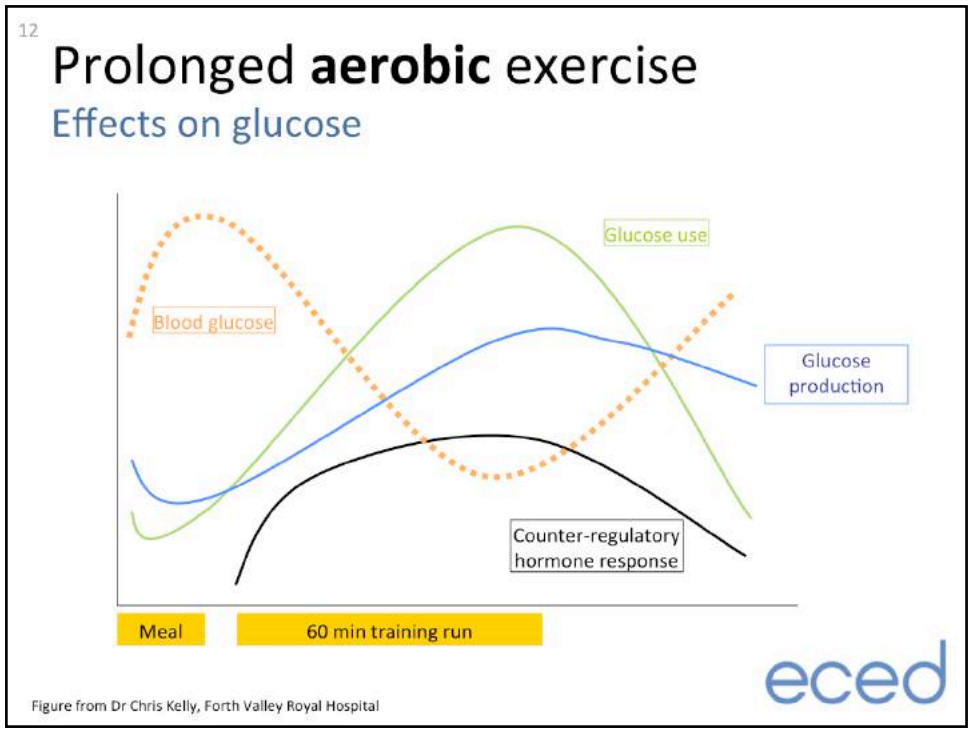
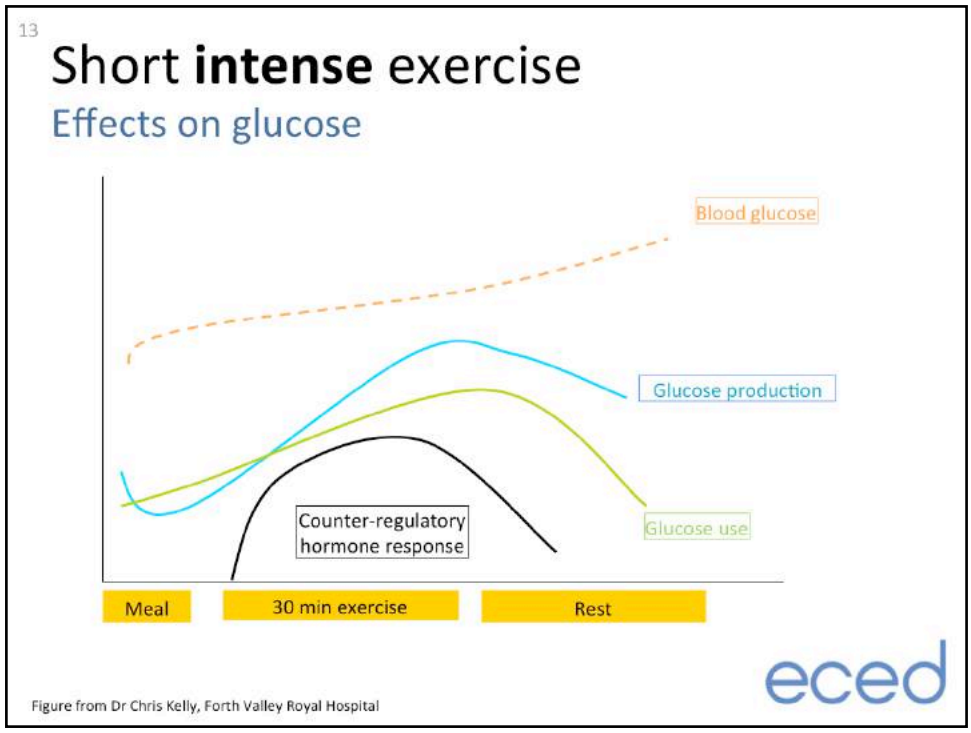


