Diabetes technology and exercise

Rob Andrews

University of Exeter

NHS Somerset NHS Foundation Trust

Declaration of interest

Investigator on number of lifestyle studies

- Early ACTID, EXTOD, EXTOD education, Motivate T2DM, EXTOD immune, EXTOD sedentary,

Positions

- Founding member of EXTOD
- Recent chair of Diabetes UK clinical study group 3 – prevention and treatment of type 2 diabetes

Overview

- Physiology of exercise in people with and without T1D.
- Advice for before and during exercise
- Advice for after exercise
- Trouble shooting when standard advice not working

If time

- Benefits of exercising regularly for people with T1D
- Barriers to exercise for people with T1D

Some physiology

The Normal response is, “I do”, Not, “ I suppose so”

Questions 1a

True or False

In people **without** diabetes

1. Glucose falls a small amount with exercise
2. Glucose can rise with anaerobic exercise but then falls .
3. During competition glucose can rise to 12-14 mmol.

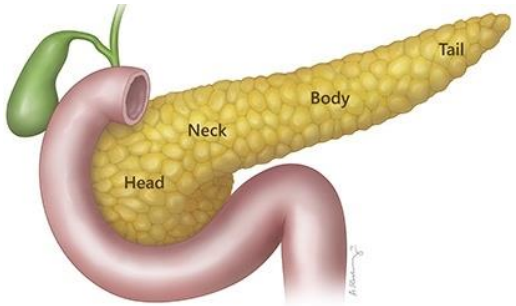
Questions 1b

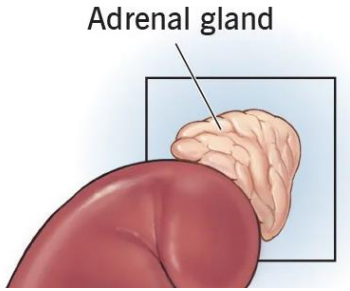
True or False

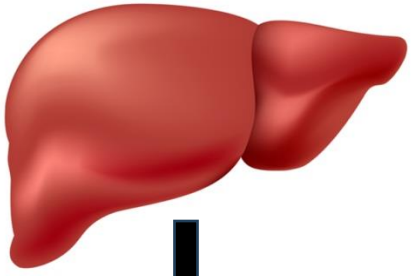
In people **with** T1

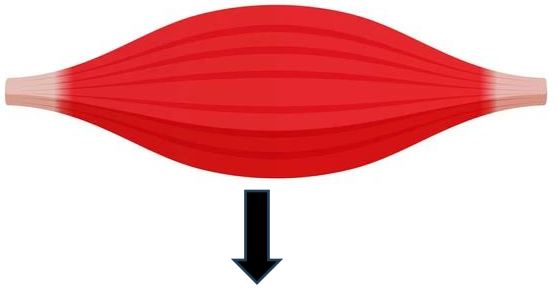
1. Glucose falls with exercise with greater fall if insulin is around.
2. Glucoses can rise with anaerobic exercise and be up at the end.
3. Hypo risk is low in the first hour after exercise.
4. Hypo risk is increased 6-8 hours after exercise.
5. Closed loop systems are associated with less hypos during exercise.

Flexibility exercise









Insulin level

Glucagon level

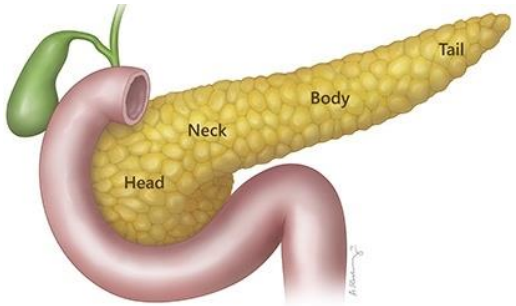
Stress hormones

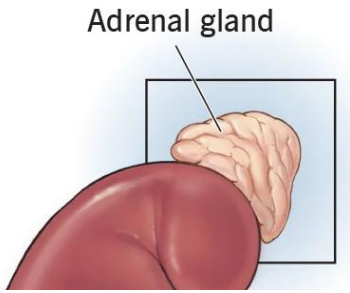
Small amount glucose secreted

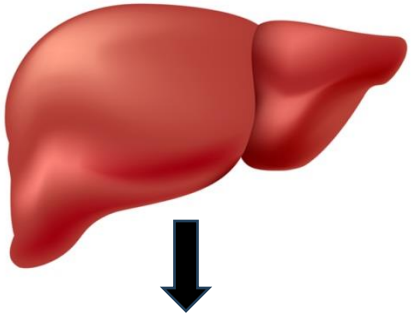
Small amount glucose used

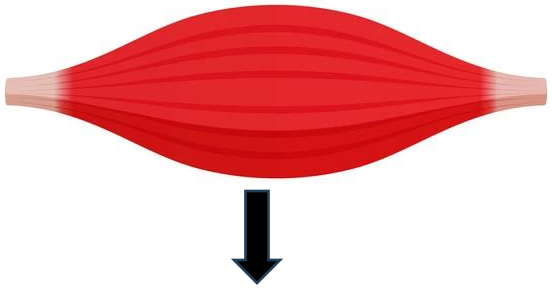
Blood glucose

Anaerobic exercise



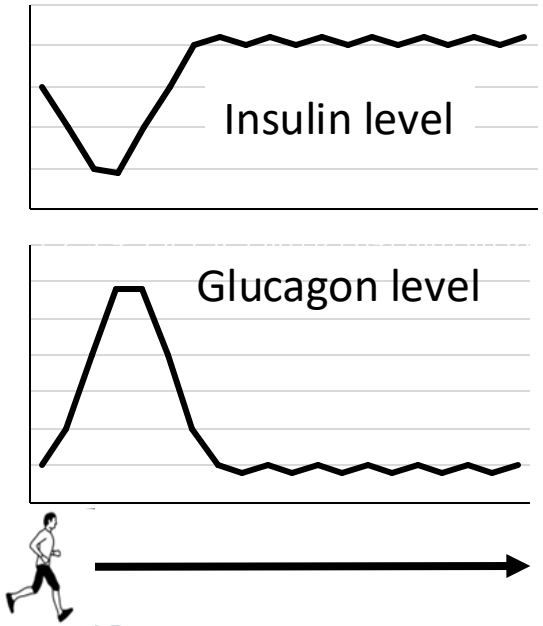


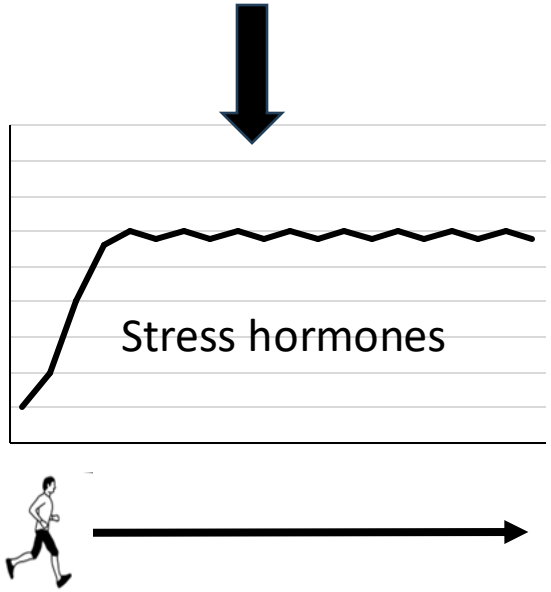


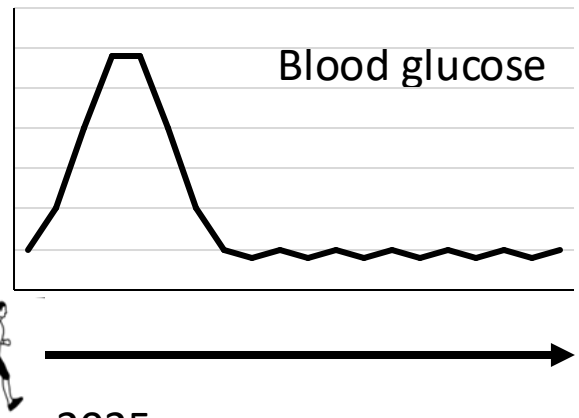


Large amount glucose secreted

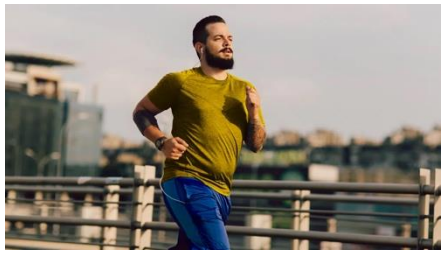
Small amount glucose used

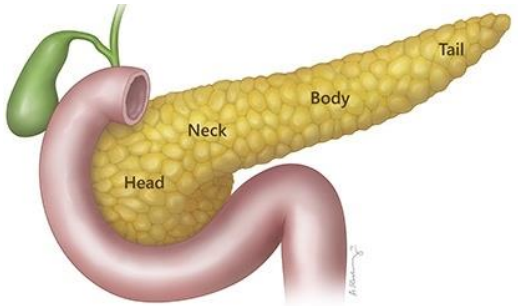


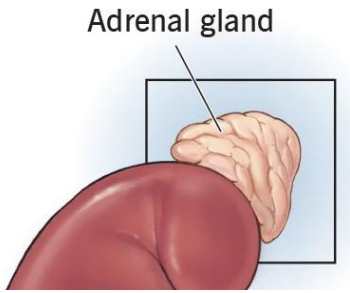


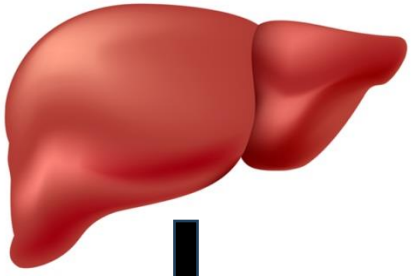


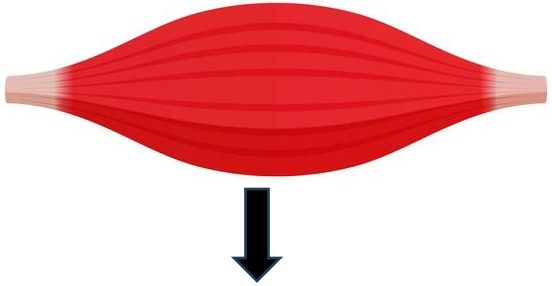
Aerobic exercise











Insulin level

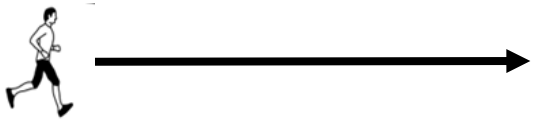
Glucagon level

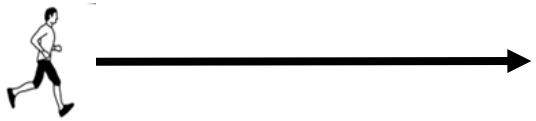
Stress hormones

Medium amount glucose secreted

Slightly more glucose used

Blood glucose





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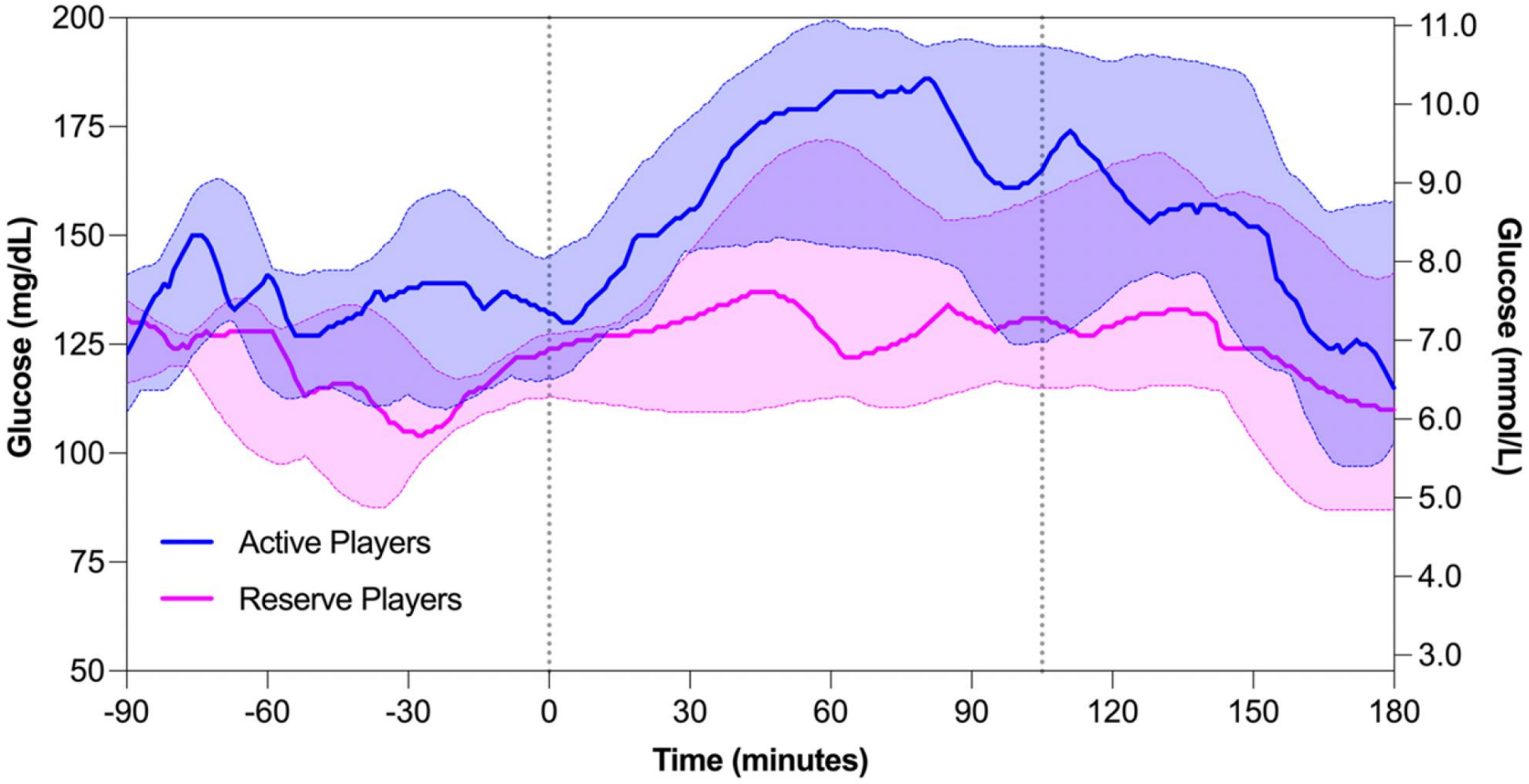
Glucose levels – Study design

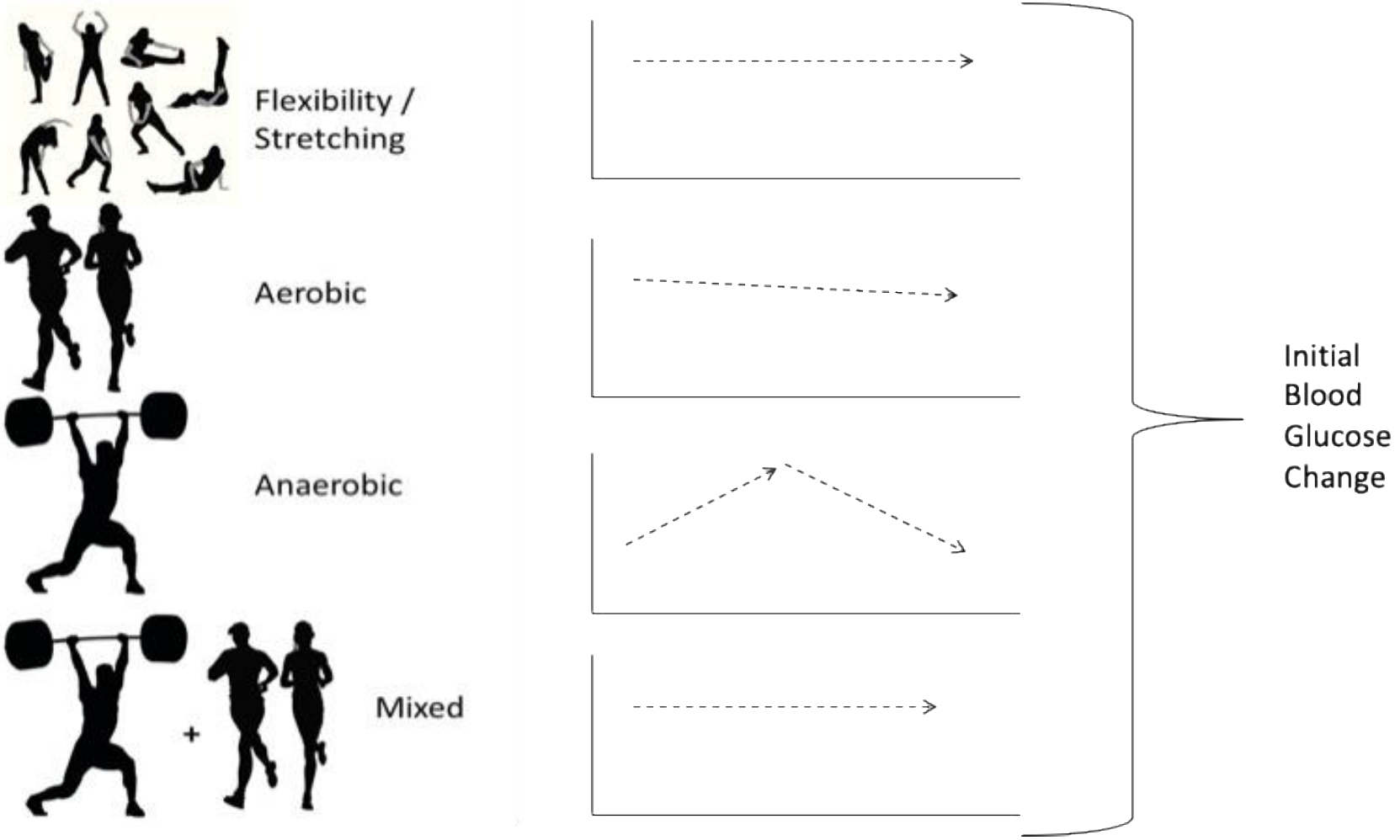
- Eighteen (n = 18) elite-level male professional football players without diabetes (age: 27.5 ± 5.1 years; height 180.1 ± 7.2 cm, weight 74.2 ± 9.1 kg)
- Each player wore a new-generation Libre Sense Glucose Sport Biosensor for up to 14 days in real-life situations.
- Footballers were categorized into two groups: (1) active players who participated in the game for at least 12 minutes (n = 10) and (2) reserve players who played for less than 12minutes (n = 4).

Skroce K et al. Conti. J Diabetes Sci Technol. 2025 Nov 14:19322968251388668. doi: 10.1177/19322968251388668

Glucose levels – results



Glucose responses to different exercises without T1D



Answers 1a

True or False

In people **without** diabetes

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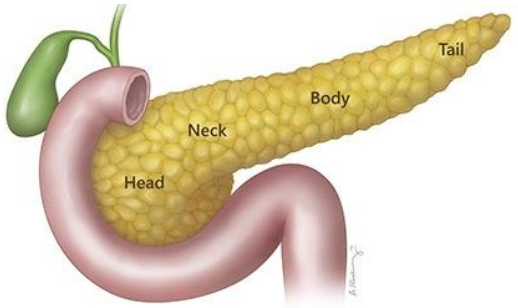
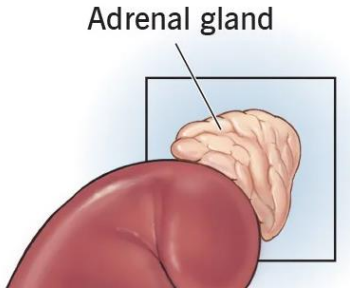
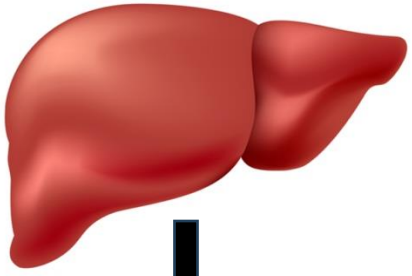
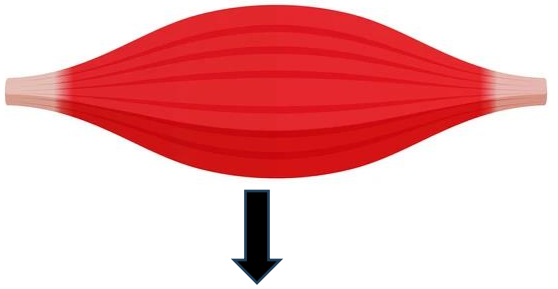
Flexibility exercise – T1D



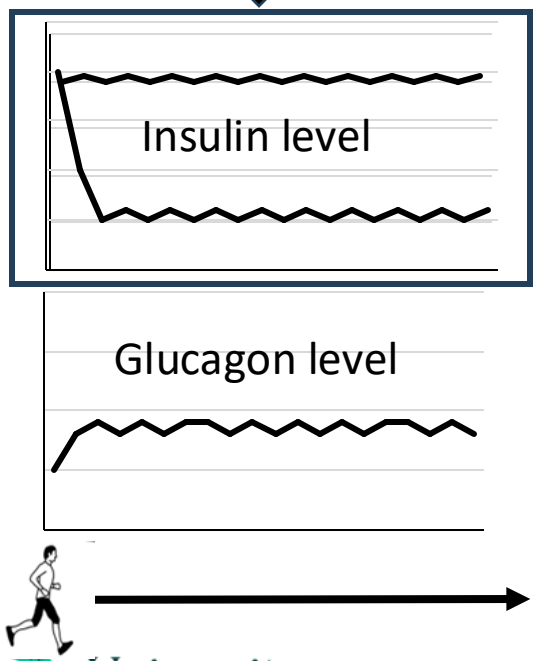


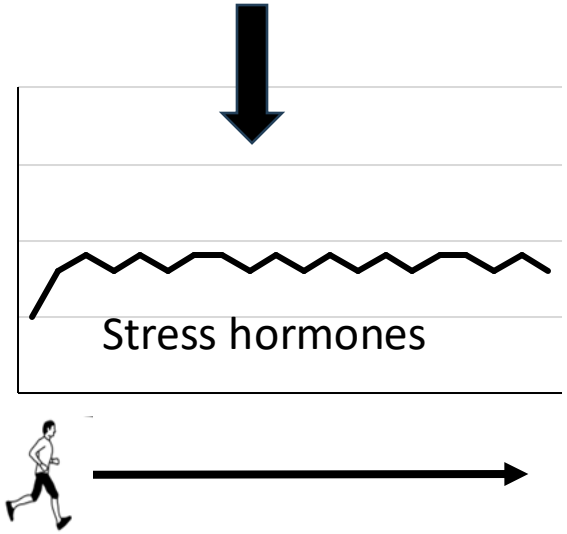


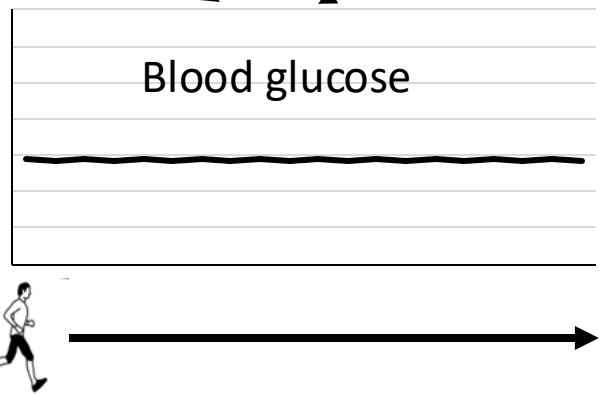


Small amount glucose secreted

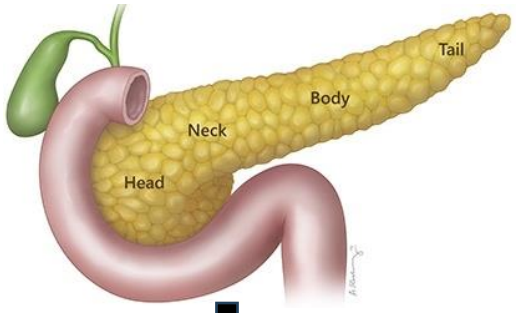
Small amount glucose used

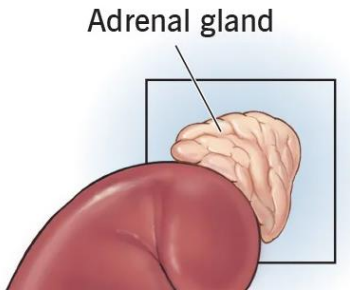


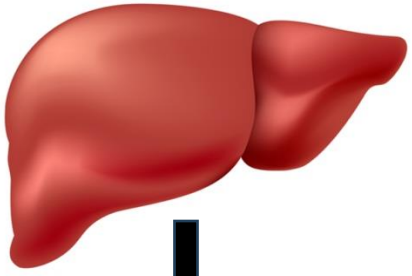


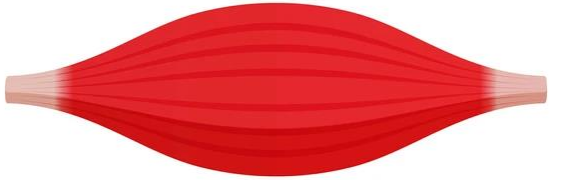


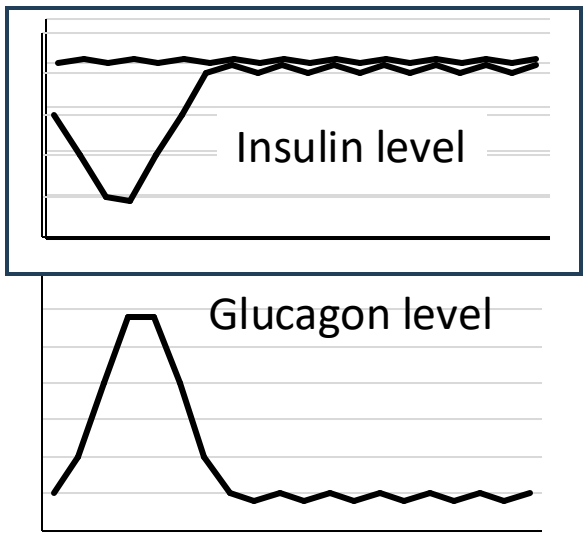
Anaerobic exercise T1D

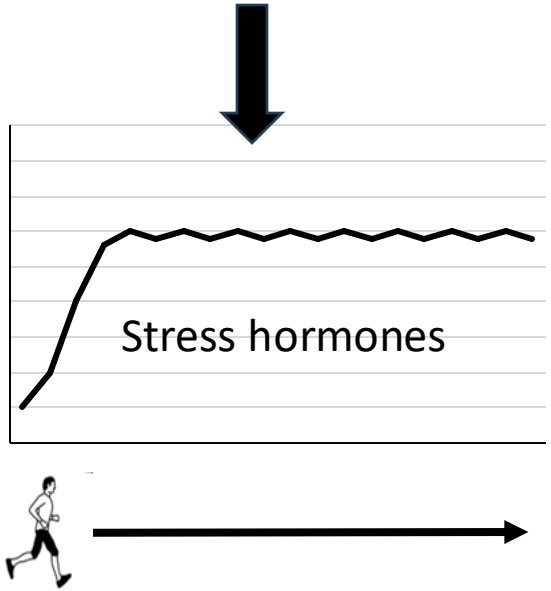






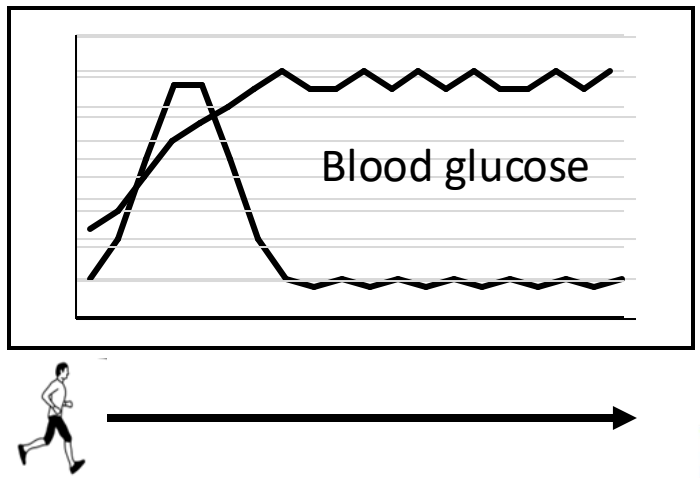






Large amount glucose secreted

Small amount glucose used



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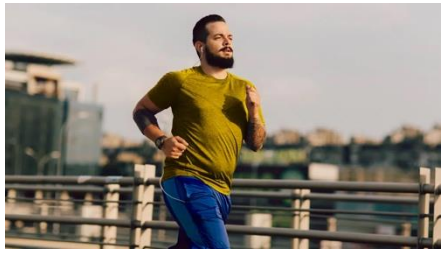
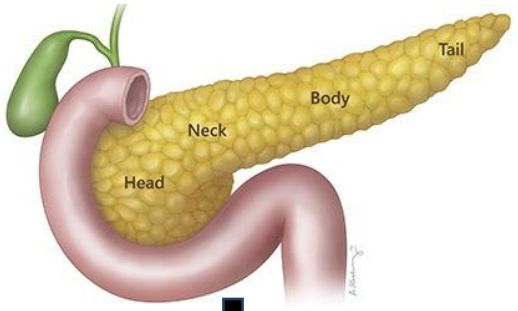
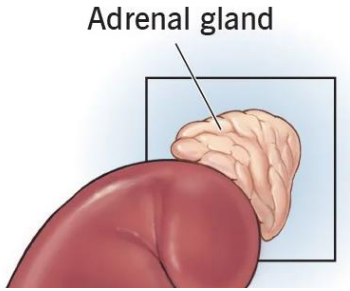
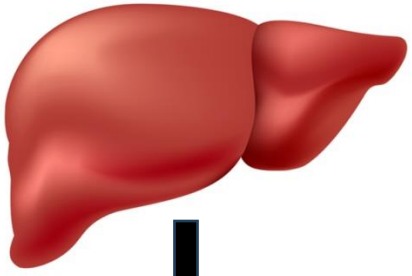
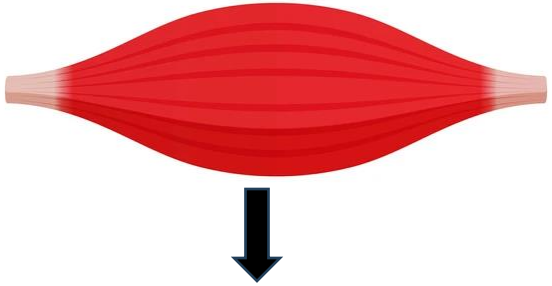
Aerobic exercise T1D





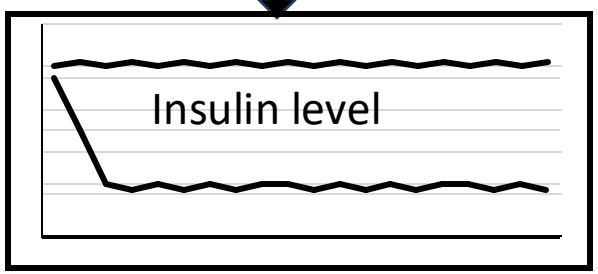


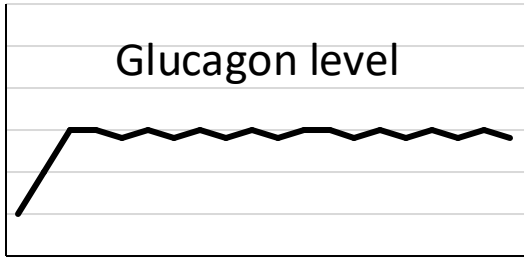


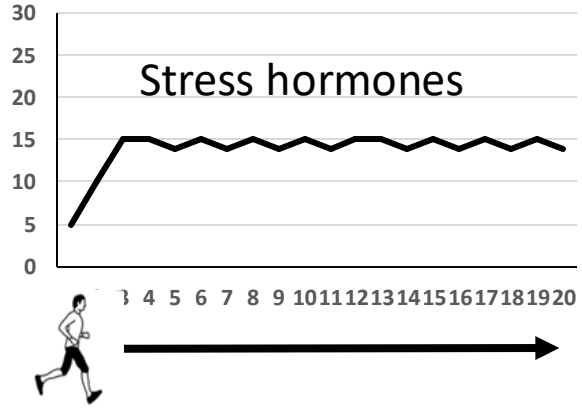


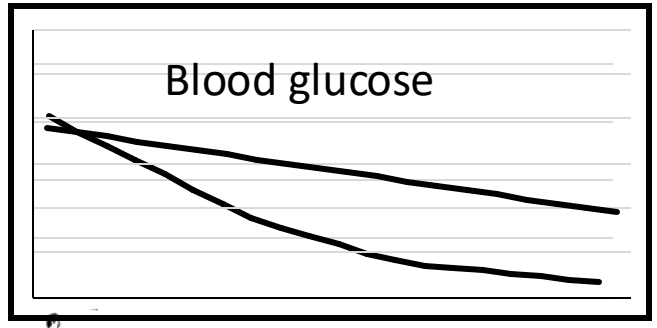
Medium amount glucose secreted

Slightly more glucose used

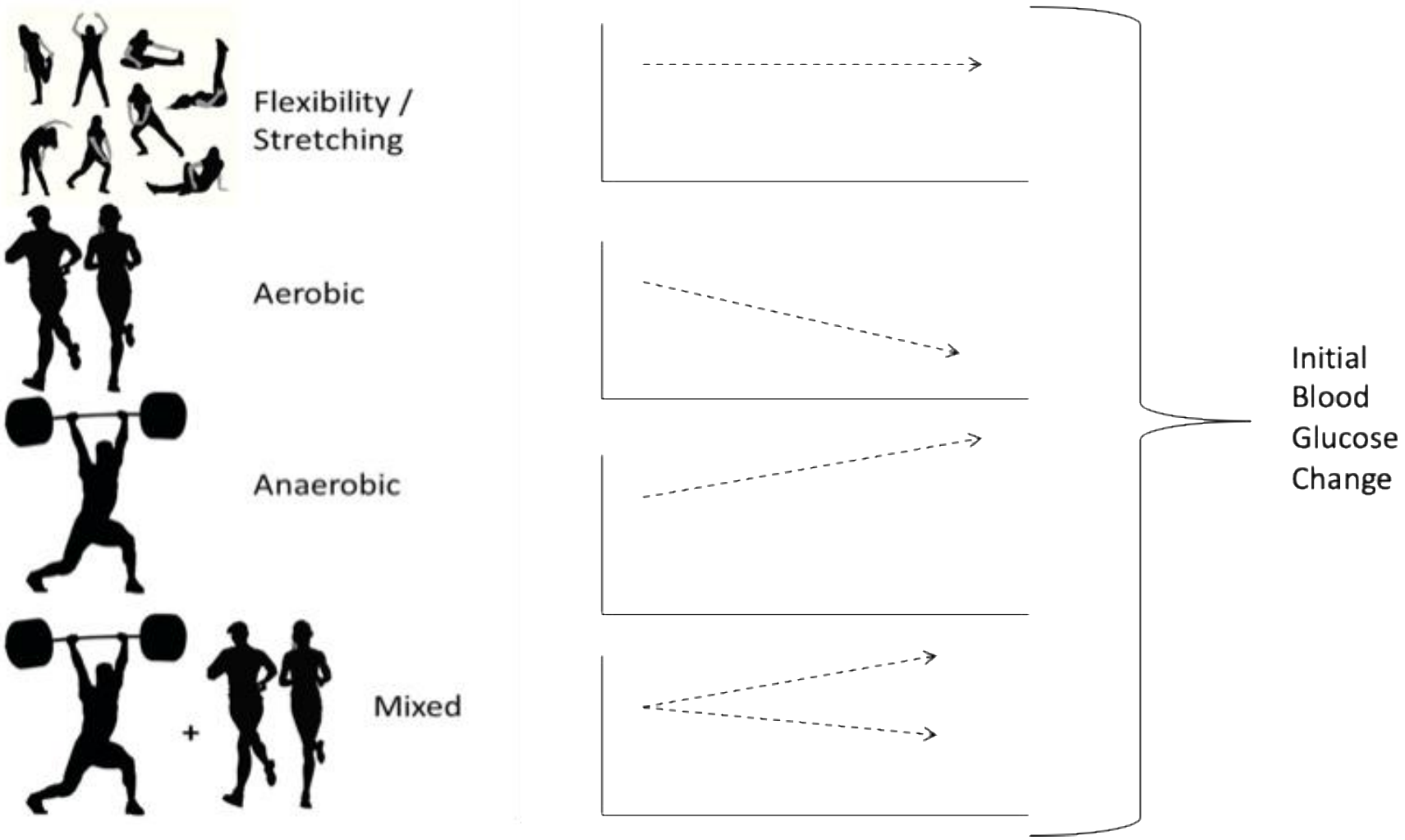








Glucose responses to different exercises with T1D



Methods

Study of 459 participants, mean age 37 + 14 years, 73% female

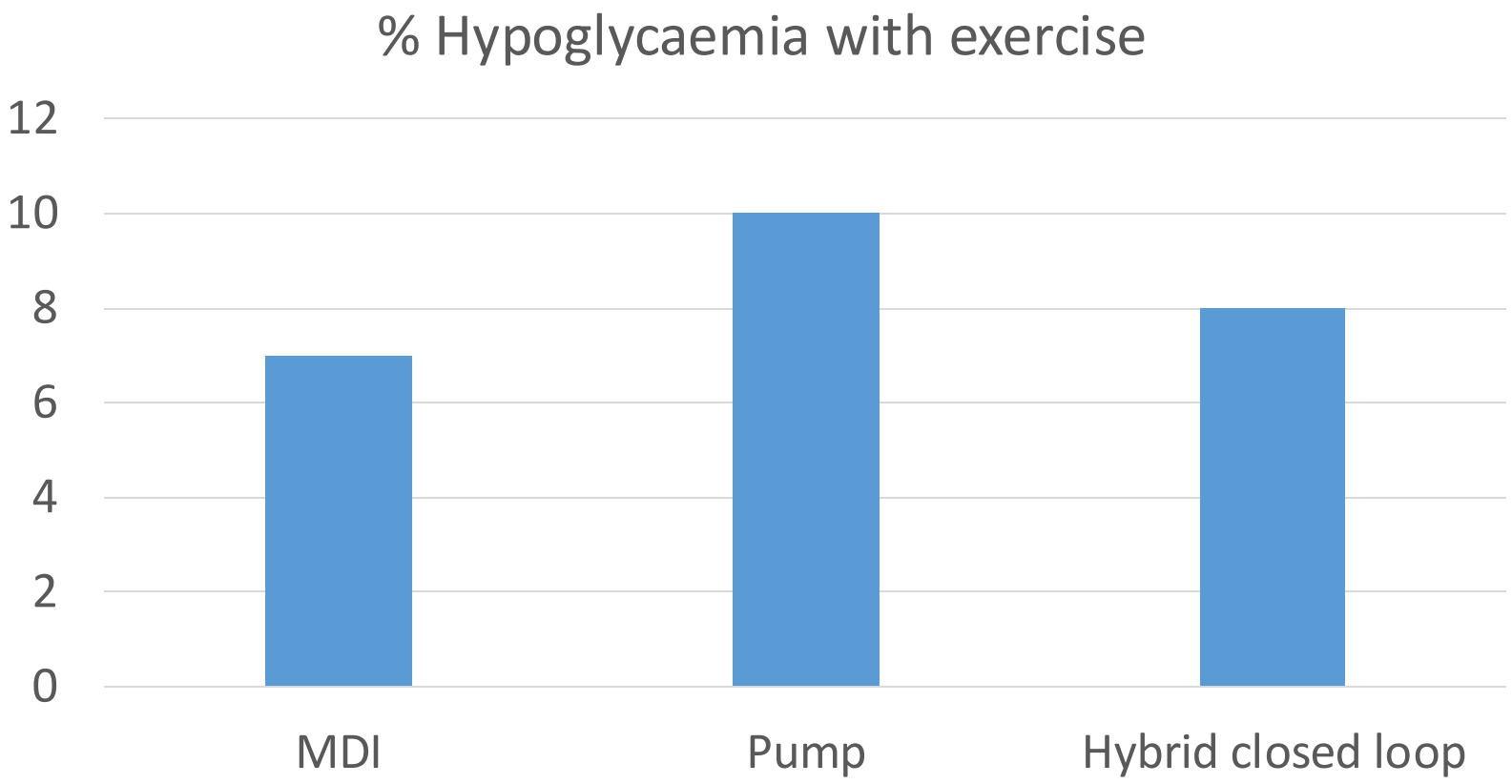
All on CGM, intensity, duration and type of exercise measured.

8,827 bouts of exercise

	Multiple daily injections	Insulin Pump	Closed looped Insulin system
Number of people	87 (17%)	187 (38%)	222 (45%)
Number of bouts of exercise	1567 (18%)	3229 (37%)	4031 (46%)

Bergford S et al Diabetes Technol Ther. 2023 Sep;25(9):602-611.
doi: 10.1089/dia.2023.0140.

Hypo risk on different treatments



Bergford S et al Diabetes Technol Ther. 2023 Sep;25(9):602-611. doi: 10.1089/dia.2023.0140.

After exercise… ‘Whip, Double dip

Immediate high BGs

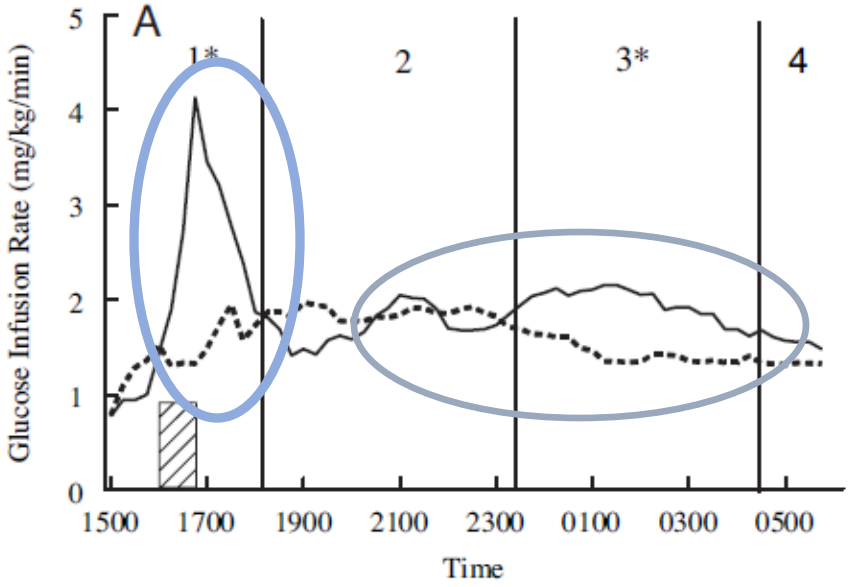
- Over fuelling with carbs
- Ongoing glucogenesis as muscles stop needing fuel
- Pump removal

Then hypos within 2hrs

- Insulin sensitivity
- Blunted glucagon response

And hypos again 6hr or on sleeping

- Insulin sensitivity
-Blunted glucagon response
- Increased muscle and liver uptake of glucose



McMahon et al (2007) *JCEM* **92(3)**:963-968

Answers 1b

True or False

In people **with** T1

1. Glucose falls with exercise with greater fall if insulin is around. True
2. Glucoses can rise with anaerobic exercise and be up at the end. True
3. Hypo risk is low in the first hour after exercise. False
4. Hypo risk is increased 6-8 hours after exercise. True
5. Closed loop systems are associated with less hypos during exercise. False

Summary 1

Patients with Type 1 diabetes have two problems

1. Inability to regulate insulin levels automatically
   - So can be too high during exercise resulting in hypos
   - Does not rise if glucose rises before, during or after
   - Is not reduced when becomes more insulin sensitive after exercise so hypos after exercise

2. Reduced hormone response when glucose falls.

But

1. Better fat burners.
2. With Insulin have ability to bulk up and recover quicker.

What is the advice to help control glucose before & during exercise?

Hey Dude when I said “curls might help, that is not what I meant!”

University of Exeter

NHS Somerset NHS Foundation Trust

Questions step 1-4 a

True or False

1. The accuracy of continuous glucose monitors is not affected by exercise.
2. The delay in glucose readings from CGMs is 3-5 minutes.
3. A reduction made in a bolus at mealtime will cause the greatest reduction in insulin levels 40-75 minutes after the meal.
4. If a 50% reduction is made in the background insulin rate on a insulin pump, at 2 hours the insulin level will have fallen by 50%.
5. It takes 10-30 minutes to reach a steady state after switching to exercise or temp mode on a hybrid closed loop system.