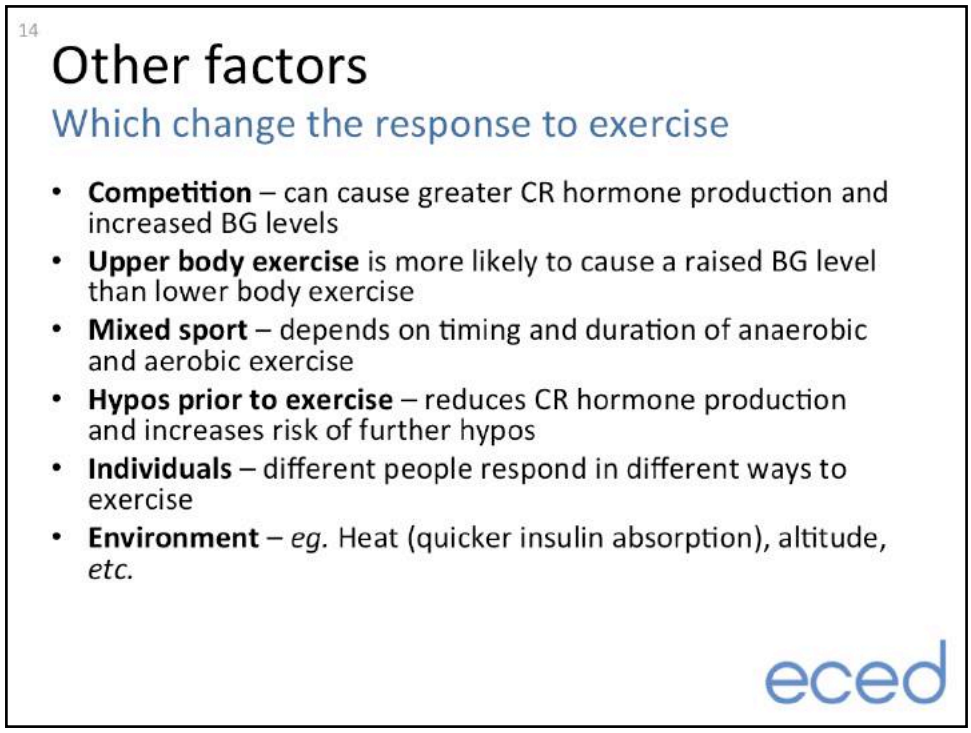
Prolonged aerobic exercise tends to cause a fall in blood glucose level – approximately 1mmol/10 minutes if no action is taken.
The fall in blood glucose is greater with increased duration and increased intensity of activity.
The fall in blood glucose is caused by glucose being used by contracting muscles at a greater rate than it can be produced by the liver.
This is because, in people with diabetes taking insulin, excess insulin prevents the liver from producing enough glucose to replace the glucose being used. In people who do not have diabetes, insulin levels drop automatically to allow the liver to produce glucose.

You can see on the figure here that because glucose use (in muscle – green line) is greater than glucose production (from liver – blue line) – blood glucose levels fall (orange line). 'Counter-regulatory hormones' are hormones which cause glucose to rise but they take a long time to act in aerobic exercise.



Short intense exercise (anaerobic) is different and can often cause blood glucose levels to rise. This is because anaerobic exercise uses less glucose and the counter-regulatory hormones (CR hormones) response is quicker and more marked. Hormones like adrenaline, glucagon, cortisol and growth hormone stimulate the liver and other organs to produce glucose.

You can see in the figure that due to the quick rise in counter-regulatory hormones, glucose production (liver – blue line) exceeds glucose use (muscle – green line) and so blood glucose levels rise (orange line).



Many factors can influence the individual's response to exercise.

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Studies in diabetes

Effects of exercise on glucose

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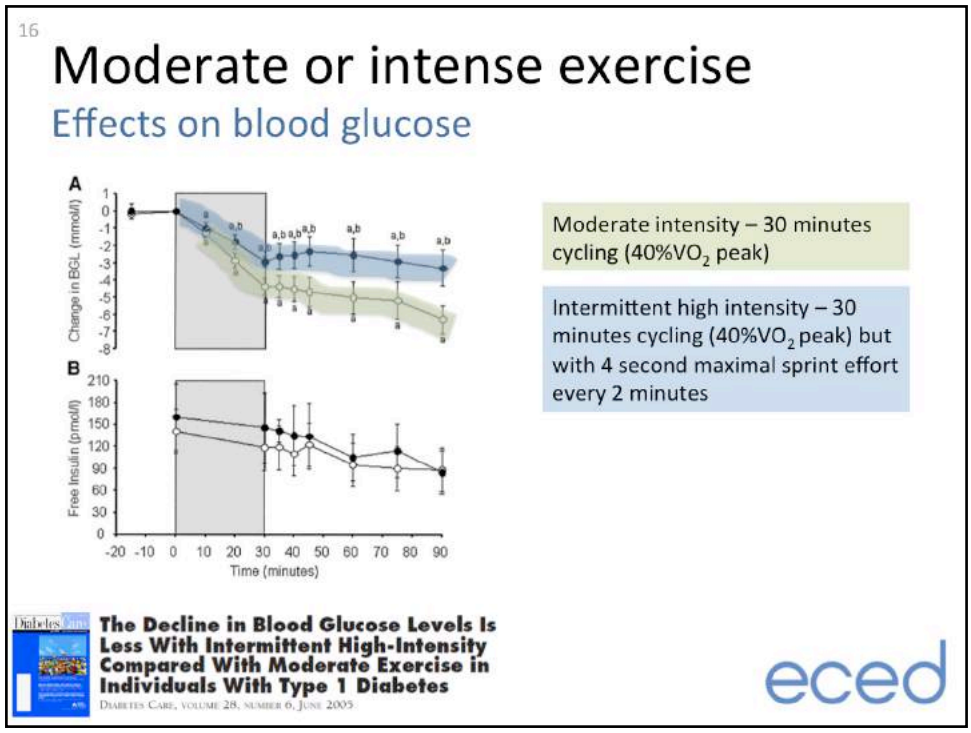


The chart to focus on here is the top panel (A) which shows blood glucose over time – the grey box is the 30 minute exercise period. People with type 1 diabetes were either exercised constantly at moderate intensity (aerobic) for 30 minutes on an exercise bike [green highlighted line] or did 30 minutes of aerobic exercise but punctuated by 4 seconds of maximum intensity sprinting every 2 minutes [blue highlighted line]. The decline in glucose is less with intermittent high intensity exercise compared to consistent moderate exercise during both the exercise period and recovery period (the next 60 minutes).

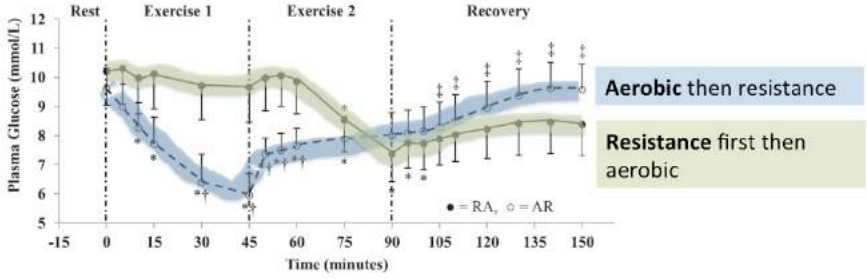
There is still a risk of delayed nocturnal hypoglycaemia with intermittent high intensity exercise, as is the case for moderate intensity exercise.

Reference: Alberto Maran, Paola Pavan, Barbara Bonsembiante, Erica Brugin, Andrea Ermolao, Angelo Avogaro, and Marco Zaccaria. Diabetes Technology & Therapeutics. October 2010, 12(10): 763-768. doi:10.1089/dia.2010.0038.

17

Resistance or aerobic

Effects of order of exercise type



Aerobic then resistance

Resistance first then aerobic

Aerobic: 45 minutes of treadmill running at 60% VO_2 peak.
Resistance: 45 minutes of resistance training three sets of eight repetitions with 90s rest between sets.

Effects of Performing Resistance Exercise Before Versus After Aerobic Exercise on Glycemia in Type 1 Diabetes

Diabetes Care 35:669–675, 2012

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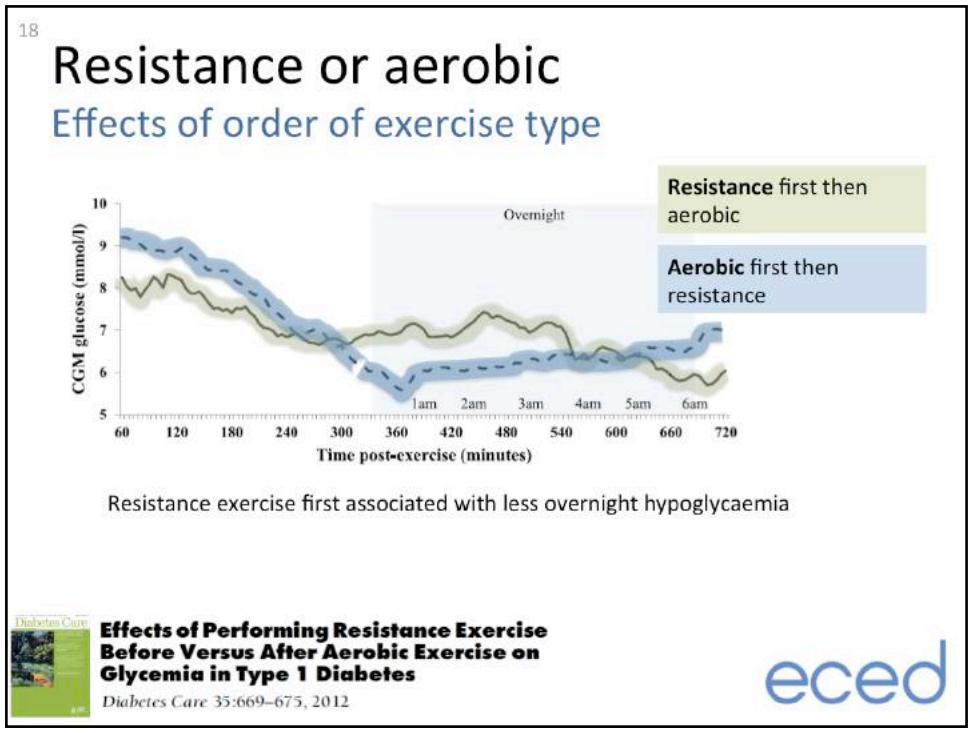
The suggestion from this study was that doing resistance (anaerobic) exercise first resulted in a less pronounced fall in glucose during the aerobic exercise and more stable glucose levels in the hour following exercise.



In the same study as the previous slide (p17), they looked at what happened over a longer period (including overnight) by using continuous glucose monitoring. You can see that people who did resistance (anaerobic) work first had more stable glucose levels in the lead up to bedtime (i.e. not falling as sharply) and were, therefore, less prone to dropping low overnight.

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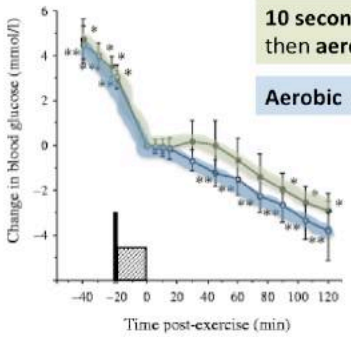
Sprint before exercise

May limit fall in glucose after aerobic exercise



10 second sprint first then **aerobic**

Aerobic exercise only

A short sprint (10s) prior to 20 minutes cycling (40% VO_2max) is associated with a smaller fall in glucose in the recovery phase.

A 10-s sprint performed prior to moderate-intensity exercise prevents early post-exercise fall in glycaemia in individuals with type 1 diabetes

Diabetologia (2007) 50:1815–1818

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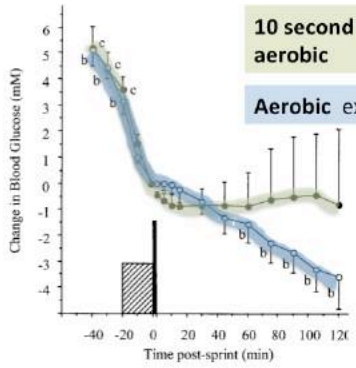
Even a relatively modest amount of anaerobic exercise (a 10 second sprint in this study) appears to reduce the fall in glucose levels following aerobic exercise (20 minute cycle in this study).

20

Sprint after exercise

Also limits fall in glucose after aerobic exercise



10 second sprint after **aerobic**

Aerobic exercise only

A short sprint (10s) **after** 20 minutes cycling (40% VO_2max) is associated with stabilisation of glucose in the following 2 hours

The 10-s Maximal Sprint

A novel approach to counter an exercise-mediated fall in glycemia in individuals with type 1 diabetes

Diabetes Care 29:601–606, 200

eced

This study is almost identical to the previous one (p19) but the sprint for 10 seconds was done AFTER 20 minutes of aerobic cycling. The effect here seems even more impressive in keeping the blood glucose steady in the 2 hours after exercise.