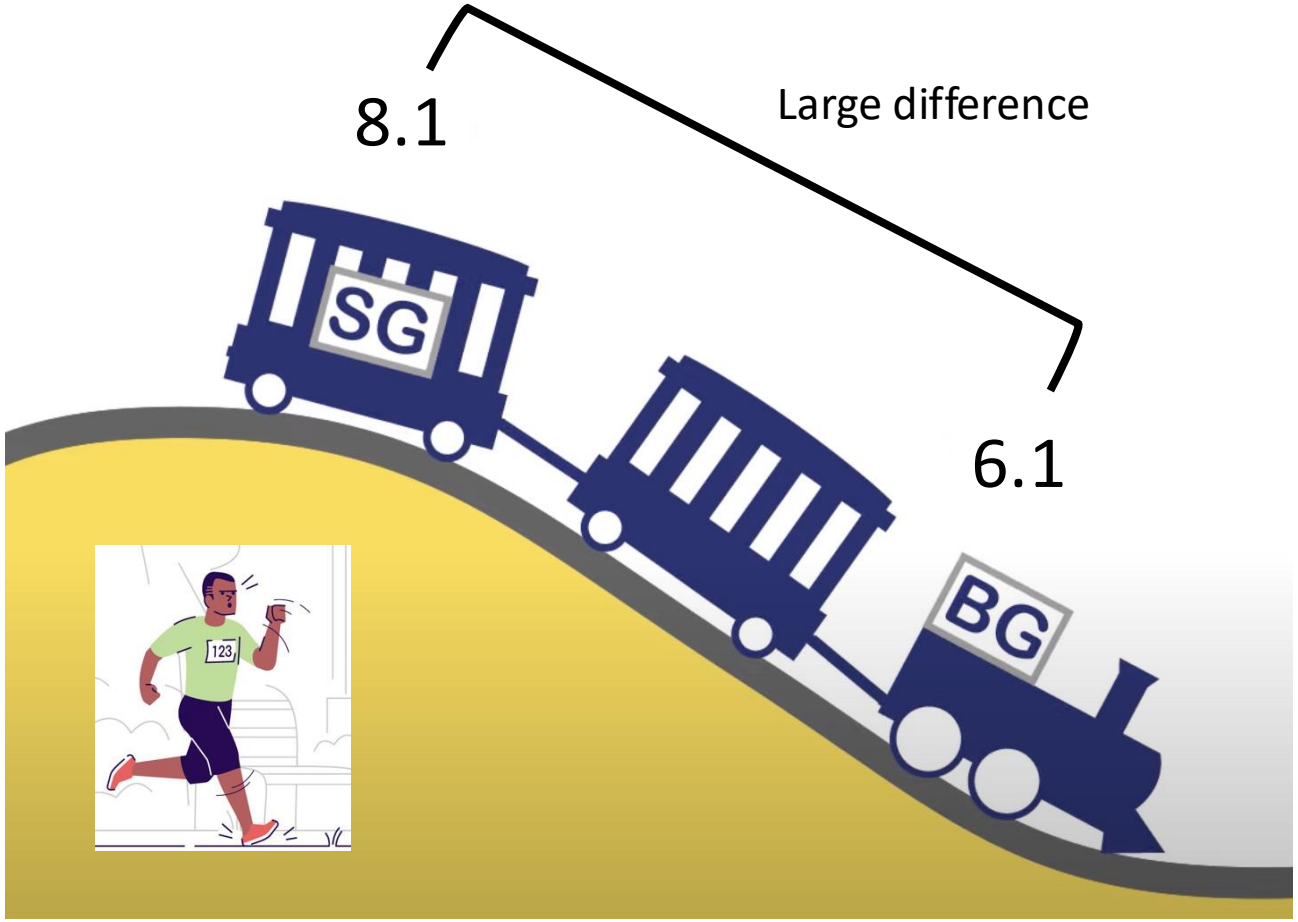
Questions step 1-4 b

True or False

1. People with T1D who exercise regularly are at greater risk of hypoglycaemia when they exercise than people who do not exercise regularly.
2. Time in hypo can help to predict hypo risk with exercise.
3. It is safe to exercise, if take precautions if had serious hypo in last 24 hours.
4. If glucose is above 15mmol/l exercise is not advised.
5. The starting glucose and how long you are going to exercise can be used to accurately predict risk of hypoglycaemia during exercise.
6. Exercising fasted first thing in the morning is the safest time to exercise.

Step 1 – explain about how CGM and pumps, close loop work

Continuous glucose monitors – effect of exercise

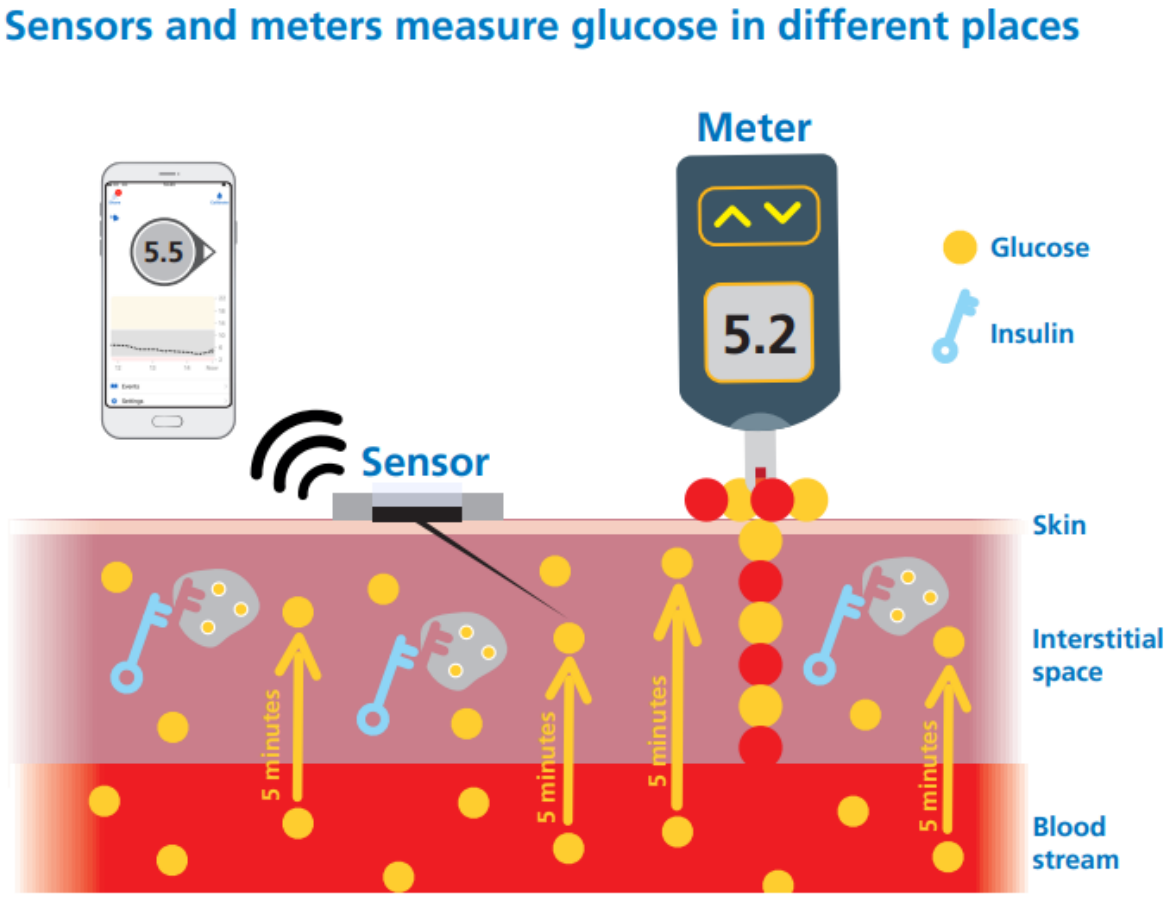


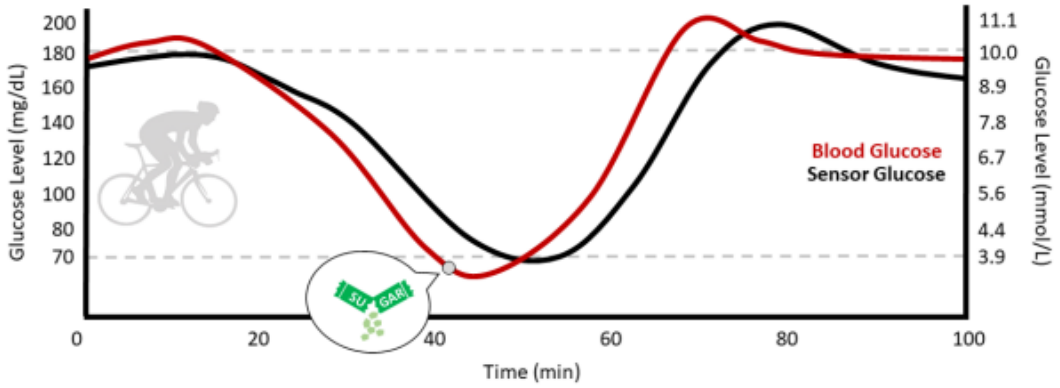
BG = blood glucose

SG = sensor glucose

Delay can be 15 minutes

CGMs and exercise

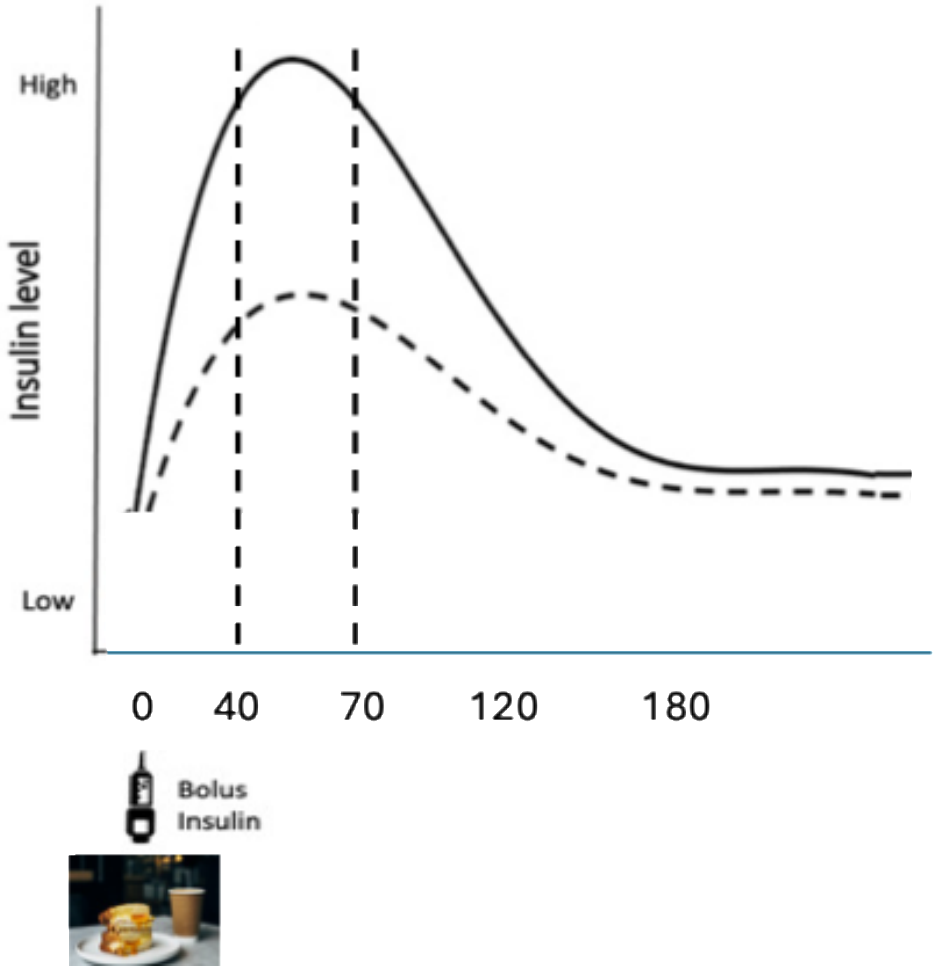




To optimise around exercise: Consider

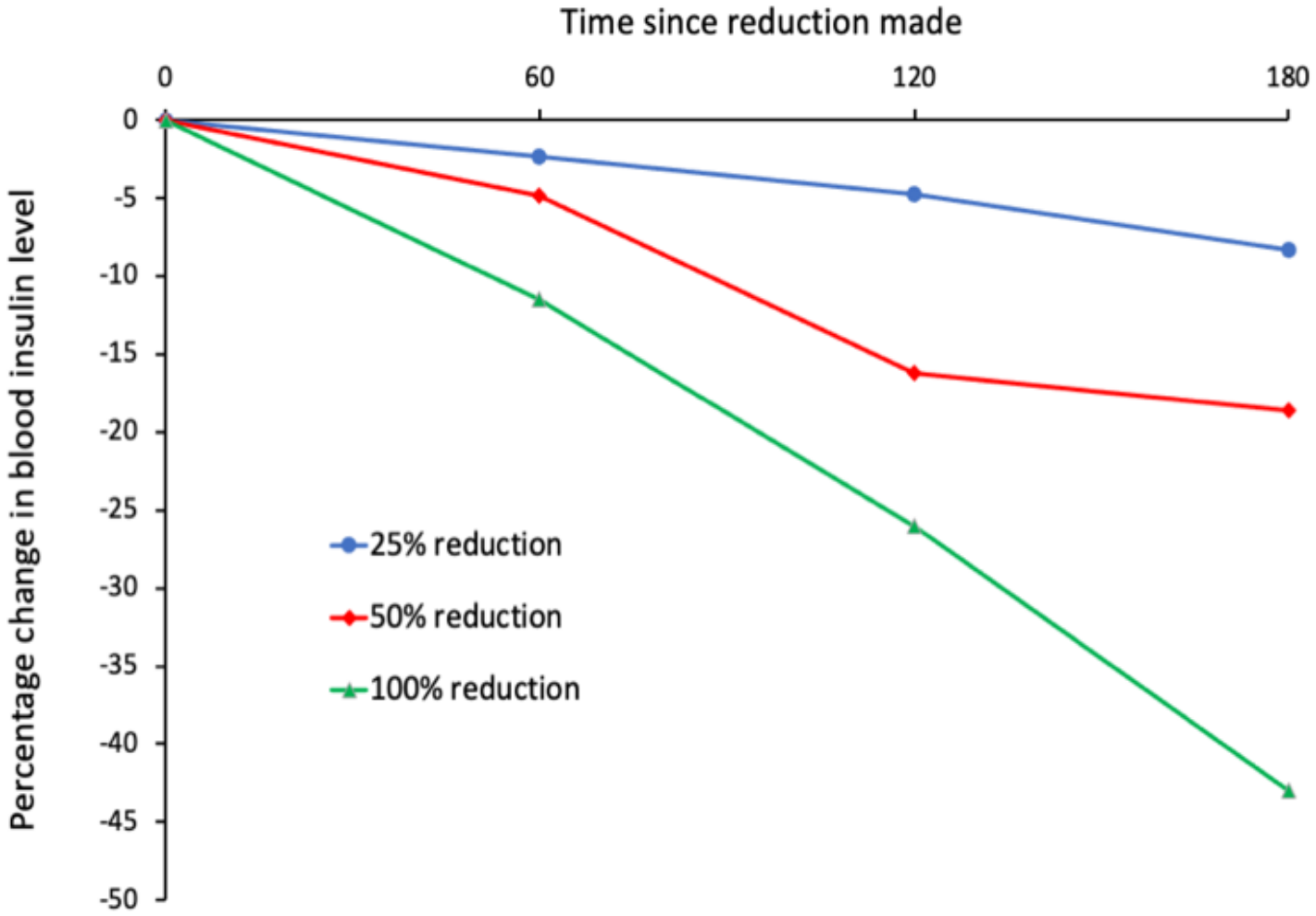
- Set low glucose alert higher at 5.5mmol/L
- Setting fall alert
- Test blood glucose if falling rapidly and close to hypo
- *EASD/ISPAD – Diabetologia* **63**, 2501–2520 (2020)

Best time to exercise after making a change in bolus at mealtime

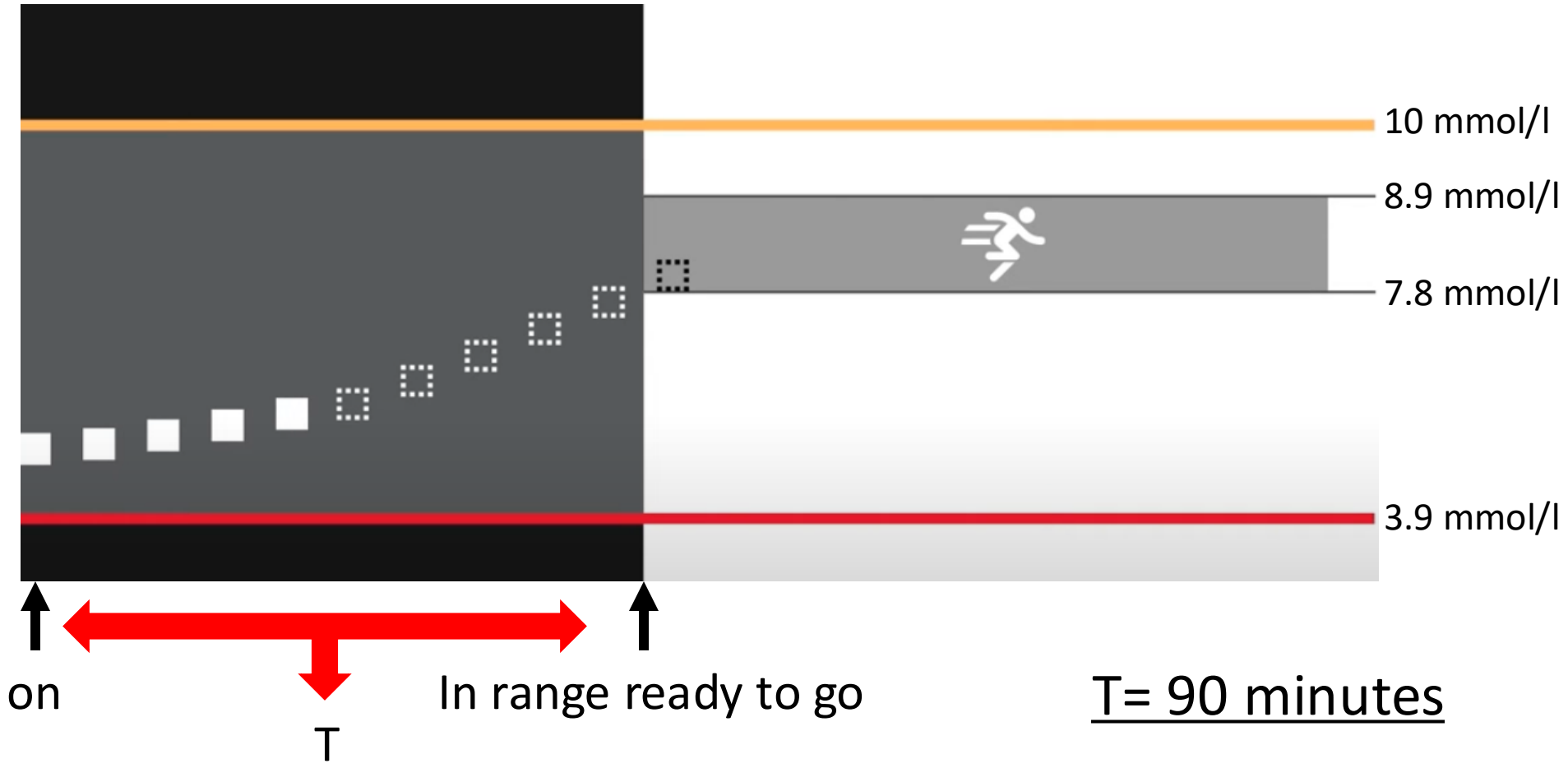


- If reduce bolus insulin dose get greatest reduction in insulin levels 40-70 minutes after dose.

Changes in insulin levels after change in background



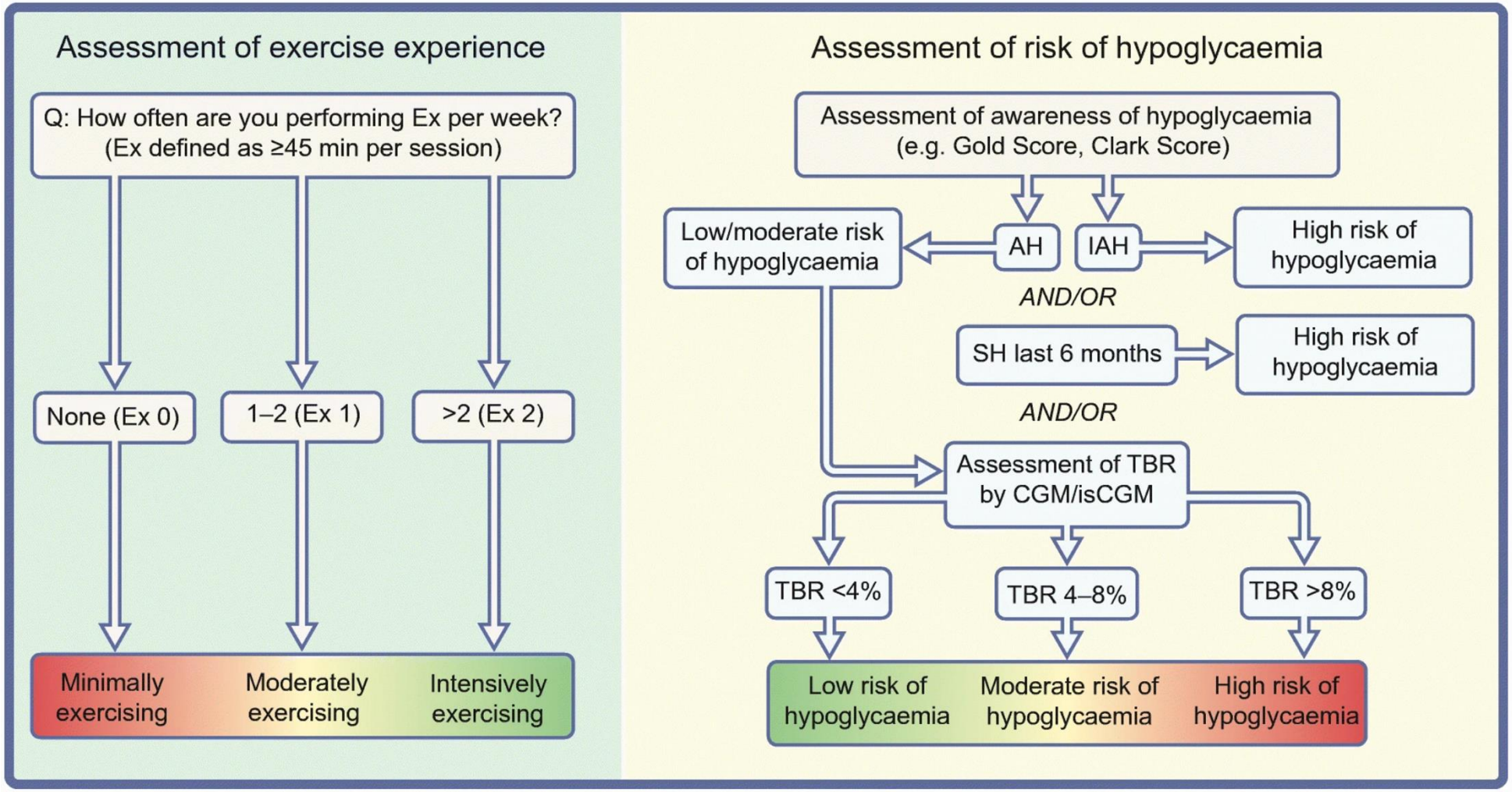
Time taken to get to steady state after switching on Activity or temp mode