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Summary

Exercise factors

- **Aerobic exercise** – glucose can fall rapidly
- **Anaerobic exercise** – glucose likely to rise
- **Nocturnal (overnight) hypoglycaemia** – significant risk with aerobic exercise (unless adjustments made)

- **Sprints (anaerobic exercise) before and/or after may reduce fall in glucose**

- **Team sports can have variable effects** depending on intensity, position and competition (rather than training)

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Planning for exercise

Adjustments in type 1 diabetes

- Pre-meal insulin adjustment
- Starting glucose
- Pump basal rates
- Night-time basal insulin
- Carbohydrate during and after

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Controlling energy supply

The science bit (bear with us)

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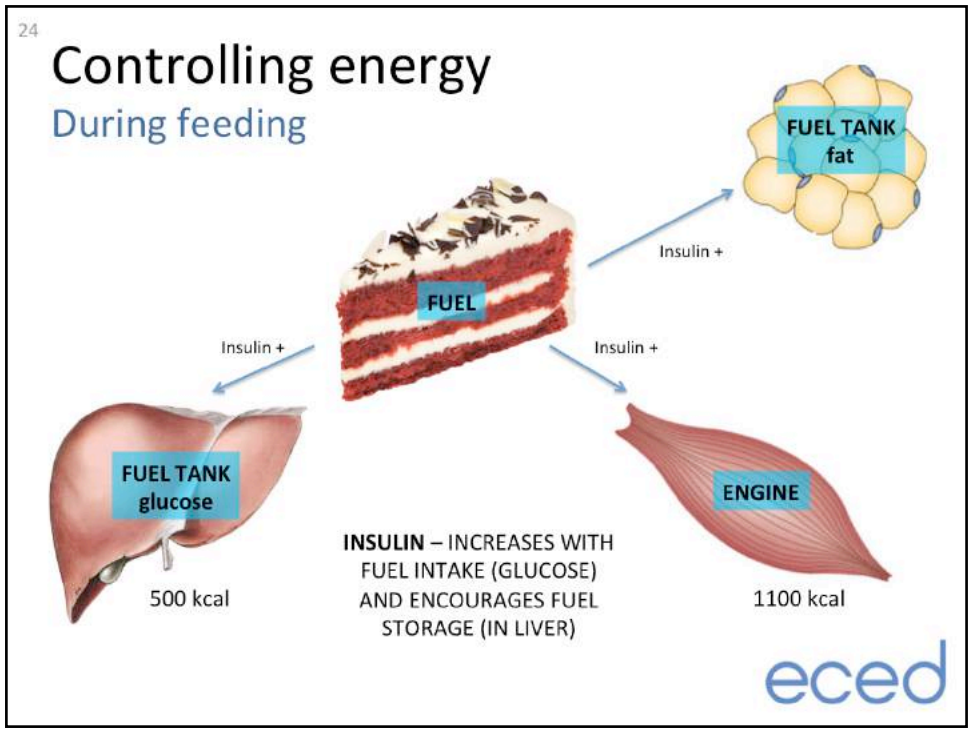
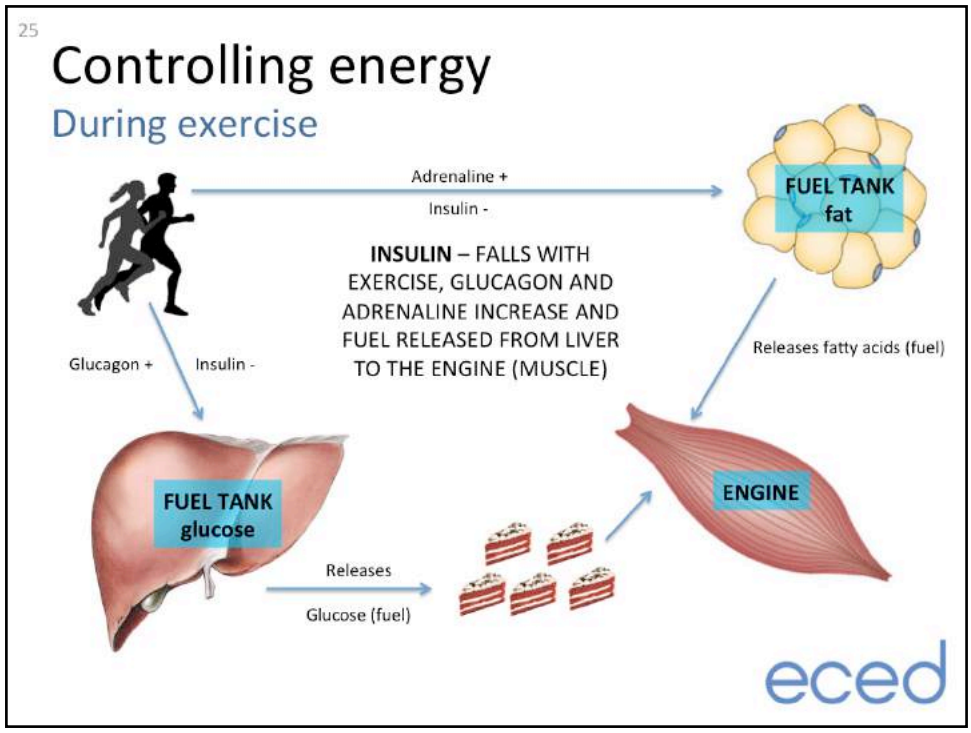


After eating the body is provided with a large supply of fuel (mainly glucose) which it needs to store for use between meals. Insulin promotes storage of energy in the liver and uptake into other tissues like muscle where energy is also stored. Glucose stored in muscle cannot leave the muscle to prevent hypos.



During exercise, in people who don't have diabetes, insulin levels fall and counter-regulatory (CR) hormones (glucagon, cortisol etc.) rise to cause release of glucose from the liver to fuel muscle power. Adrenaline and a fall in insulin also cause release of a different type of fuel from fat (free fatty acids) to power the muscles.

In type 1 diabetes, insulin levels are almost always too high to allow the liver to produce glucose adequately during exercise.
Often in type 1 diabetes, the CR hormones are also reduced, further diminishing glucose supply.
CR hormone production is reduced for around 24 hours after a hypo – increasing the chances of further hypos – especially in the context of exercise.
Starting with a very high blood glucose will not help because your blood does not contain enough glucose to meet demand (even with a BG of 15, this only contains around 25g of available glucose – enough to perform moderate exercise for around 12 minutes) – so this is not the answer!

So what is the answer…

Adjusting insulin

Quick acting (bolus)

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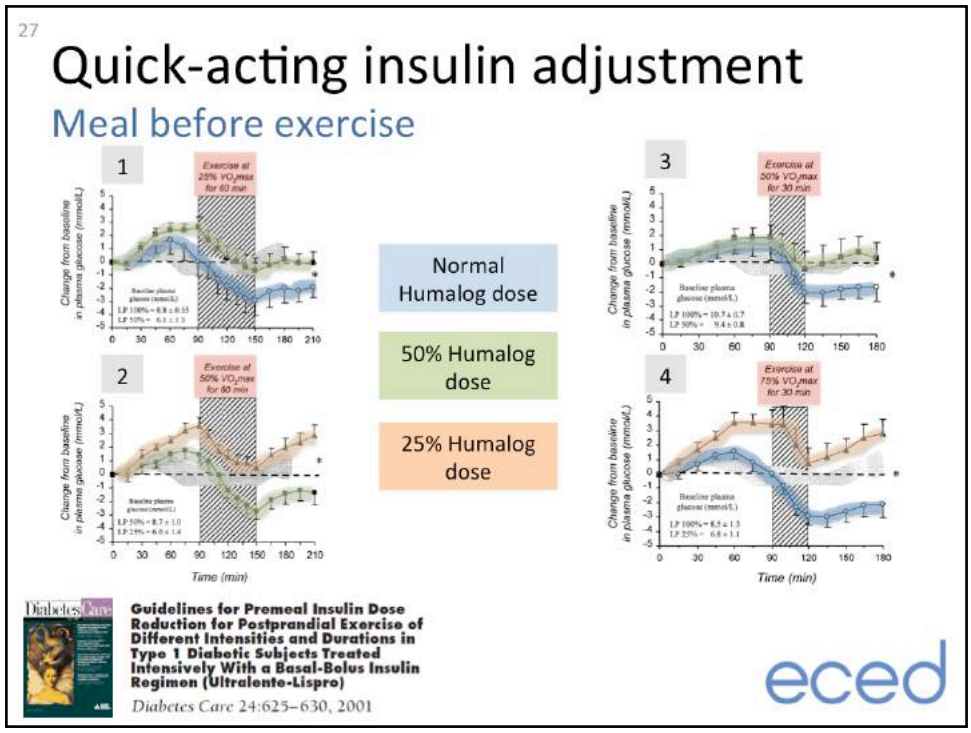


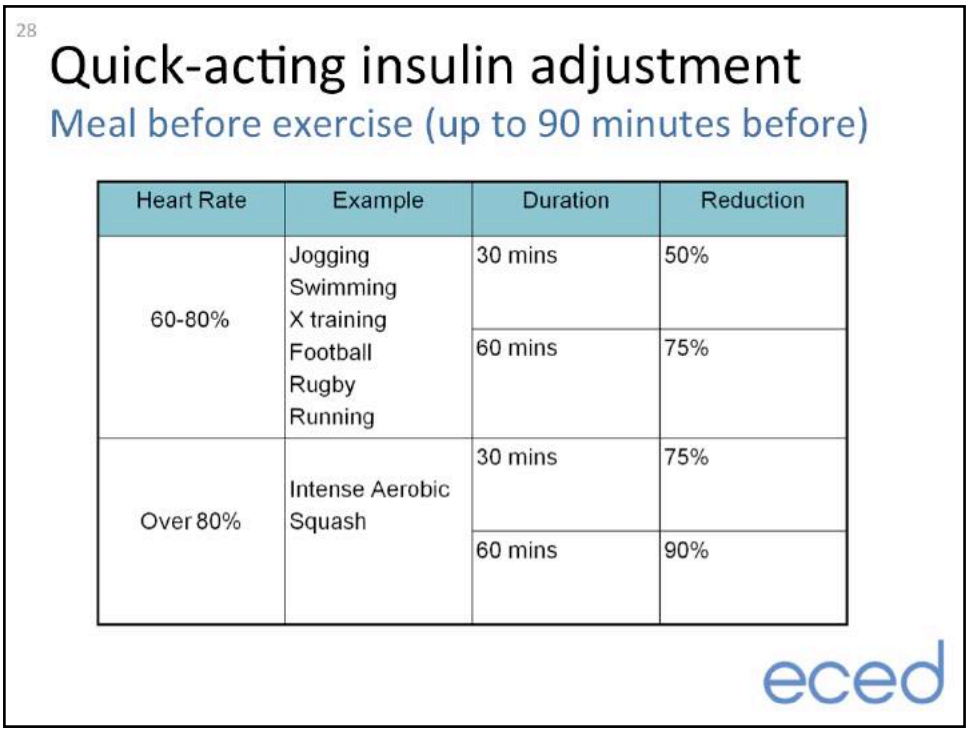
This slide is quite busy but it is basically showing the effect of reducing the quick-acting insulin dose for a meal which was eaten 90 minutes before 4 different types of exercise.

Example 1 is 60 minutes of exercise at 25% VO2 max – taking the normal dose of humalog has caused a drop in glucose of about 3 mmol/L – reducing the dose to 50% of usual has kept things stable.