T= 90 minutes

Step 2 – workout their hypo risk with exercise

Work out personalised target for exercise



Moser et al (2020)
Diabetologia
63:2501-2520

Step 3 – Give them clear advice on starting glucoses

Blood glucose levels that say “no”

Low blood glucose

- Blood glucose < 3.5 mmol/L

- Severe hypoglycaemia (needed help)
  - Don’t exercise for 24 hours

- Self-treated hypoglycaemia
  - Be careful for 24 hours
  - If it occurs before exercise – treat and have stable glucose for 60 minutes before starting
  - If it occurs during exercise – stop, treat, recommence after stable for 45 minutes

High blood glucose

- Blood glucose >15 mmol/L

- Ketone greater than 1.5 mmol/L
  - Take insulin wait until ketones have dropped before exercise

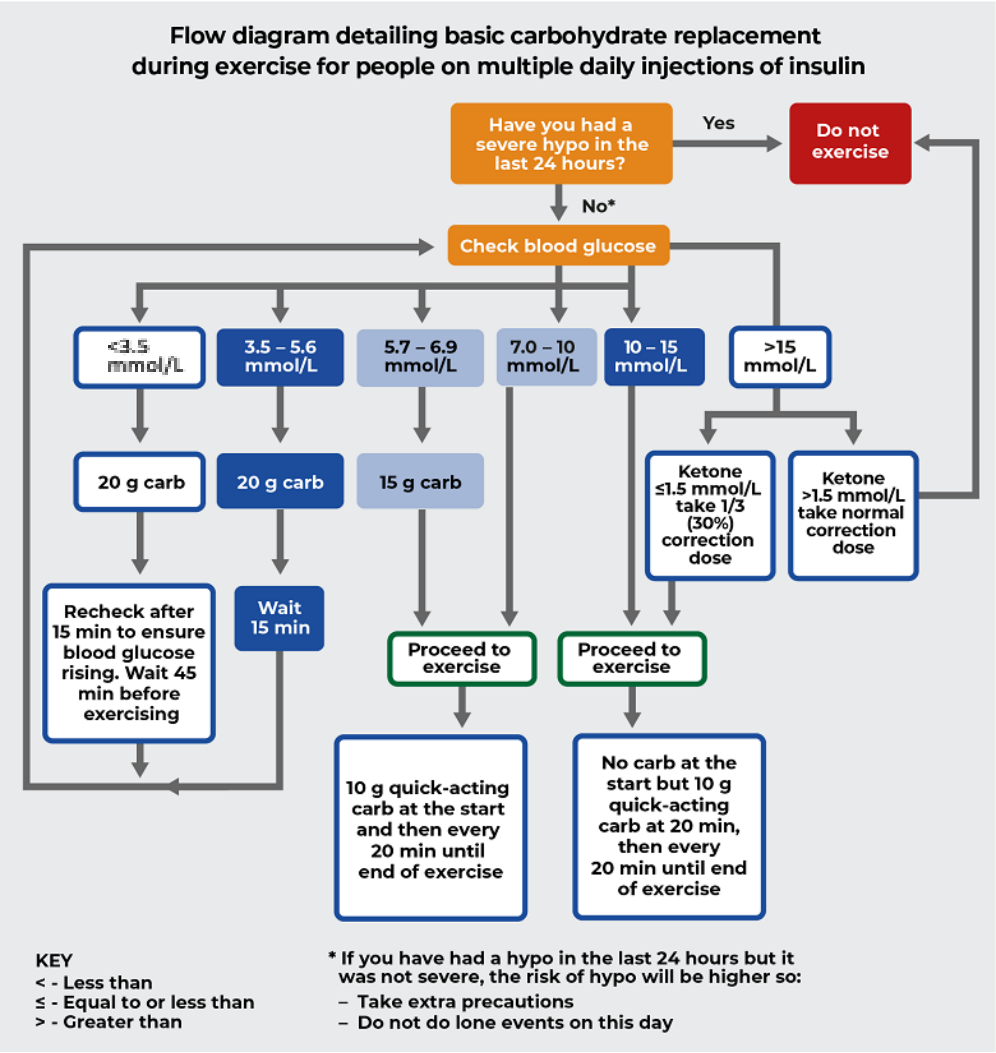
- Ketones less than or equal to 1.5 mmol/L
  - Eaten <2 hours: just monitor
  - Eaten >2 hours: take extra insulin
  - Can do low to moderate intensity exercise

University of Exeter

If you cannot measure your blood ketones we suggest you take a 1/3 of your normal correction dose and then wait until your blood glucose is below 15 before exercising and ensure that you do not do anaerobic exercise on that day

NHS Somerset NHS Foundation Trust

EXTOD guidelines for starting glucose for exercise



Additional information

Confirm with BG reading if

- Glucose <5.0
- Glucose >15

Libre / Dexcom / Medtronic	Description	% of suggested carbs
↑↑↑	Rapidly rising	0%
↑ ↑↑	Rising	50%
↗ ↑	Slowly rising	75%
→	Stable	100%
↘ ↓	Slowly falling	125%
↓ ↓↓	Falling	150%
↓↓↓	Rapidly falling	200%

More complex adjustments

Pre-exercise sensor glucose for different groups in T1D			Trend arrow	Action	
Ex 2 and/or low hypo risk	Ex 1 and/or moderate hypo risk[a]	Ex 0 and/or high hypo risk[b]	Direction	Increase in sensor glucose expected	Decrease in sensor glucose expected
>15.0 mmol/l (>270 mg/dl) AND >1.5 mmol/l blood ketones			↑↗→↘↓	No Ex, Insulin correction	
>15.0 mmol/l (>270 mg/dl) AND ≤1.5 mmol/l blood ketones			↗↑	Consider insulin correction[c], Can start AE	Consider insulin correction[c], Can start all Ex
			→	Consider insulin correction[c], Can start AE	Consider insulin correction[c], Can start all Ex
			↘↓	Can start all Ex	
10.1–15.0 mmol/l (181–270 mg/dl)	11.1–15.0 mmol/l (199–270 mg/dl)	12.1–15.0 mmol/l (217–270 mg/dl)	↗↑	Can start AE Consider insulin correction for RT, HIT[c]	
			→	Can start all Ex, Consider insulin correction[c]	Can start all Ex
			↘↓	Can start all Ex	
7.0–10.0 mmol/l (126–180 mg/dl)	8.0–11.0 mmol/l (145–198 mg/dl)	9.0–12.0 mmol/l (162–216 mg/dl)	↗↑	Can start all Ex	
			→		
			↘↓	Can start all Ex	~15 g CHO, Can start all Ex
5.0–6.9 mmol/l (90–125 mg/dl)	5.0–7.9 mmol/l (90–144 mg/dl)	5.0–8.9 mmol/l (90–161 mg/dl)	↗↑	Can start all Ex	~15 g CHO, Can start all Ex
			→	~10 g CHO, Can start all Ex	~20 g CHO, Can start all Ex
			↘	~15 g CHO, Delay all Ex[d]	~25 g CHO, Delay all Ex[d]
			↓	20 g CHO, Delay all Ex[d]	~30 g CHO, Delay all Ex[d]
3.9–4.9 mmol/l (70–89 mg/dl)			↑	~10 g CHO, Can start all Ex	~20 g CHO, Delay all Ex[d]
			↗	~15 g CHO, Delay all Ex[e]	~25 g CHO, Delay all Ex[d]
			→	20 g CHO, Delay all Ex[e]	~30 g CHO, Delay all Ex[d]
			↘	~25 g CHO, Delay all Ex[e]	~35 g CHO, Delay all Ex[d]
			↓	Individual amount CHO ingestion, Delay all Ex[e]	Individual amount CHO ingestion, Delay all Ex[d]
<3.9 mmol/l (<70 mg/dl)			Individual amount CHO ingestion, Delay all Ex[f]		

Moser et al (2020)
Diabetologia
63:2501-2520

More complex adjustments

Pre-exercise sensor glucose for different groups in T1D			Trend arrow	Action	
Ex 2 and/or low hypo risk	Ex 1 and/or moderate hypo risk[a]	Ex 0 and/or high hypo risk[b]	Direction	Increase in sensor glucose expected	Decrease in sensor glucose expected
7.0–10.0 mmol/l (126–180 mg/dl)	8.0–11.0 mmol/l (145–198 mg/dl)	9.0–12.0 mmol/l (162–216 mg/dl)	↗↑	Can start all Ex	
			→		
			↘↓	Can start all Ex	~15 g CHO, Can start all Ex
5.0–6.9 mmol/l (90–125 mg/dl)	5.0–7.9 mmol/l (90–144 mg/dl)	5.0–8.9 mmol/l (90–161 mg/dl)	↗↑	Can start all Ex	~15 g CHO, Can start all Ex
			→	~10 g CHO, Can start all Ex	~20 g CHO, Can start all Ex
			↘	~15 g CHO, Delay all Ex[d]	~25 g CHO, Delay all Ex[d]
			↓	20 g CHO, Delay all Ex[d]	~30 g CHO, Delay all Ex[d]

Moser et al (2020) Diabetologia 63:2501-2520

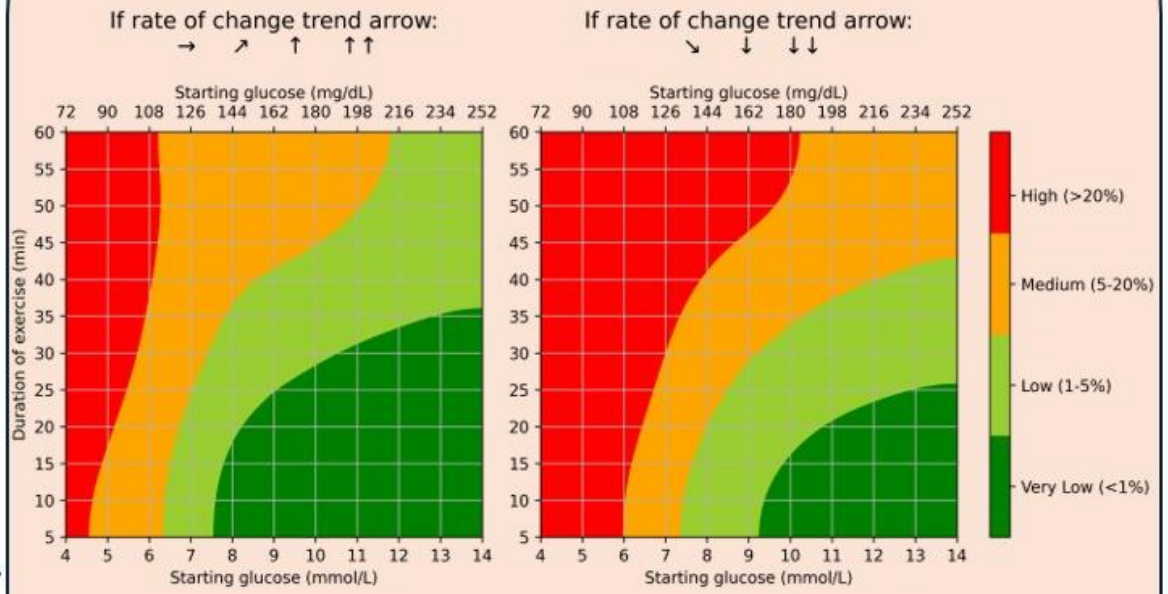
GlucoseGo: A simple tool to predict hypoglycaemia during exercise

Fear of hypoglycaemia major barrier to exercise for people with type 1 diabetes

Machine Learning identified 3 key variables for prediction:

1. Starting glucose
2. Duration of exercise
3. Glucose trend arrows

GlucoseGo Heatmap

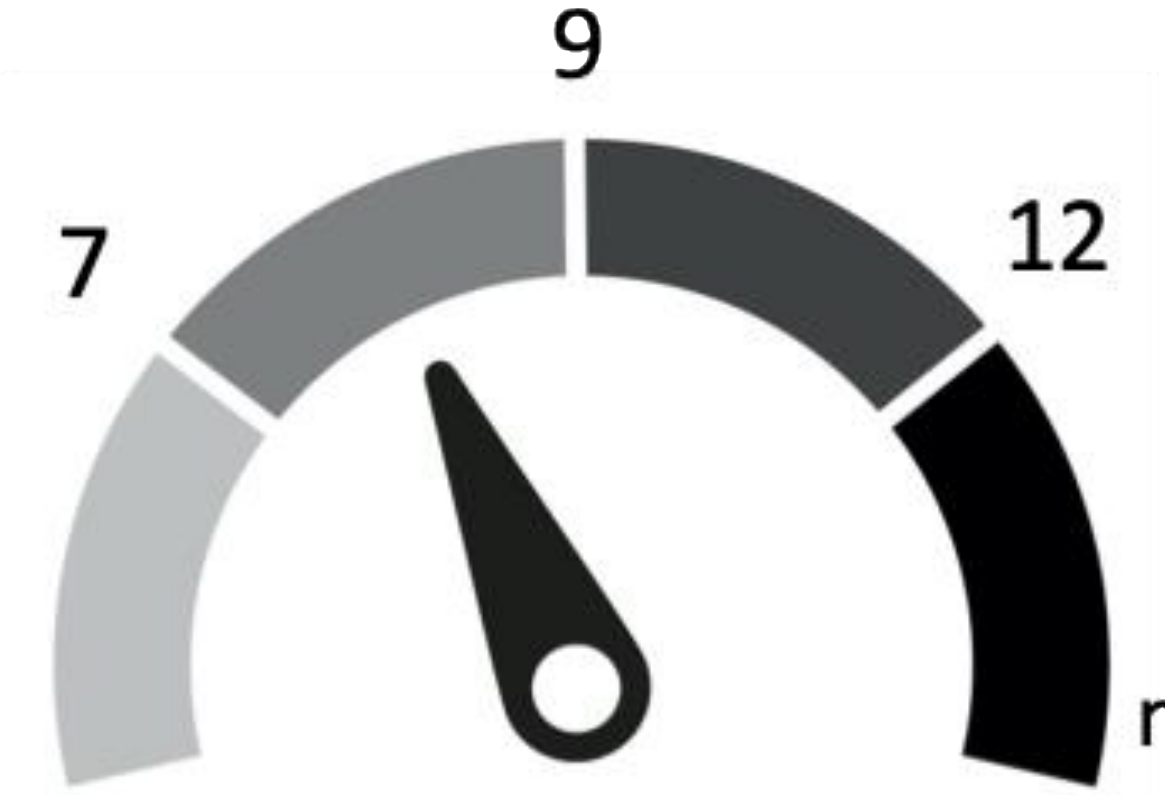


Accurate

Simple, usable tool

C Russon et al
In press with Diabetologia

Sensor glucose target range for exercise



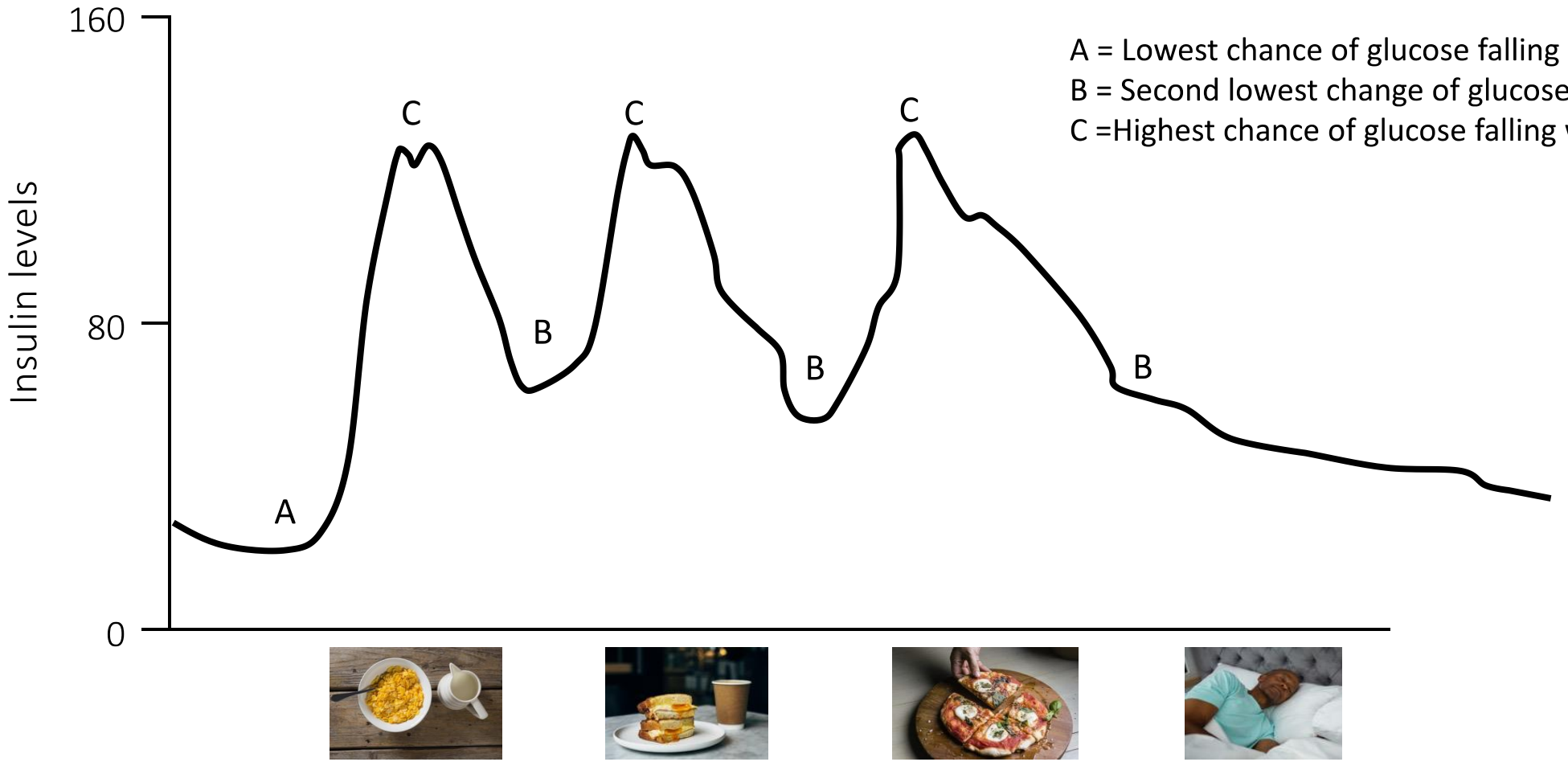
8-10 if medium risk hypo
9-11 if high risk hypo

But if on closed loop 7-9 best

Aim for 7-9 mmol/l

Step 4 – Suggest trying to exercise at point with lowest insulin concentration

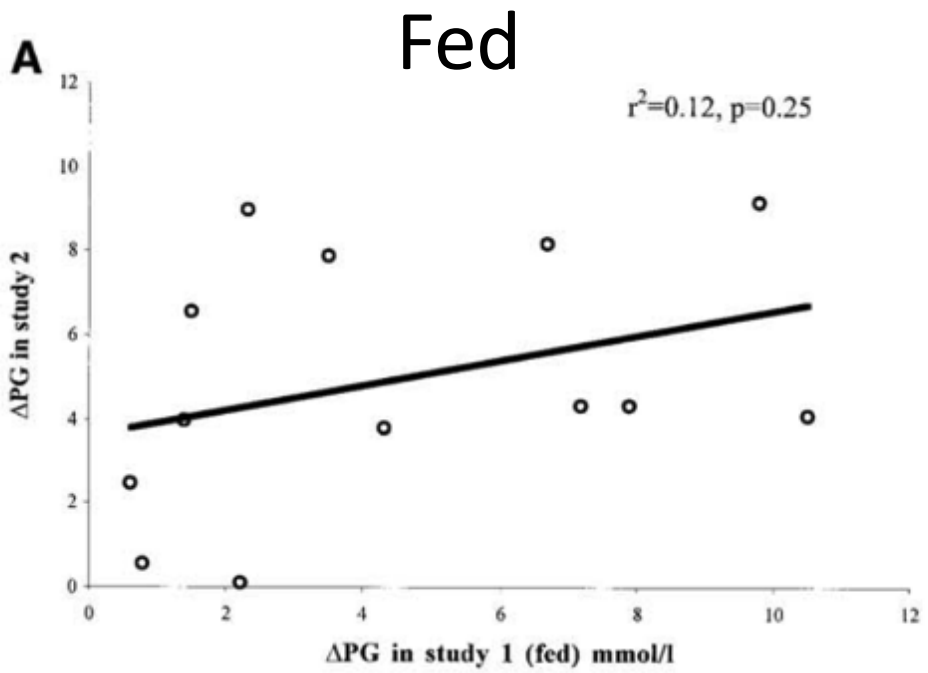
Prevailing insulin concentration



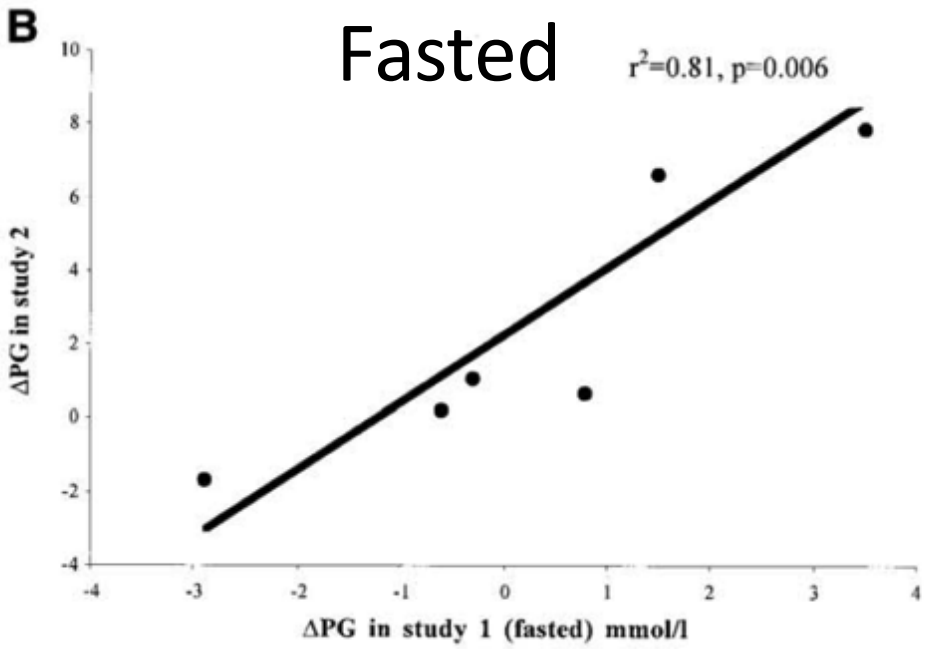
A = Lowest chance of glucose falling with exercise
B = Second lowest change of glucose falling with exercise
C =Highest chance of glucose falling with exercise