Example 2 is 60 minutes of exercise at 50% VO2 max – taking 50% of the normal dose is still too much – reducing to 25% of the normal dose has resulted in less of a fall in glucose – although it is a bit higher later.

Example 3 is 30 minutes of exercise at 50% VO2 max – taking 50% of the normal humalog dose has worked well here – taking the normal dose causes a fall in glucose.

Example 4 is 30 minutes at 75% VO2 max – taking 25% of the normal dose has been the better option than keeping the normal humalog dose.



If you are exercising within 90 minutes of a meal, this table gives some approximate suggestions about how much you should reduce the dose of bolus (quick-acting) insulin by.

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Carbohydrate support

Before, during and after

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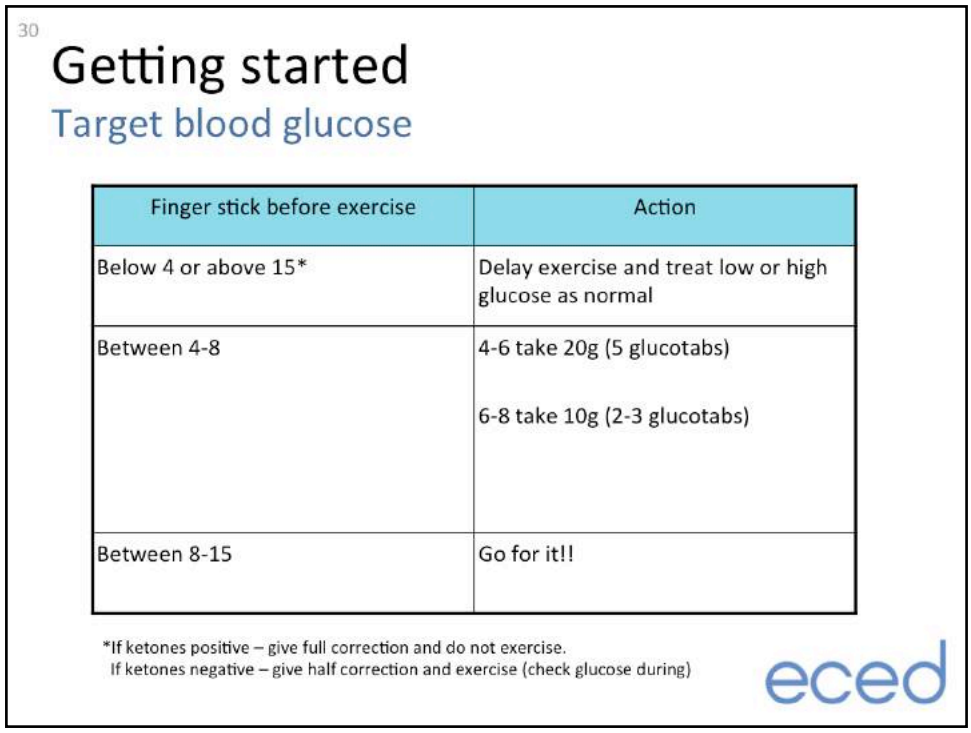

This is a rough guide on what to do prior to exercise. As with everything else, it is important to check carefully to determine what works best for you.

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Carb replacement during activity

Based on weight, intensity and duration

	Carb replacement (grams) every 30 minutes of activity			
Weight of person (Kg)	45kg	70kg	90kg	115kg
Light activity	5g	8g	10g	12g
Moderate activity	8g	10g	12g	15g
Intense activity	12g	18g	24g	30g

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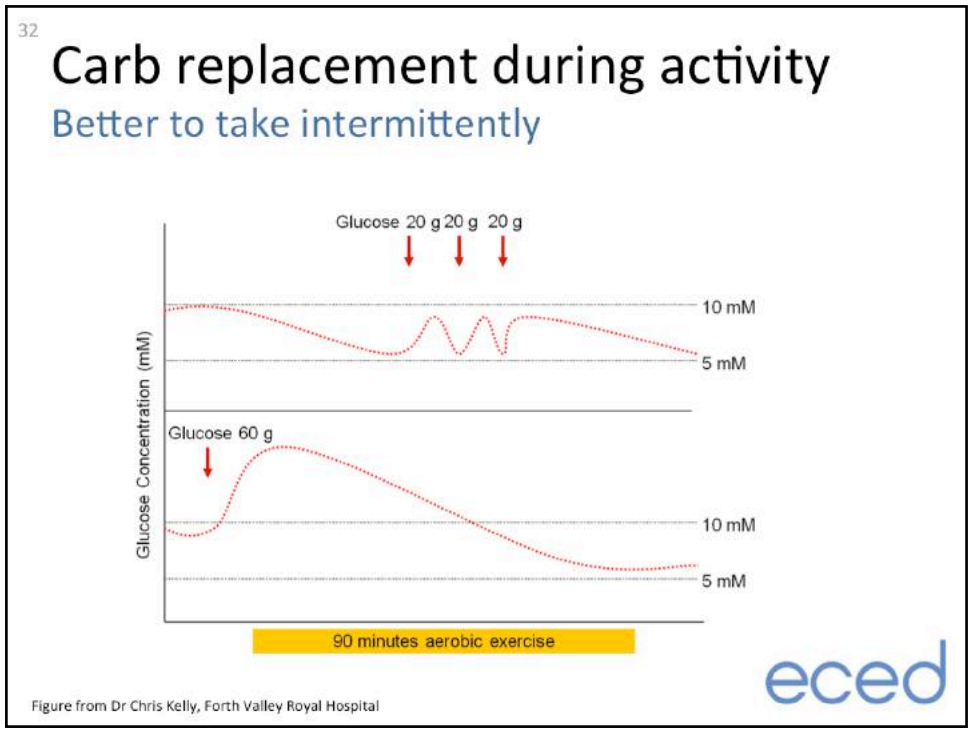
During exercise, you should aim to replenish your carbohydrate stores by taking glucose. This is particularly important during prolonged exercise to avoid hypoglycaemia. If muscle glucose stores are depleted, they will take in glucose later on, leaving you at risk of delayed hypoglycaemia.