Exercising fasted gives more reproducible glucose changes

Biankin et al., Diabetes Care 2003

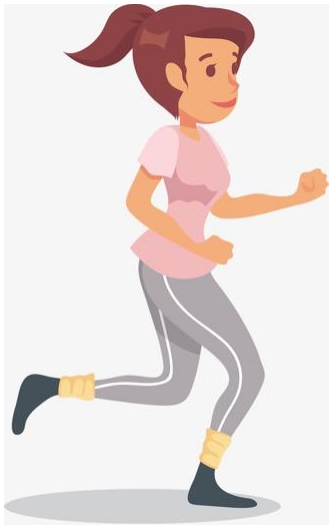


Poor reproducibility in the blood glucose response to aerobic exercise in individuals with T1D in the post meal state



Good reproducibility in the blood glucose response to aerobic exercise in individuals with T1D in the fasted state

Exercising in the morning has less risk of hypoglycaemia



Greater risk of hypo if exercise undertaken after 4pm

Insulin resistance

Wakefulness

Answers step 1-4 a

True or False

1. The accuracy of continuous glucose monitors is not affected by exercise. False – get worse
2. The delay in glucose readings from CGM is 3-5 minutes. False – 15 min
3. A reduction made in a bolus at mealtime will cause the greatest reduction in insulin levels 40-75 minutes after the meal. True
4. If a 50% reduction is made in the background insulin rate on a insulin pump, at 2 hours the insulin level will have fallen by 50%. False
5. It takes 10-30 minutes to reach a steady state after switching to exercise or temp mode on a hybrid closed loop system. False

Answers step 1-4 b

True or False

1. People with T1D who exercise regularly are at greater risk of hypoglycaemia when they exercise than people who do not exercise regularly. False – less risk of hypo
2. Time in hypo can help to predict hypo risk with exercise. True
3. It is safe to exercise, if take precautions if had serious hypo in last 24 hours. False – should not exercise
4. If glucose is above 15mmol/l exercise is not advised. False – depends on ketones
5. The starting glucose and how long you are going to exercise can be used to accurately predict risk of hypoglycaemia during exercise. True
6. Exercising fasted first thing in the morning is the safest time to exercise. True

Step 5 – three options

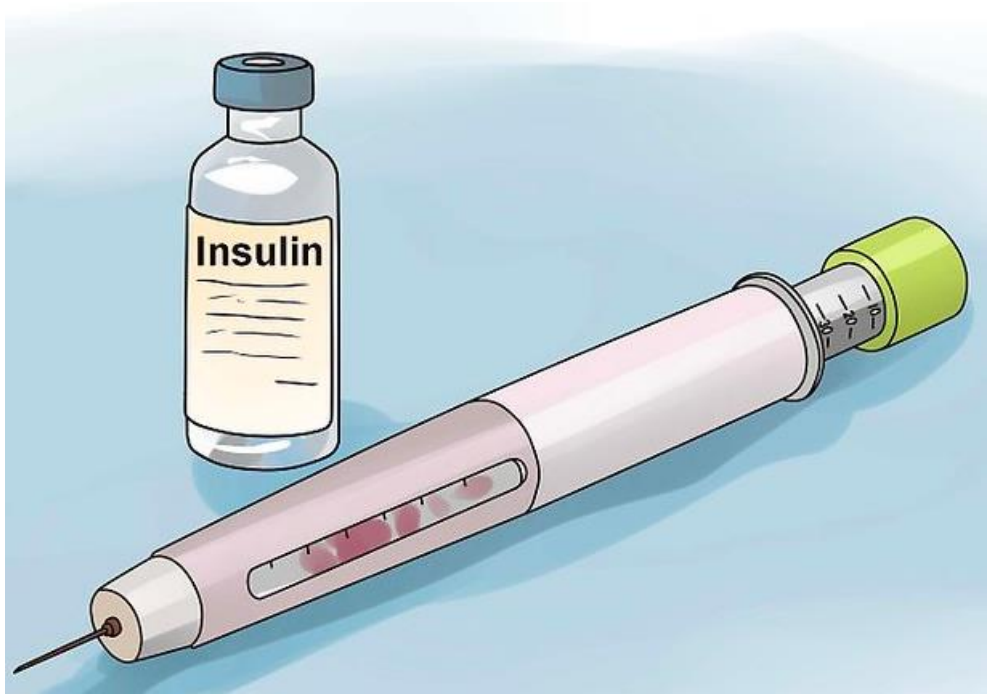
Three ways to manage glucose during exercise - ICE

Insulin

Carbohydrate

Exercise

Step 4a – changing insulin level – best if trying to lose weight

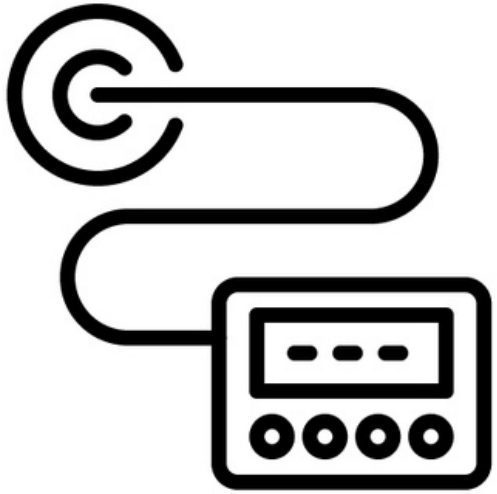


Questions step 5 a part 1

True or False for people on pumps

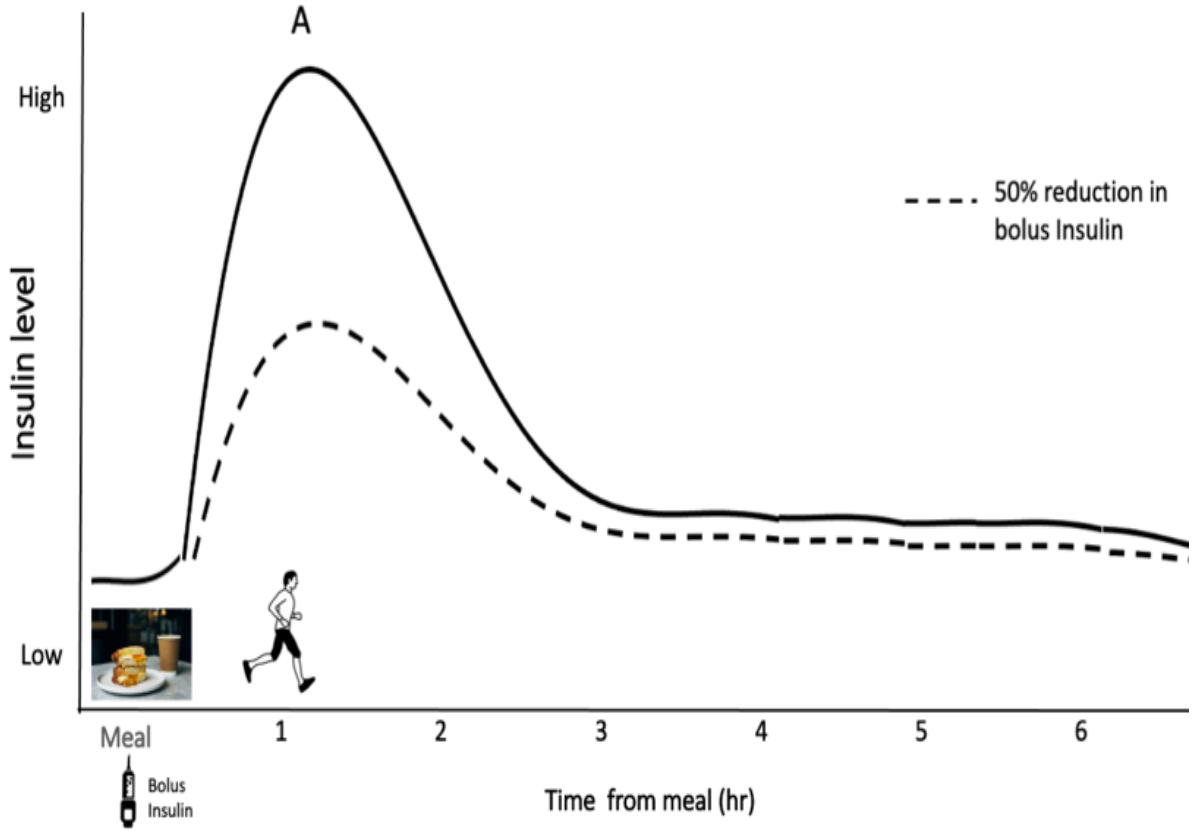
1. For those using an insulin pump and exercising within two hours of a meal, it is advisable to **reduce the basal rate by 50% approximately 90 minutes before exercise** and to **administer 50% less of the meal bolus**.
2. The **type and intensity of exercise** can be used to determine appropriate adjustments to both bolus and basal insulin.
3. For **spontaneous exercise**, those on insulin pumps have the option to **temporarily disconnect**, which can be helpful in reducing the risk of hypoglycaemia.

Pump changes for exercise



Insulin Pump

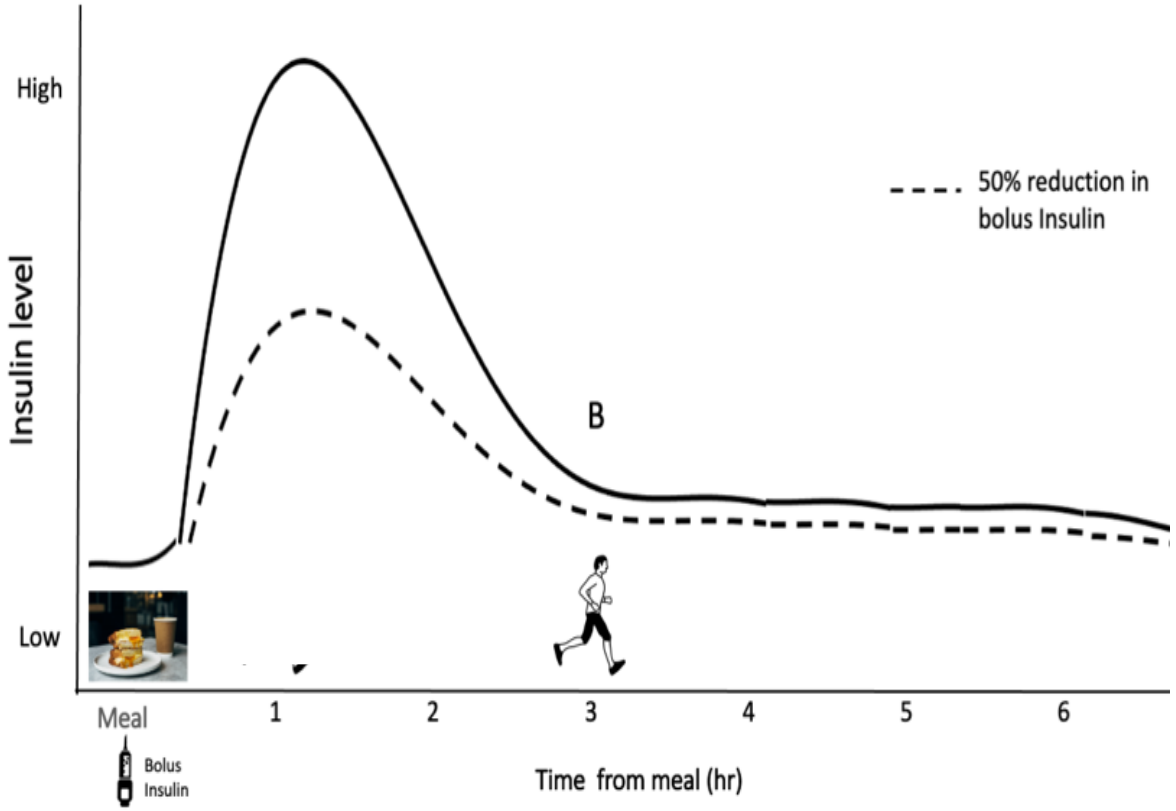
Simple strategy if exercising within 2 hrs of meal



If exercising within 2 hours of quick acting (bolus) insulin (point A).

Pumps

Simple strategy if exercising >2hrs after meal



If exercising greater than 2 hours after meal (point B).

Pumps

Changes in bolus insulin by intensity and duration of exercise for MDI and pump

Exercise intensity (%V02 max)	% dose reduction	% dose reduction
	30 mins of exercise	60 mins of exercise
Low	25	50
Moderate	50	75
High	75	100

Only helps if exercising within 2 hours of taking bolus insulin

Background changes for insulin pumps

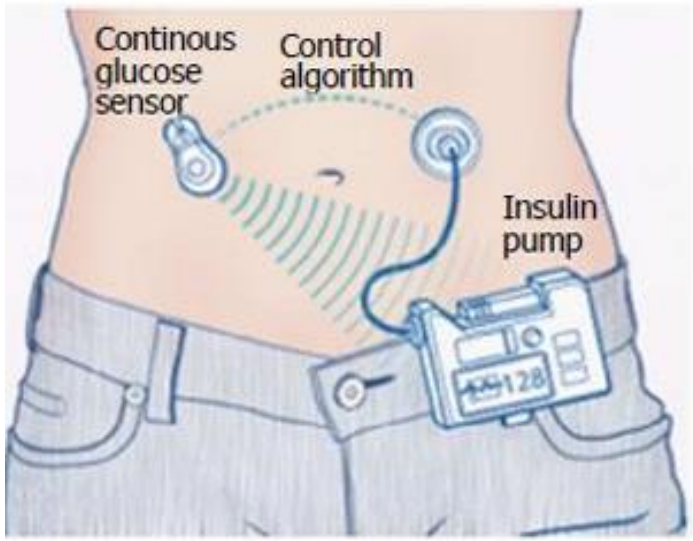
	Changes in basal insulin	
Exercise	**30 min of exercise**	**60 min of exercise**
Aerobic	50% reduction in basal rate 90 minutes before exercise	80% reduction in basal rate 90 minutes before exercise.
Anaerobic	No reduction	50% reduction in basal rate 90 minutes before exercise
High intensity interval training	No reduction	No reduction
Mixed: intermittent aerobic and anaerobic	100% reduction at exercise start	50% reduction in basal rate 90 minutes before exercise

Answers step 5 a part 1

True or False for people on pumps

1. For those using an insulin pump and exercising within two hours of a meal, it is advisable to **reduce the basal rate by 50% approximately 90 minutes before exercise** and to **administer 50% less of the meal bolus**. False only change bolus
2. The **type and intensity of exercise** can be used to determine appropriate adjustments to both bolus and basal insulin. True
3. For **spontaneous exercise**, those on insulin pumps have the option to **temporarily disconnect**, which can be helpful in reducing the risk of hypoglycaemia. True

Hybrid closed loop system changes for exercise



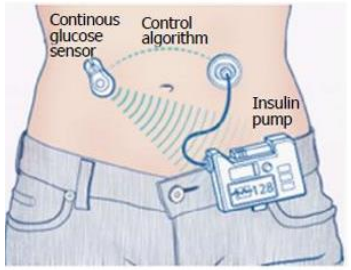
Hybrid closed loop system

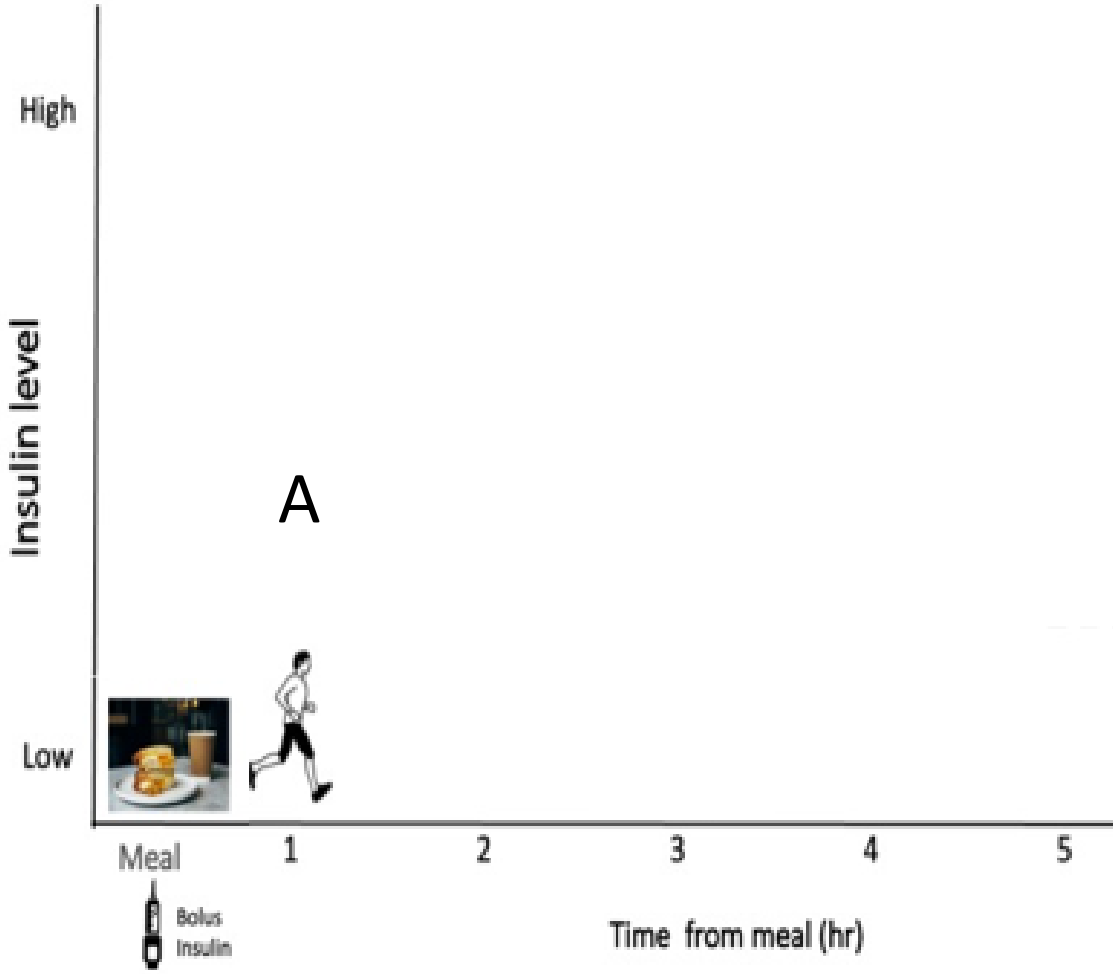
Questions step 5 a part 2

True or False for people on closed loops

1. When aerobic exercising within two hours of a meal, a reduction in bolus insulin is often unnecessary for individuals using a closed-loop system.
2. For aerobic exercise taking place more than two hours after a meal, activity mode should be activated approximately 30 minutes before starting.
3. The type and intensity of exercise can help inform appropriate adjustments to both bolus insulin and the use of activity mode.
4. A range of tools have been developed to support more detailed and individualised adjustments for different types of physical activity.
5. If where previously on a pump and had worked out a system that worked manually should stick with that when move to closed loop.

Simple strategy if exercising within 2 hrs of meal

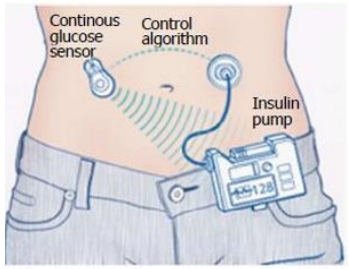


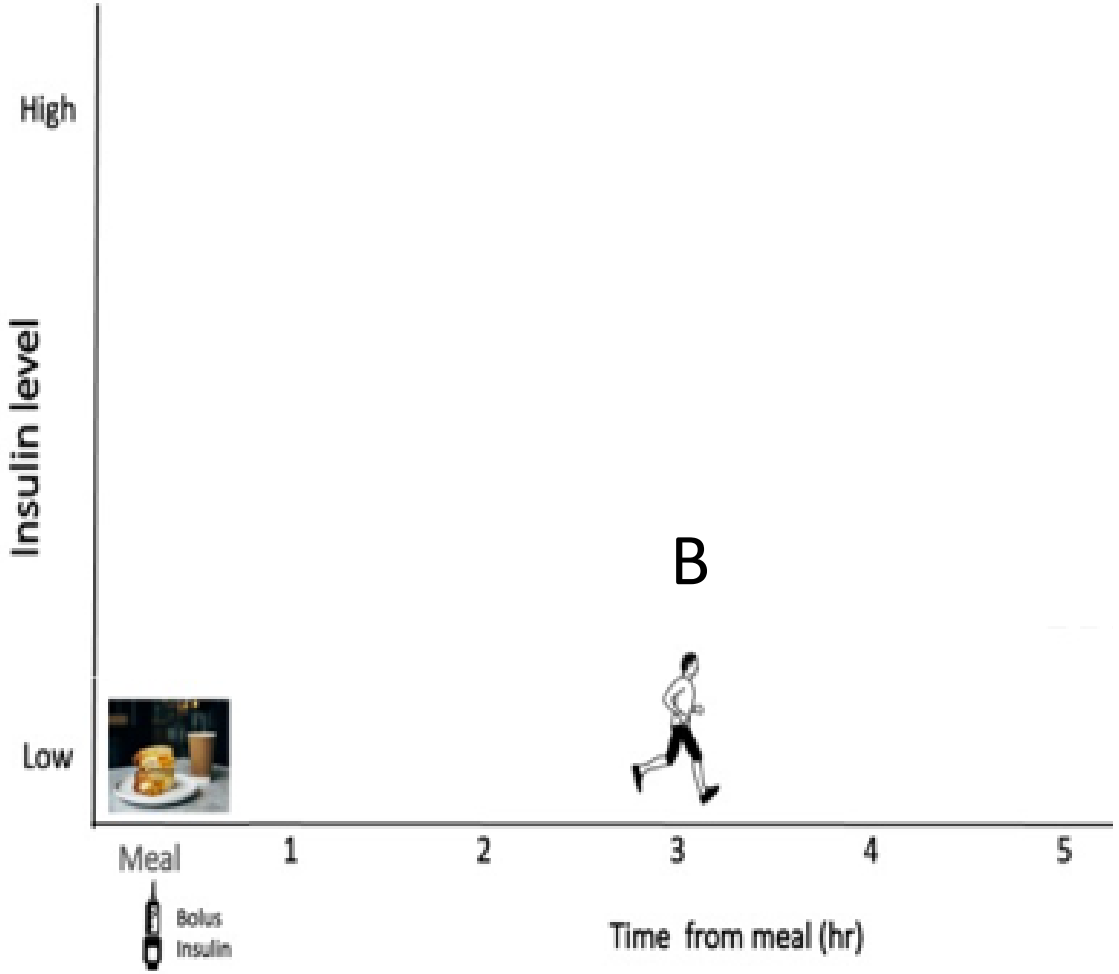


If exercising within 2 hours of quick acting (bolus) insulin point A.