It is best to take glucose intermittently during exercise than 'front-loading' a large amount at the beginning – as is shown in the figure above.

33

General nutrition

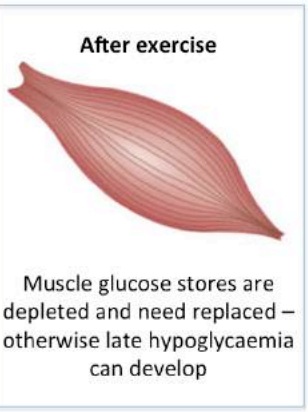
During and after exercise

During

- Carbohydrate
  - 30-60 g per hr
- Fluid
  - 500ml per hr

Recovery

- Carbohydrate
  - 1g per kg (60-120) as a drink or snack
- Insulin
  - may need insulin with snack (reduced dose)
  - may need less basal insulin



Muscle glucose stores are depleted and need replaced – otherwise late hypoglycaemia can develop

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Immediately after exercise your BG may transiently rise or remain steady.
In the 1-2 hours after exercise, you may experience hypoglycaemia due to ongoing muscle uptake of glucose.
To prevent this take carbohydrate immediately after exercise, with a reduced insulin dose.

Avoiding late hypoglycaemia

After exercise

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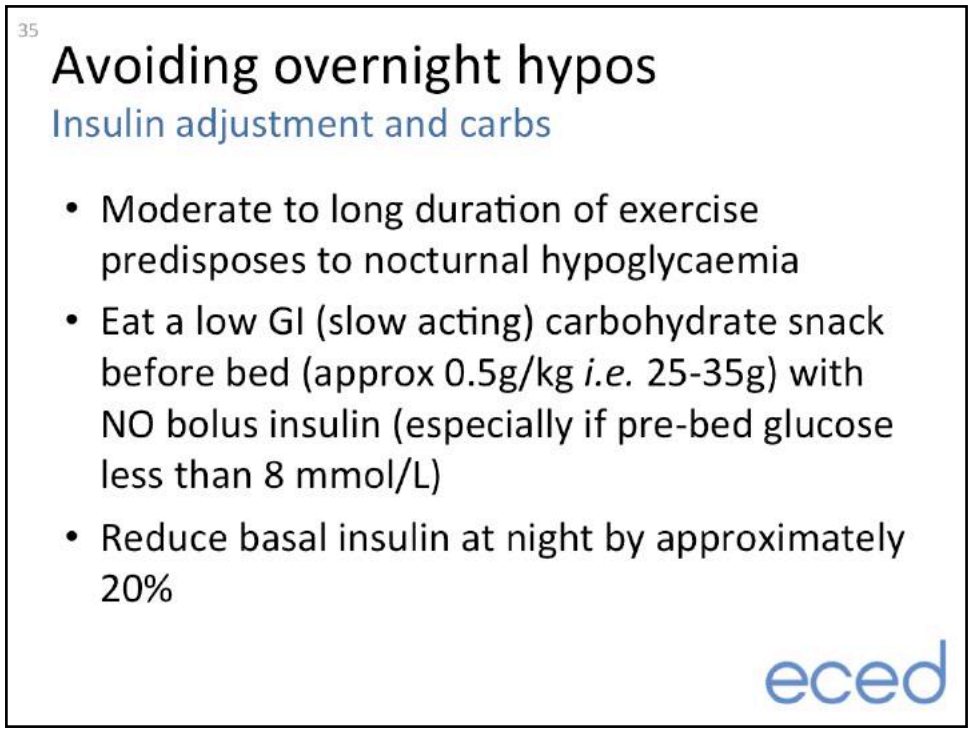
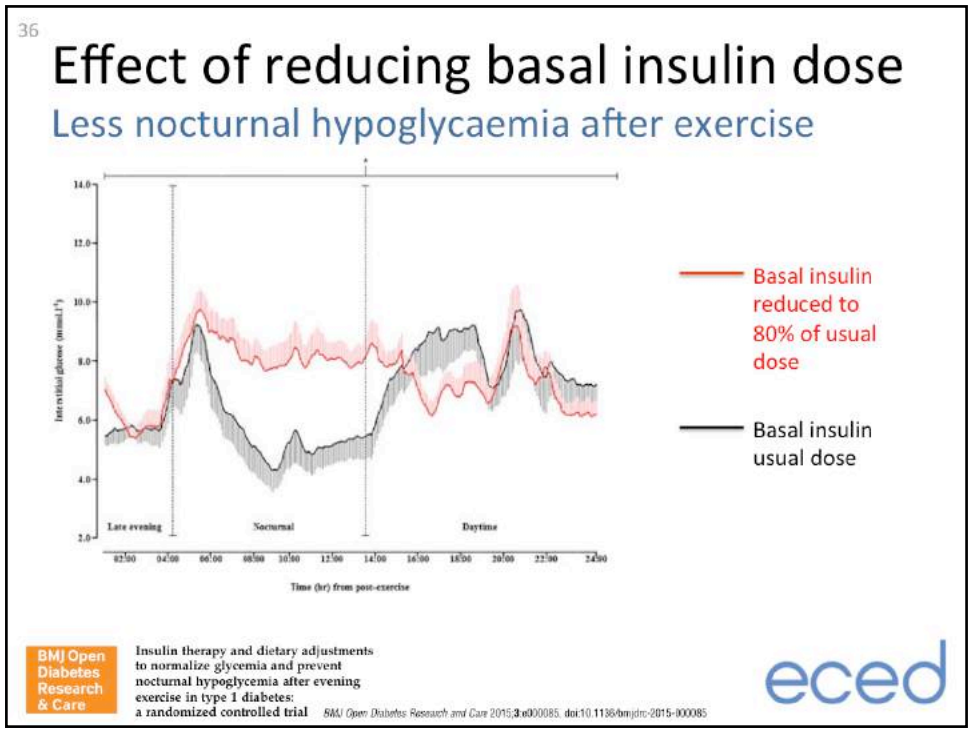


'Delayed hypoglycaemia' overnight following exercise is common.
This is due to increased muscle insulin sensitivity for around 6 – 48 hours post exercise – i.e. the same amount of insulin will cause a larger fall in glucose.
People with diabetes use more muscle glycogen but less liver glycogen and fat than those without, so this needs to be adequately replaced with carbohydrate to prevent fatigue.
Reduce overnight basal insulin following prolonged exercise.
Take a long acting carbohydrate snack before bed.

It is worth carefully assessing whether you are at risk of delayed nocturnal hypoglycaemia by checking 3am glucose levels on a few occasions after exercise.



This study assessed the effect of reducing the basal (background) insulin dose to 80% of usual (i.e. a 20% reduction). You can see that this resulted in less of a fall in glucose levels overnight – thereby reducing the risk of nocturnal hypoglycaemia.

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Insulin pumps

Adjusting the basal rate

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Exercise and pumps

The benefits

- Enables normal basal insulin to be markedly reduced or suspended whist performing exercise.
- Lower post exercise nocturnal basal rate with intermittent exercise patterns.
- The gold standard for serious athletes where practical.

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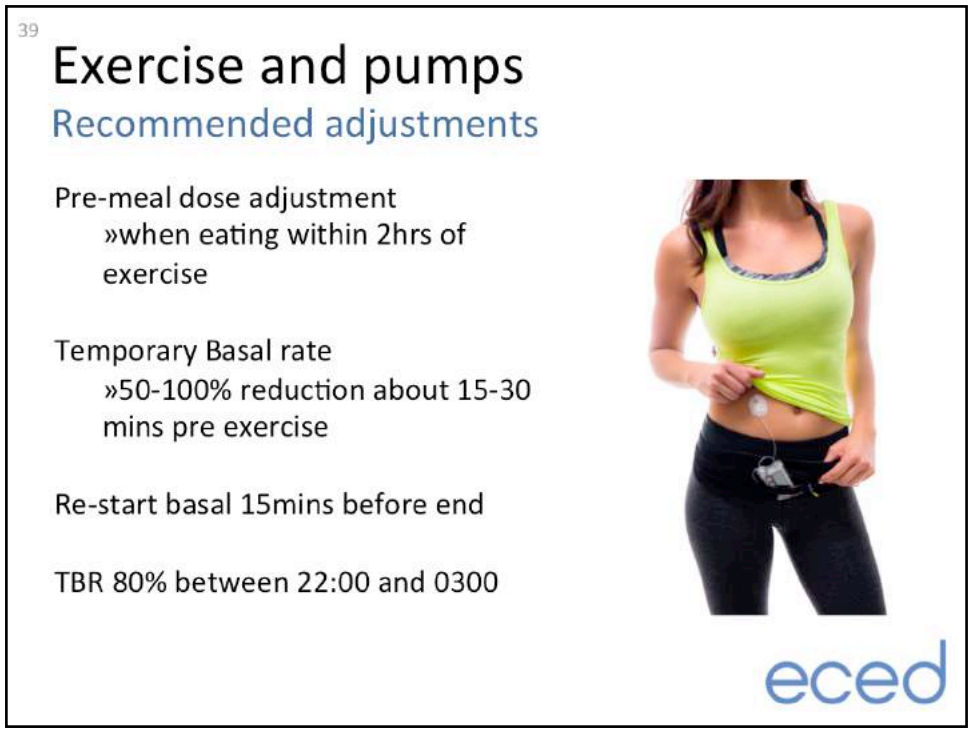

Pre-meal bolus adjustments – same as advice for people on injectable insulin (page 27 and 28),

TBR is temporary basal rate – typically reduce basal infusion by 20% (i.e. run at 80% of normal) between 22:00 and 03:00 where the risk of delayed hypogycaemia is greatest.

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Exercise and type 1 diabetes

Summary

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Strategies for moderate exercise

Pros and cons

Strategy	Advantages	Disadvantages
Reducing preexercise bolus insulin	Reduces hypoglycaemia during and following exercise; reduces CHO requirement	Needs preplanning; not helpful for spontaneous exercise or for late postprandial exercise
Reducing preexercise basal insulin	As above	As above, causes pre- and late postexercise hyperglycaemia
Taking extra CHO with exercise	Useful for unplanned or prolonged exercise	May not be possible with some exercises; not helpful where weight control important; easy to overreplace causing hyperglycaemia
Pre- or postsprint exercise burst	Reduces hypoglycaemia during and following sports	Effect limited to shorter and less intense exercise
Insulin pump therapy	Offers flexibility and rapid change in insulin infusion rates postexercise	Expensive; may not be practical for contact sports (eg, rugby/ football/judo)
Reducing basal insulin postexercise	Reduces nocturnal hypoglycaemia	May cause morning hyperglycaemia

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Exercise and type 1 diabetes

Summary

- Everyone is slightly different – find out what works for you
- Check glucose regularly
- Consider sprints to reduce hypo risk
- Avoid injecting in 'exercise areas'
- Adjust insulins and take carb as indicated

eced

The avoid injecting in 'exercise areas' refers to the fact insulin is absorbed quicker from the legs during exercise which uses the leg muscles. It may be preferable to inject in the abdomen to avoid this issue.

Dr Ian Gallen has extensive experience in type 1 diabetes and sport/exercise. His website runsweet.com is an excellent resource with specific advice related to almost every form of sport you can imagine.

The TeamBG website is another good source of information. It also contains details of the events run by TeamBG which people with type 1 diabetes can sign up for.

We are always keen to hear from you if you have questions or wish to discuss your glucose results in detail.