Closed loop systems

Simple strategy for Insulin when exercising 2 hours outside of last bolus





If exercising greater than 2 hours after meal point B

Closed loop systems

Advanced changes for hybrid closed loops

	Changes to hybrid closed loop	
Exercise	Mealtime insulin if exercising with 2 hours of meal	Activity or temp target put on or not 90 minutes before exercise
Aerobic	25-30% reduction in bolus for meal prior to exercise	On
Anaerobic	Regular bolus for meal prior to exercise	Off
High intensity interval training	Regular bolus for meal prior to exercise	Off
Mixed: intermittent aerobic and anaerobic	25-30% reduction in bolus for meal prior to exercise	On

Helpful additional aids

Figure 1 Exercise intensity and mode	After food, sustained, continuous, low stress hormone response	Mixed activity: Individual and team	Fasted overnight, burst, explosive, competitive anaerobic, high stress hormone response
			
Average glucose response to exercise	↓ ↘	→	↗ ↑
Exogenous insulin requirements around exercise	↓ ↘	→	↗ ↑
Carbohydrate intake requirements around exercise	↑ ↗	→	↘ ↓

Figure 2

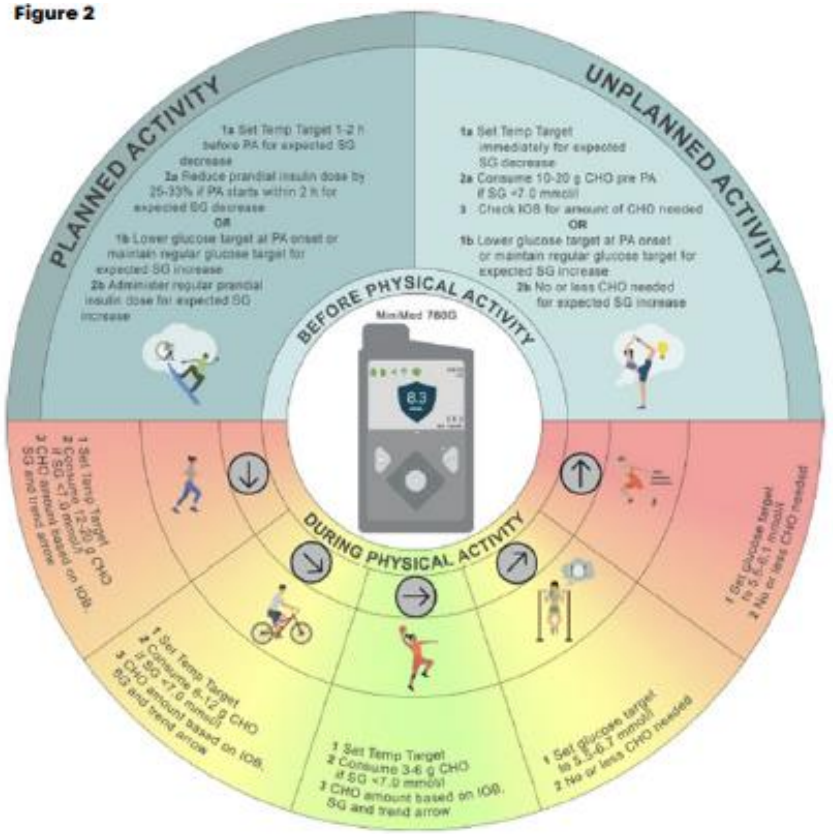
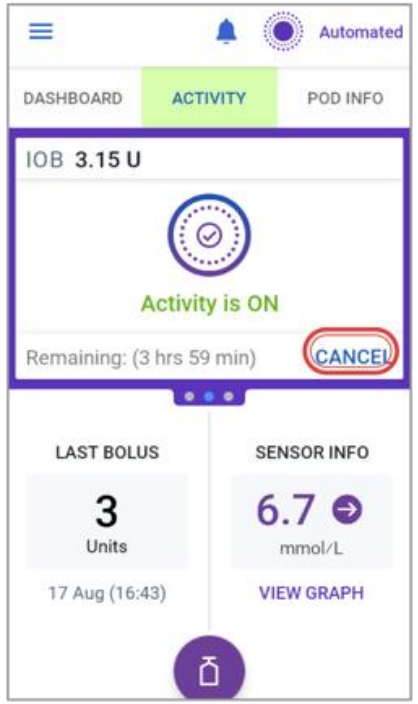
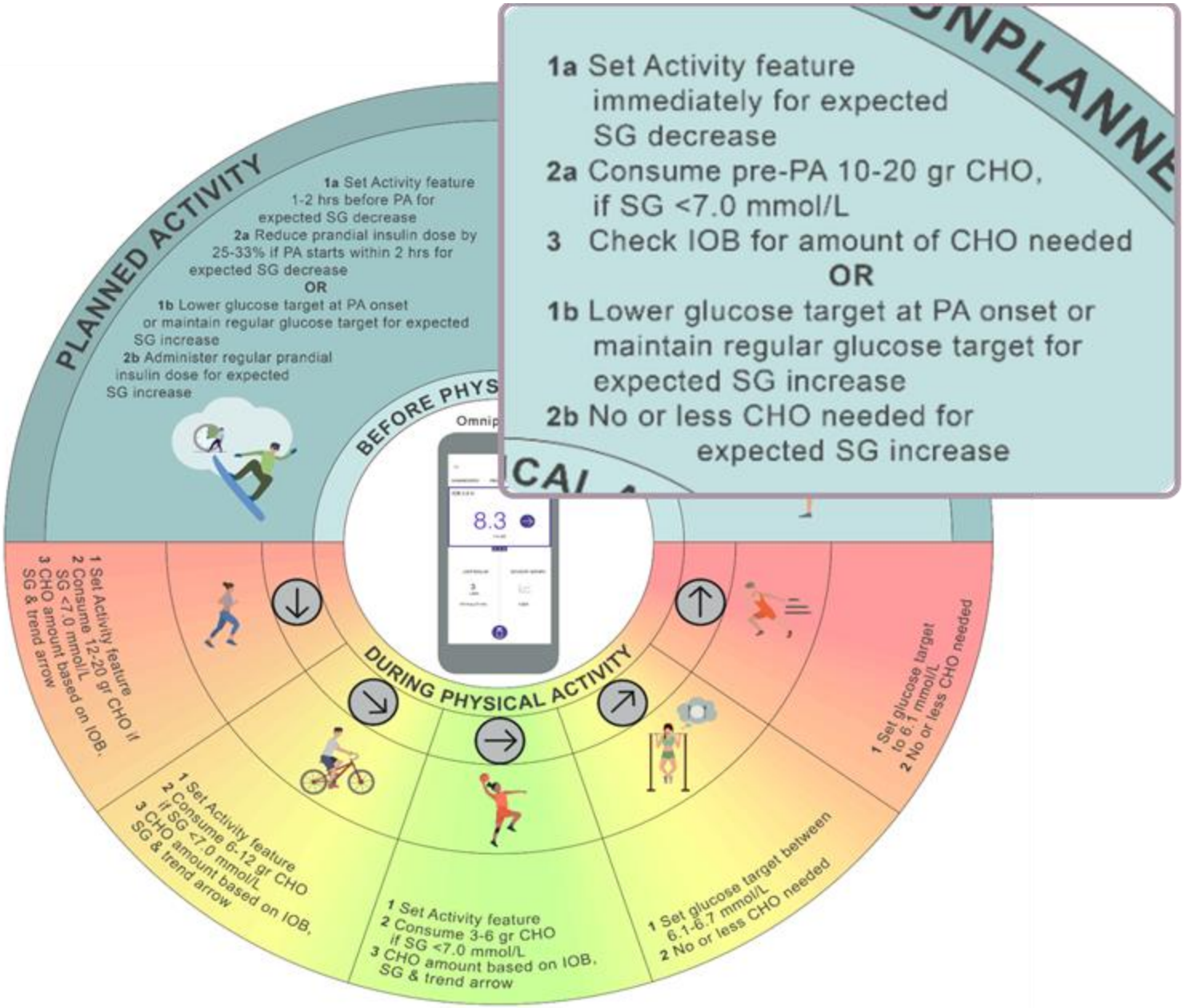


Figure 1: Adolfsson, P. et al (2022). ISPAD.

Figure 2: Moser, O. et sl (2025). Diabetologia. Feb; 68(2):255-280.

Omnipod 5®





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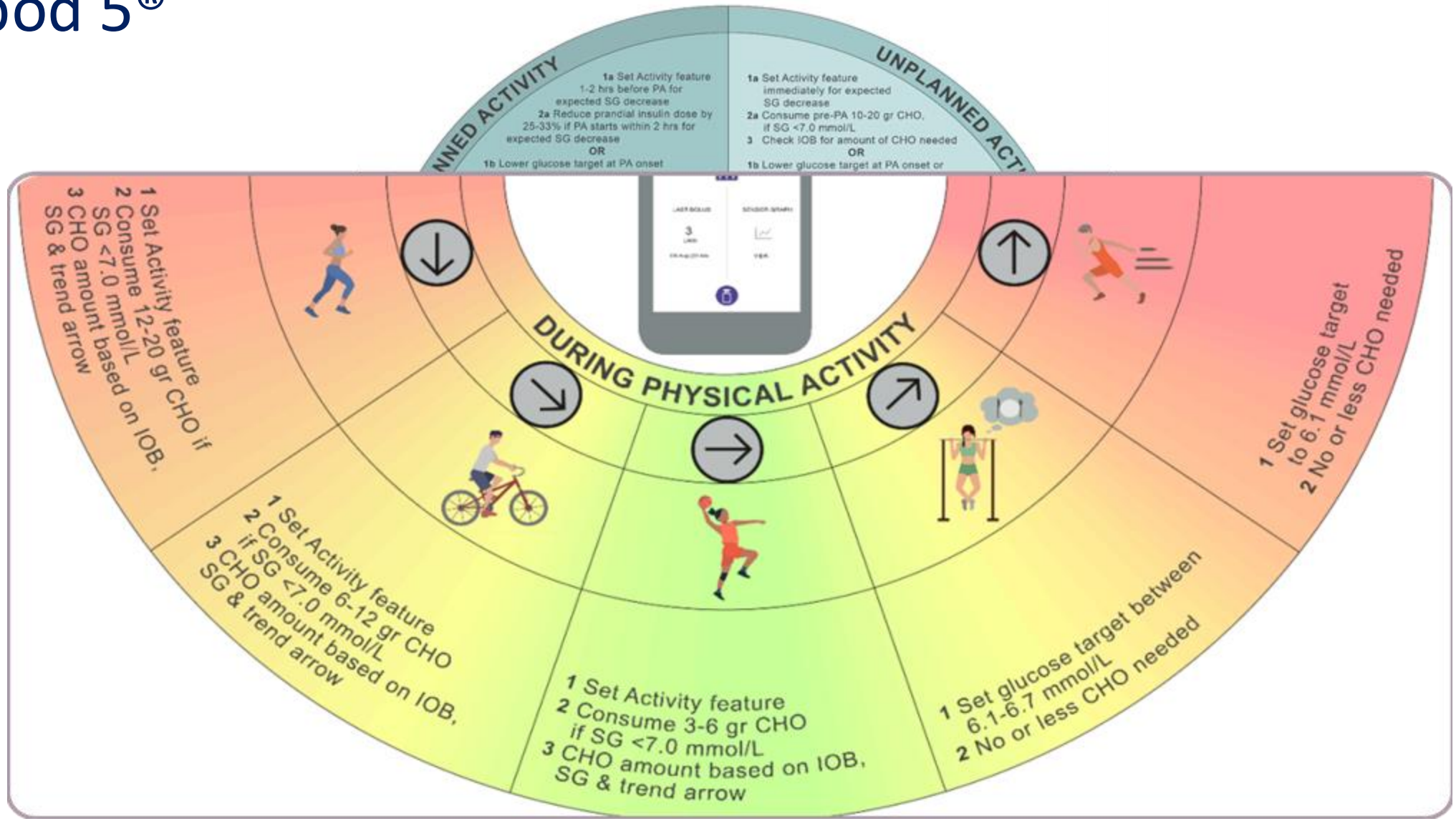

NNED ACTIVITY
1a Set Activity feature 1-2 hrs before PA for expected SG decrease
2a Reduce prandial insulin dose by 25-33% if PA starts within 2 hrs for expected SG decrease
OR
1b Lower glucose target at PA onset
UNPLANNED ACT
1a Set Activity feature immediately for expected SG decrease
2a Consume pre-PA 10-20 gr CHO, if SG <7.0 mmol/L
3 Check IOB for amount of CHO needed
OR
1b Lower glucose target at PA onset or
DURING PHYSICAL ACTIVITY
1 Set Activity feature
2 Consume 12-20 gr CHO if SG <7.0 mmol/L
3 CHO amount based on IOB, SG & trend arrow
1 Set Activity feature
2 Consume 6-12 gr CHO if SG <7.0 mmol/L
3 CHO amount based on IOB, SG & trend arrow
1 Set Activity feature
2 Consume 3-6 gr CHO if SG <7.0 mmol/L
3 CHO amount based on IOB, SG & trend arrow
1 Set glucose target between 6.1-6.7 mmol/L
2 No or less CHO needed
1 Set glucose target to 6.1 mmol/L
2 No or less CHO needed

Answers step 5 a part 2

True or False for people on closed loops

1. When aerobic exercising within two hours of a meal, a reduction in bolus insulin is often unnecessary for individuals using a closed-loop system. False
2. For aerobic exercise taking place more than two hours after a meal, activity mode should be activated approximately 30 minutes before starting. False
3. The type and intensity of exercise can help inform appropriate adjustments to both bolus insulin and the use of activity mode. True
4. A range of tools have been developed to support more detailed and individualised adjustments for different types of physical activity. True
5. If where previously on a pump and had worked out a system that worked manually should stick with that when move to closed loop. True

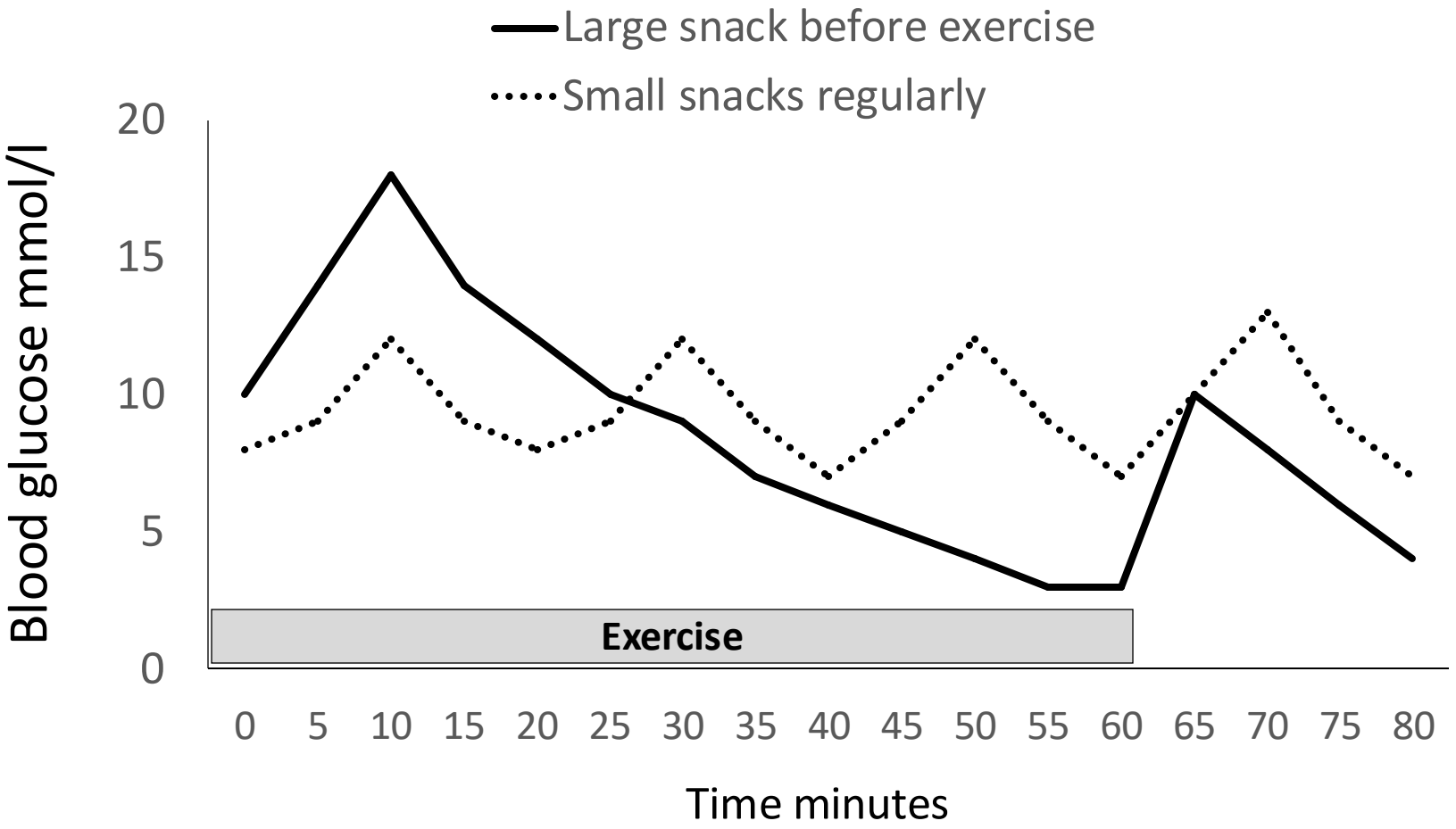
Step 4b – carbohydrate – good for spontaneous exercise

Questions step 5 b

True or False

1. On a pump giving carbohydrates at the start of exercise but for people on closed loops this should be avoided unless needed to prevent hypos.
2. For people on pump carbohydrate should be given every 20 minutes.
3. For people on closed loop systems carbohydrates may need to be taken every 10 minutes to stop glucose going above 10 mmol/l.
4. A simple calculator can be used to help to manage carbohydrate across exercise dependent on GCM readings.

Simple carbohydrate replacement



MDI/ Pump
Start with 0.5 grams/ kg / hr

Closed loop
Start with 0.25 grams/ kg / hr

Take carbs every 20 mins or every 10 if on Hybrid close loop

Carb replacement based on CGM readings

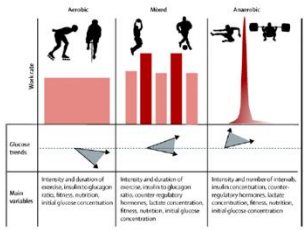
Based on guidelines John Pemberton has made a PDF that people can work out how much carbohydrate to take dependent on flash or continuous glucose readings

GNL

Type 1 Diabetes Exercise Carbohydrate Calculator

I agree: This is for information only and I will check with my diabetes team: Yes

1. What's your name: Rob Andrews
2. What activity are you doing ?: running
3. Weight in kilograms (kg)?: 80
4. What is your exercise hypoglycaemia risk?: Low (All of: 1. Exercise more than 2 times a week, 2. TBR less than 4%, 3. Hypo aware
5. What type of activity are you doing (see pictures)?: Aerobic
9. What glucose units does your device use?: mmol/L
10. At what glucose & ketone level should you stop exercise?: ≥15.0mmol/L (270mg/dL) & ≥1.5mmol/L



Guidelines the Type 1 DEC is based on (click & read):

- Moser et al (2020) EASD/ISPAD CGM& Exercise
- Adolfsson et el (2018) ISPAD Paediatric Exercise
- Riddell et al (2017) Type 1 Exercise Consensus (where the graphic is from)

Disclaimer

- Carbohydrate plans must be made by a qualified diabetes professional
- Always consult a qualified diabetes professional before trying or adapting a plan

www.theglucoseneverlies.com

University of Exeter

NHS Somerset NHS Foundation Trust

Carb replacement based on CGM readings

What looks like if on pump or MDI and Libre

Rob Andrews running

Sensor Gucose Level	Trend arrow & action to take	Carbohydrate grams needed for 20 mins	Dextrose (3g)	Glucotab (4g)
<4.0mmol/L Check BG	<3.0mmol/L: NO exercise	18 Treat & re-check in 20 minutes	6	5
4.0-4.9 mmol/L	↓	30 & delay exercise for 20 minutes	10	8
	↘	24 & delay exercise for 20 minutes	8	6
	→	18 & delay exercise for 20 minutes	6	5
	↗	12 & delay exercise for 20 minutes	4	3
	↑	6 & delay exercise for 20 minutes	2	2
5.0-6.9 mmol/L	↓	30 & start exercise check in 20 mins	10	8
	↘	24 & start exercise check in 20 mins	8	6
	→	18 & start exercise check in 20 mins	6	5
	↗ ↑	12 & start exercise check in 20 mins	4	3
7.0-10.0 mmol/L	↘ ↓	18 & start exercise check in 20 mins	6	5
	→	0 & start exercise check in 20 mins		
	↗ ↑	0 & start exercise check in 20 mins		
10.1-14.9 mmol/L	All Arrows	0 & start exercise check in 20 mins		
≥15.0mmol/L (Check BG) & ketones <1.5mmol/L	→ ↘ ↓	OK to exercise: No carbohydrate for 20 minutes		
	↗ ↑	OK to exercise: Consider 50% of correction dose before starting		
≥15.0mmol/L & ketones ≥1.5mmol/L	All Arrows	No exercise: Correction dose & ketones <1.5mmol/L before starting exercise		

University of Exeter

NHS Somerset NHS Foundation Trust

Answers step 5 b

True or False

1. On a pump giving carbohydrates at the start of exercise but for people on closed loops this should be avoided unless needed to prevent hypos. True
2. For people on pump carbohydrate should be given every 20 minutes. True
3. For people on closed loop systems carbohydrates may need to be taken every 10 minutes to stop glucose going above 10 mmol/l. True
4. A simple calculator can be used to help to manage carbohydrate across exercise dependent on GCM readings. True

Step 4c – using exercise – the eye opener

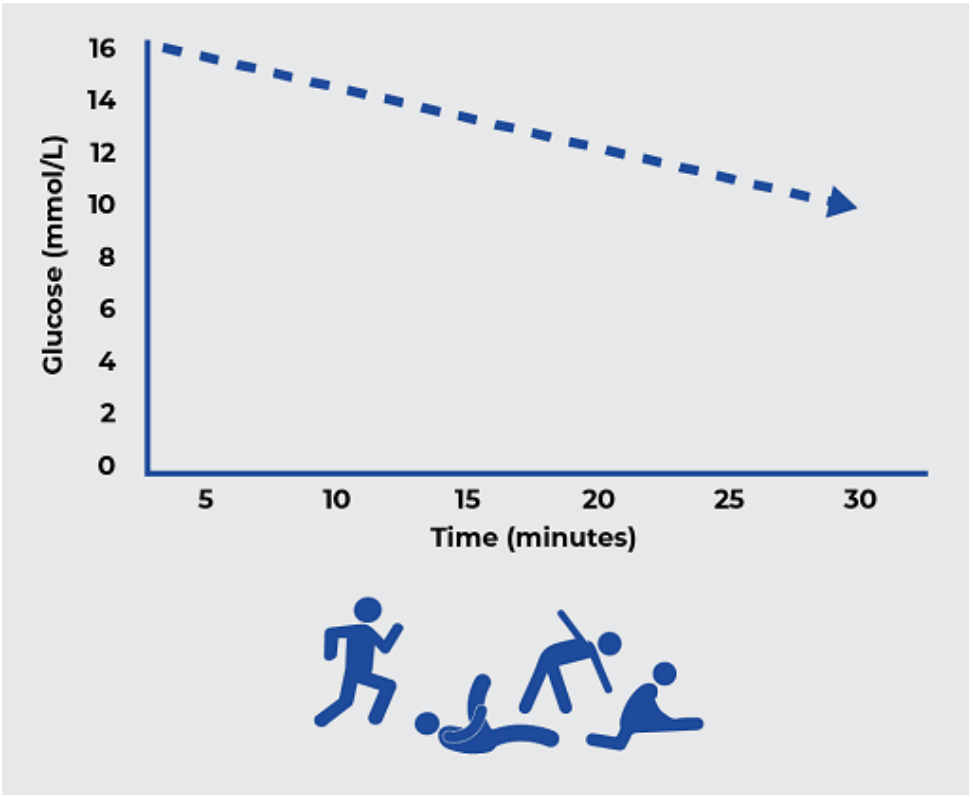
Questions step 5 c

True or False

1. 20 minutes of moderate exercise can lower glucose by 4 mmol/l before exercise.
2. Changing the order of exercise can help to manage glucose.
3. A 10 seconds sprint can protect against glucose falling with exercise for 30-40 minutes.

High glucose before exercise

Prolonged warm up



Post prandial study

Step 1 – "Is glucose level about 10 mmol/L?"

Step 2: - "has bolus insulin been given <4hrs?"

Physical activity works best if a bolus insulin was given in the last 4hrs

Step 3 – Complete 20 minutes of Physical Activity

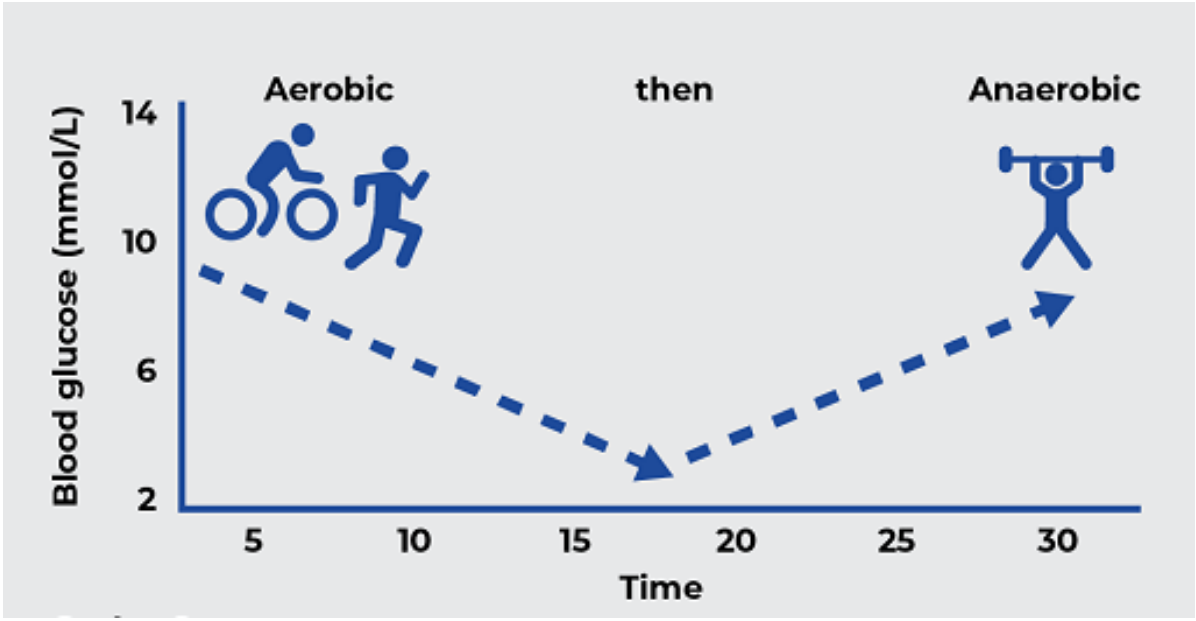
Light to moderate activity (walking is ideal but anything enjoyable is best!)

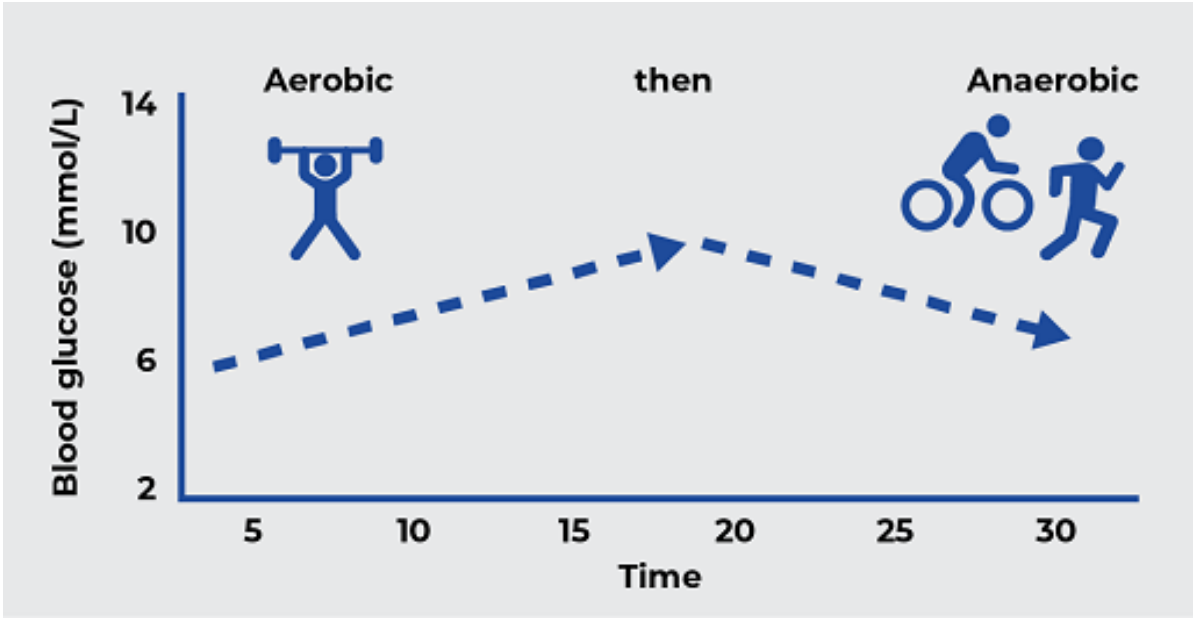
Result: 20 by 2

20 minutes of physical activity lowers glucose by ~2mmol/L

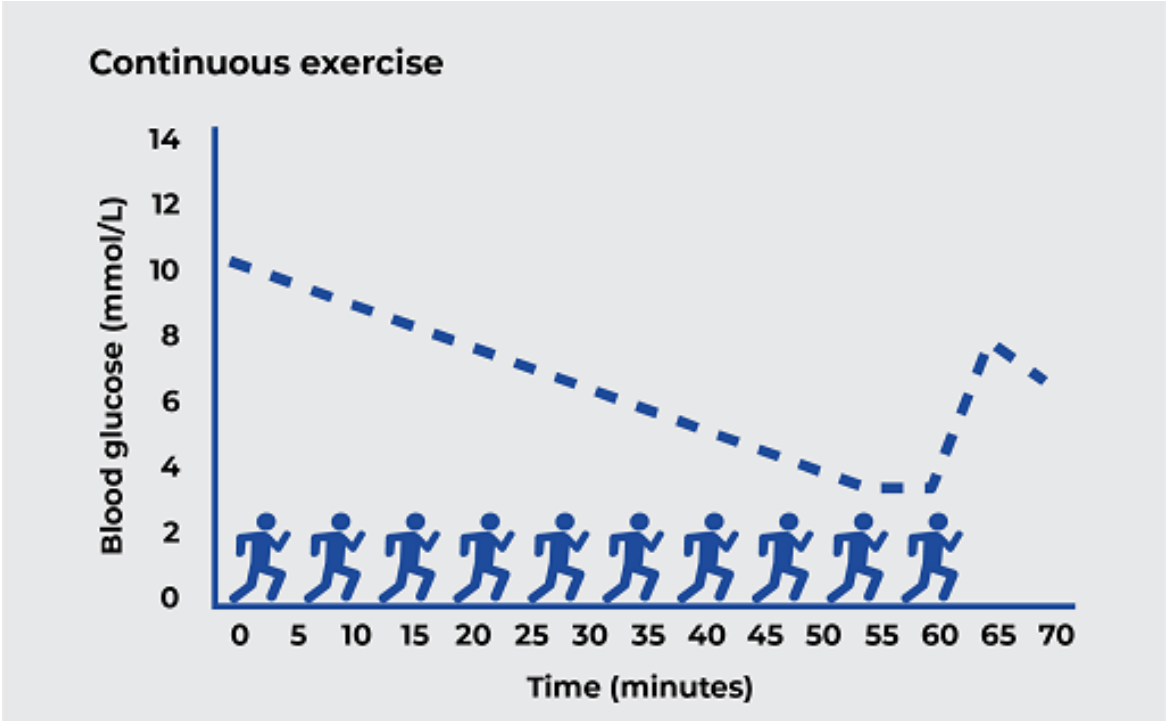
Pemberton JS et al. Diabet Med. 2025 Dec;42(12):e70146. doi: 10.1111/dme.70146.

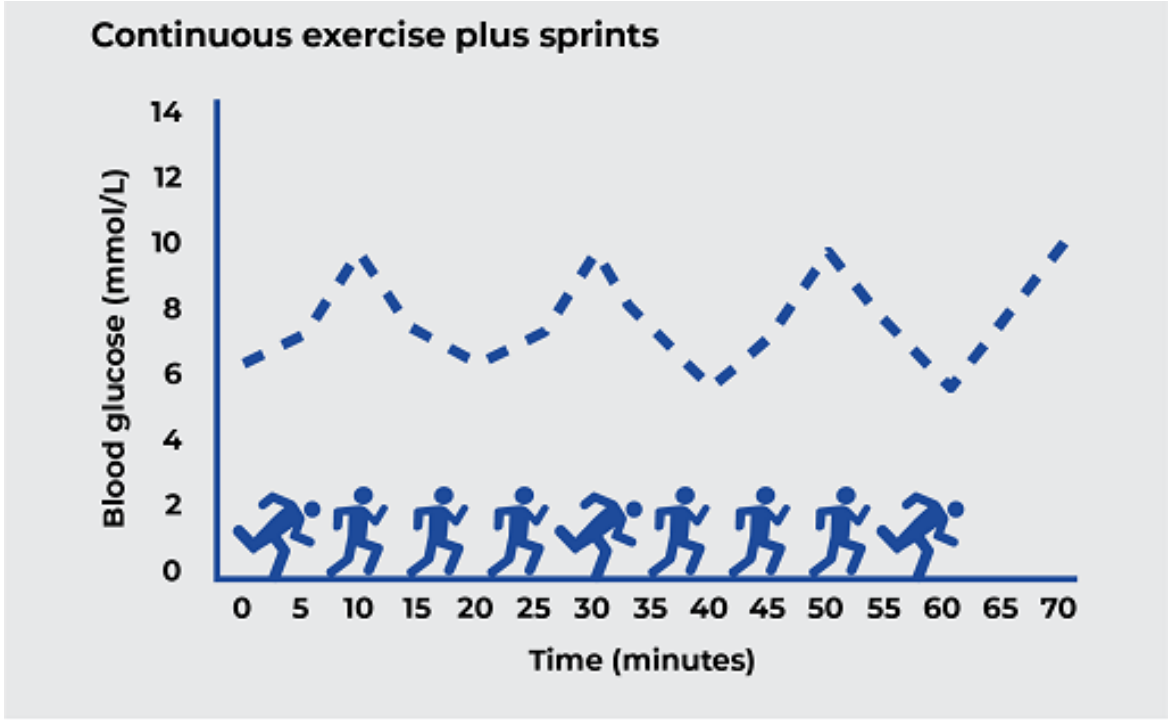
Changing the order of exercise





Sprints can help to control glucose during exercise





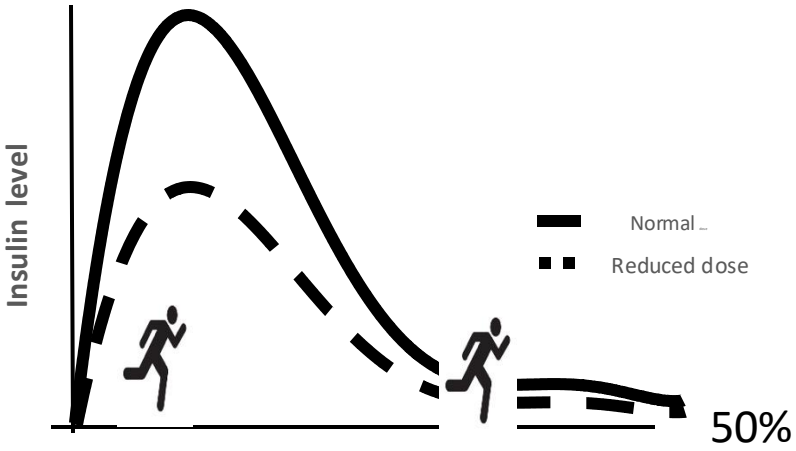
Answers step 5 c

True or False

1. 20 minutes of moderate exercise can lower glucose by 4 mmol/l before exercise. False
2. Changing the order of exercise can help to manage glucose. True
3. A 10 seconds sprint can protect against glucose falling with exercise for 30-40 minutes. True

Summary 2 - Options for managing glucose during exercise

Insulin – how do you alter it



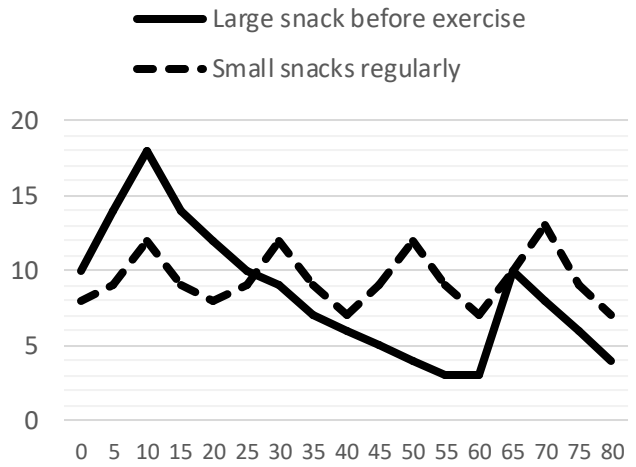
If exercising more than 2 hrs after meal

- MDI – no changes
- Pump – 50% background from 90 min before
- Closed loop – temp/ Ex mode from 90 min before

If exercising more within 2 hrs after meal

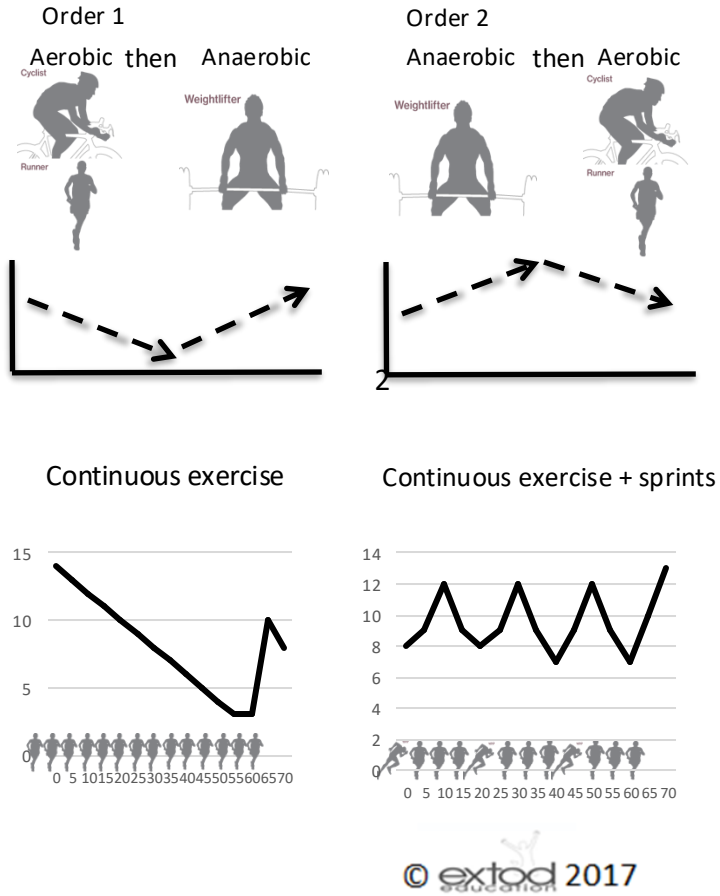
- MDI + Pump – 50% reduction bolus
- Closed loop – 25% reduction bolus + Temp/Ex mode from 90 minutes before

Carbohydrate for exercise

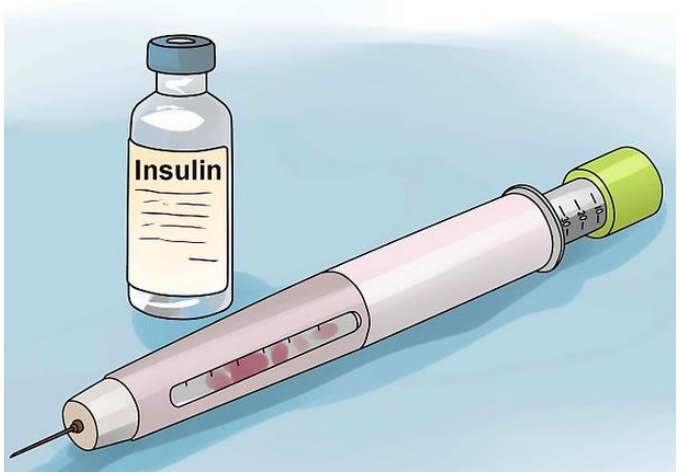


1. 0.5 grams/kg/hr if on MDI or pump. 0.25 grams/kg/hr if on closed loop.
2. Use calculated table

Exercise type and intensity



Three ways to manage glucose post exercise **ICE**

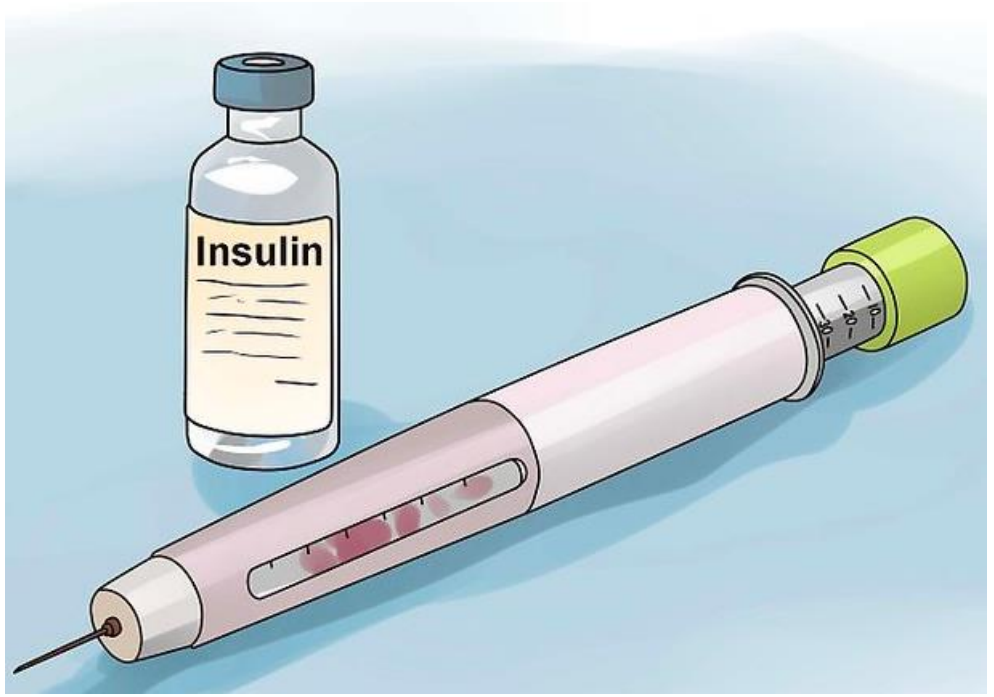


Insulin

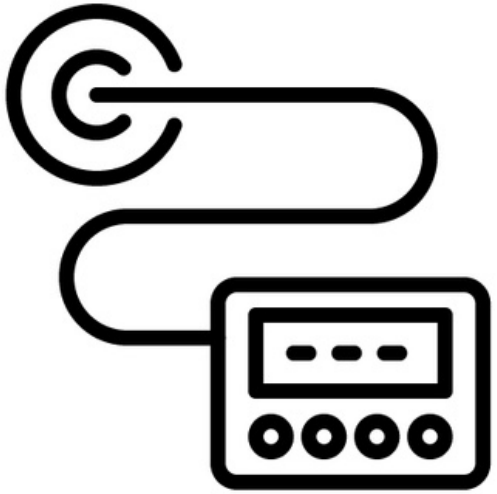
Carbohydrate

Exercise

Option 1 – Insulin changes



MDI and pump changes after exercise

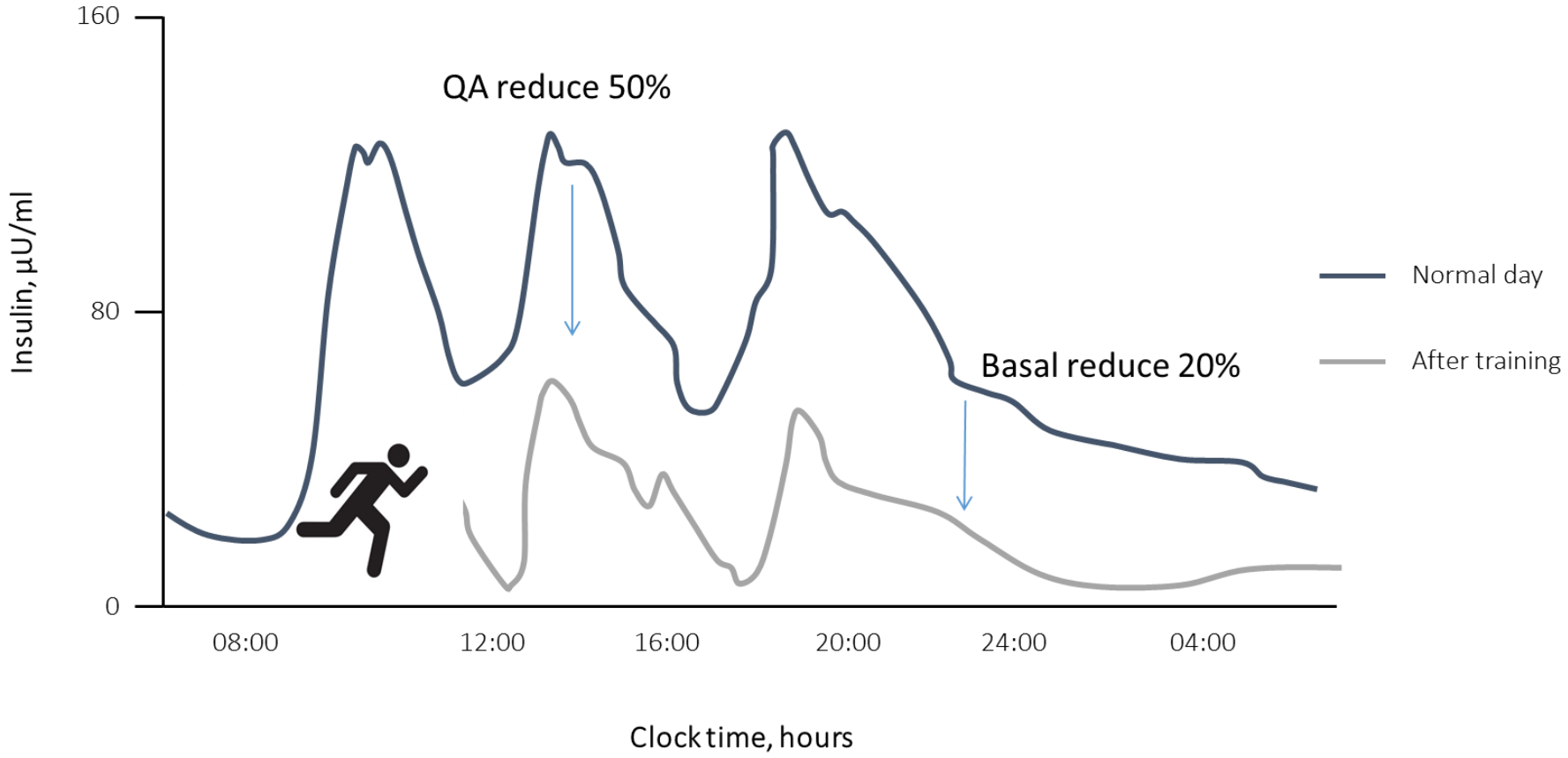


Insulin Pump

Option 1 – questions part 1 – true or false

1. For the first meal following exercise, the bolus insulin dose should be reduced by 50%. Any correction dose should also be reduced by 50%.
2. No adjustment to the bolus dose is required for the second meal after exercise.
3. For insulin pump users, the background rate should be reduced by 20% for six hours from the time of going to bed if they have done a new sport.
4. No adjustments are necessary if exercising on four or more days per week.

Effect of exercise on Insulin sensitivity



The 50-50-20 rule

- Reduce standard bolus insulin by 50% for the next two meals.
- Reduce standard correction doses by 50% for the next 12 hours.
- Reduce evening background insulin by 20% if **any** of the following apply:
    - After 4:00 p.m.
    - More than two hours of exercise
    - New exercise

For MDI (Multiple Daily Injections): Applies only to Tresiba, glargine, detemir, or intermediate-acting insulin.

For insulin pump users: Reduce background (basal) insulin by 20% for six hours from the time of going to bed

Advanced changes for insulin pumps

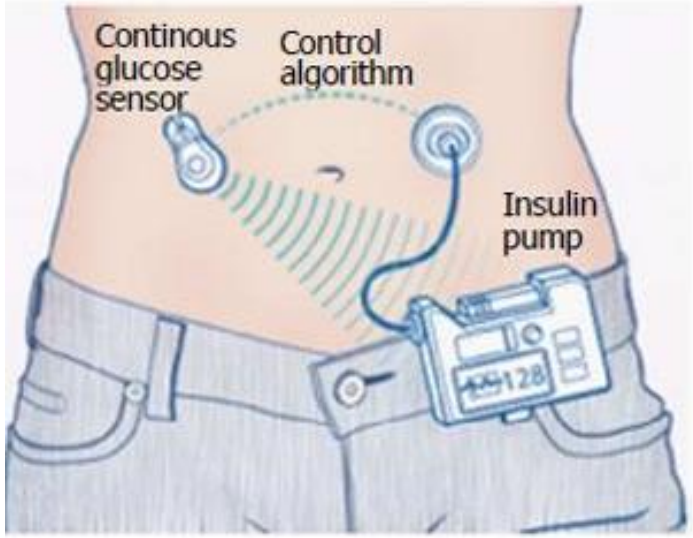
Exercise	Changes in Bolus insulin	Changes in evening background*
Aerobic	50% reduction	20% reduction
Anaerobic	25% reduction	10% reduction
High intensity interval training	No reduction	No reduction
Mixed: intermittent aerobic and anaerobic	25% reduction	10% reduction

* These changes are only made if the exercise lasted more than 2 hrs, the exercise took place after 4pm, the exercise was new or unfamiliar

Option 1– Answers part 1

1. For the first meal following exercise, the bolus insulin dose should be reduced by 50%. Any correction dose should also be reduced by 50%. True
2. No adjustment to the bolus dose is required for the second meal after exercise. False
3. For insulin pump users, the background rate should be reduced by 20% for six hours from the time of going to bed if they have done a new sport. True
4. No adjustments are necessary if exercising on four or more days per week. True

Hybrid closed loop system changes after exercise



Hybrid closed loop system

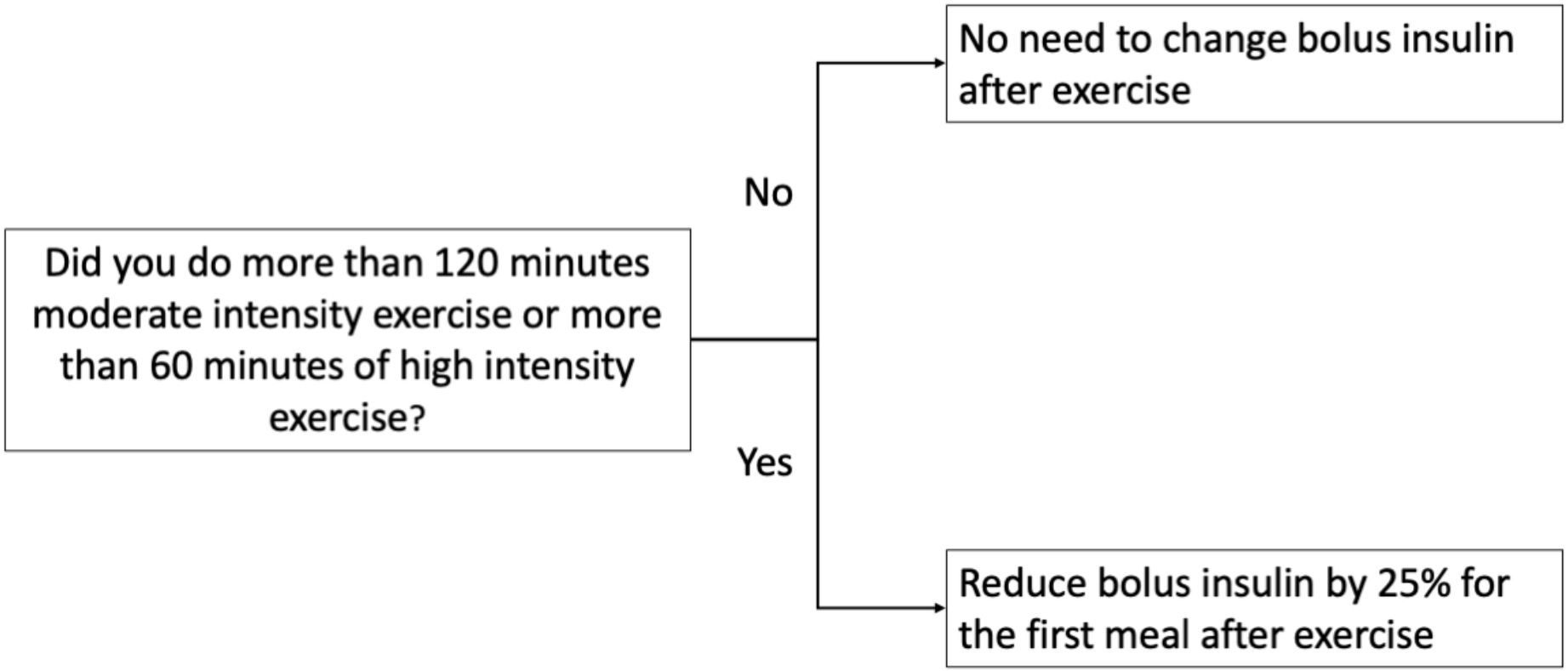
Option 1 - questions part 2 – true or false

1. For the first meal following two hours of exercise, the bolus insulin dose should be reduced by 50%.
2. No adjustment to the bolus dose is required for the second meal after exercise.
3. If hypoglycaemia has been occurring post-exercise, continuing "exercise mode" for one hour after completing activity may help reduce the risk.
4. Overnight hypoglycaemia is uncommon in individuals using closed-loop insulin delivery systems following exercise.

Hybrid closed loops - after exercise

- Normal bolus for first meal
- No changes for second meal
- Come out of exercise mode at end of exercise

When to change bolus after exercise



Hybrid closed loops – if lows after exercise

- 25% of normal bolus for first meal
- No changes for second meal
- Stay in exercise mode for 1 hour after finishing exercise

Option 1 – answers part 2

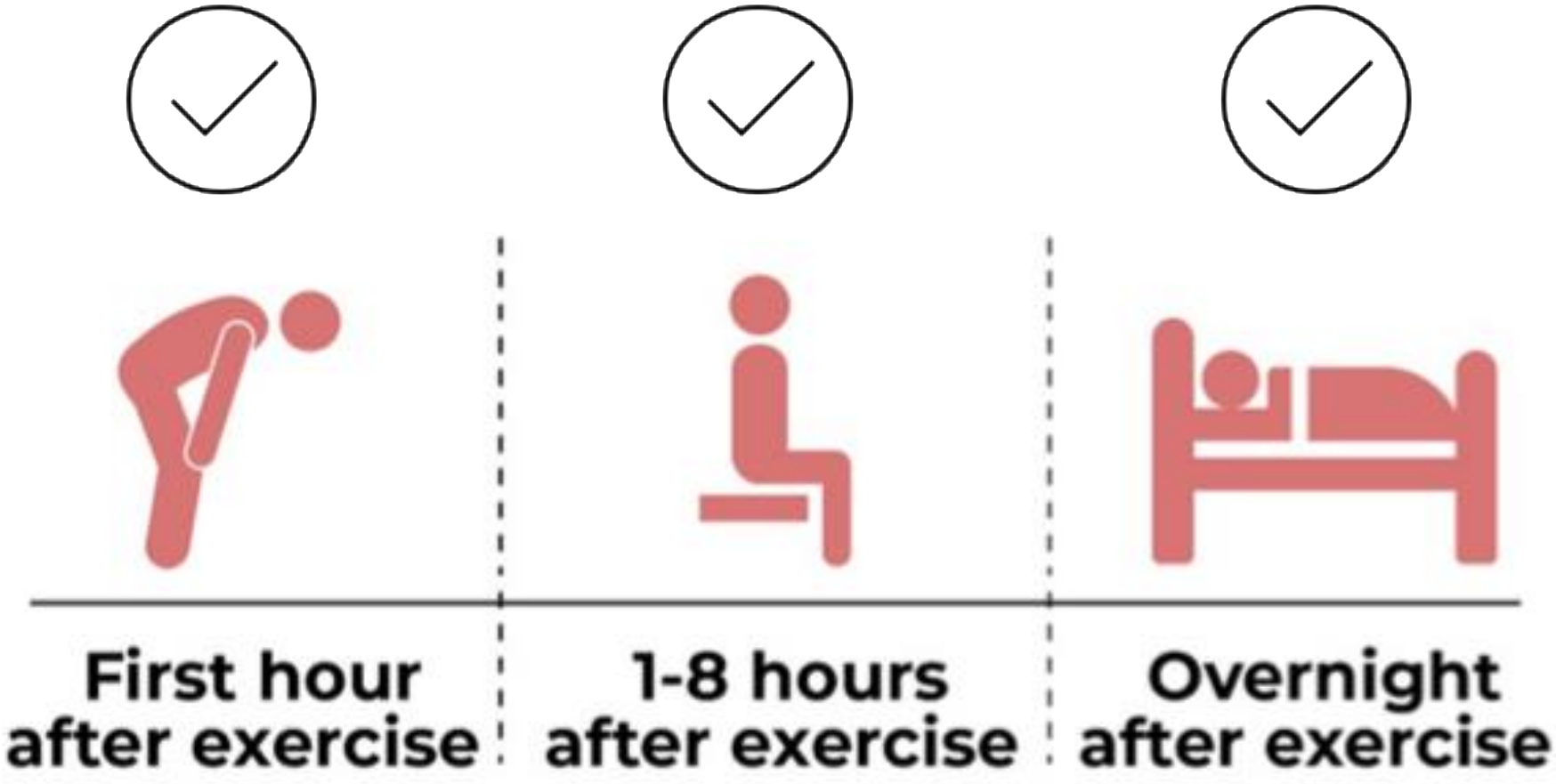
1. For the first meal following two hours of exercise, the bolus insulin dose should be reduced by 50%. False
2. No adjustment to the bolus dose is required for the second meal after exercise. True
3. If hypoglycaemia has been occurring post-exercise, continuing "exercise mode" for one hour after completing activity may help reduce the risk. True
4. Overnight hypoglycaemia is uncommon in individuals using closed-loop insulin delivery systems following exercise. True

Option 2 & 3 – questions– true or false

1. Hydration does not help lower glucose post exercise.
2. Taking carbohydrate and protein within 1 & ½ hours after exercise can help prevent hypos after exercise.
3. A nighttime snack of carbohydrate and protein can always prevent hypo overnight after exercise.
4. Exercise can not help protect against hypo during the first hour after exercise.
5. Exercising more regularly can simplify changes that need to be made after exercise.

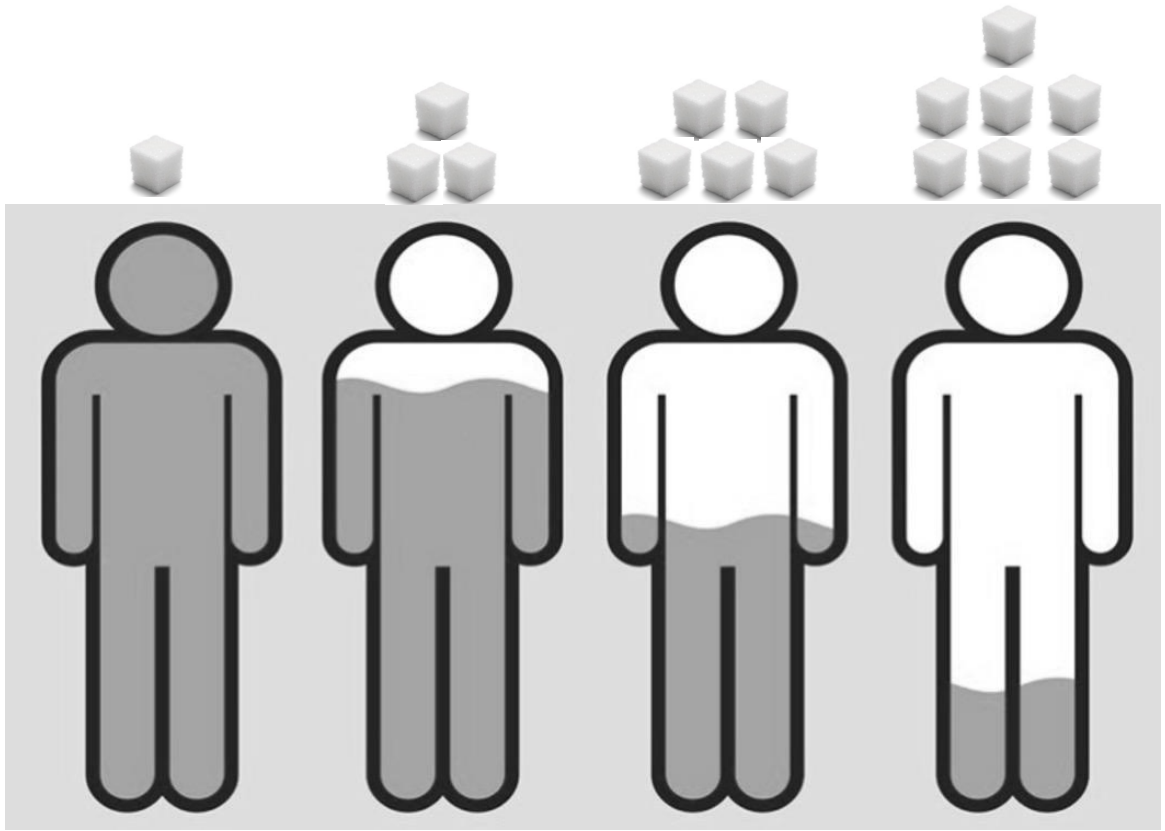
Option 2– carbohydrate

Times that carbohydrate can help glucose control after exercise



Rehydration is important

Blood glucose concentration



Dehydration may be a cause of raised glucose

Thus rehydration may lower glucose

Dehydration

Hydration

University of Exeter

NHS Somerset NHS Foundation Trust

Recovery meal can reduce risk of hypoglycaemia after exercise and add training

Did you do more than 60 minutes of moderate intensity exercise or more than 30 minutes of high intensity exercise?

No → No recovery food needed

Yes → Have food with a carbohydrate to protein ratio of 4:1.

For example:

Ham sandwich

Milkshake

Cereal and milk

* Advice might be different for children

Preventing hypoglycaemia overnight – bedtime snacks

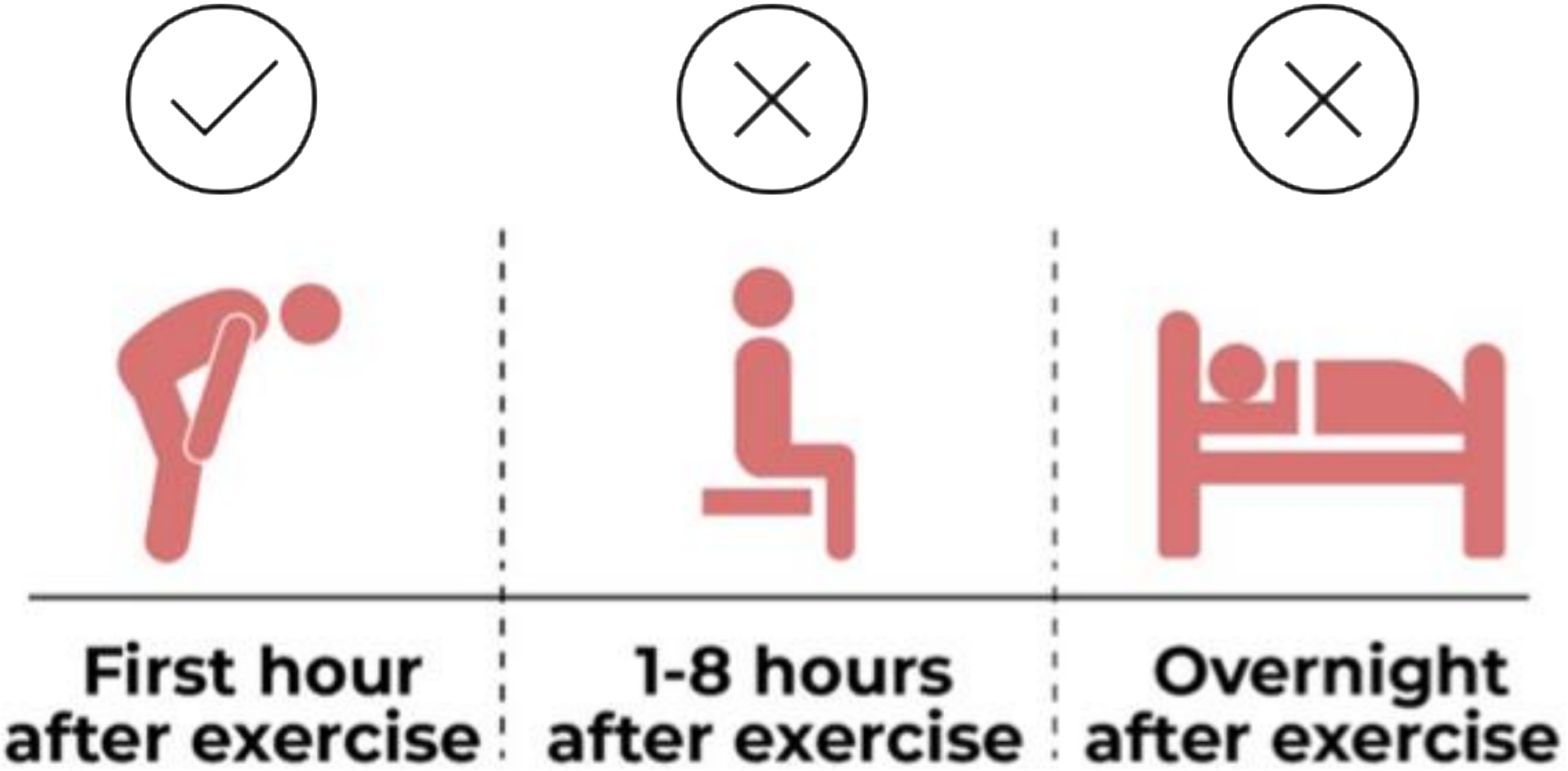
If blood glucose 7-10 mmol/l before bed then try protein and carbohydrate snack (30 grams carb + 15 gram protein).

If blood glucose <7 before bed, as well as snack may need to make reduction in background insulin/basal rate of 10%.

* Different advice for children

Option 3 - exercise

Times that exercise can help glucose control after exercise

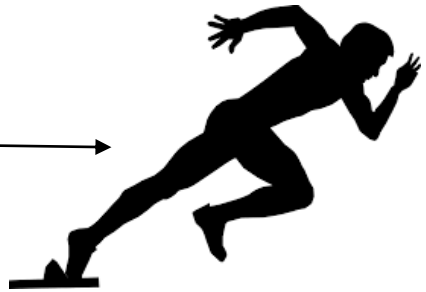


Using exercise to manage glucose post exercise

Glucose >10 →

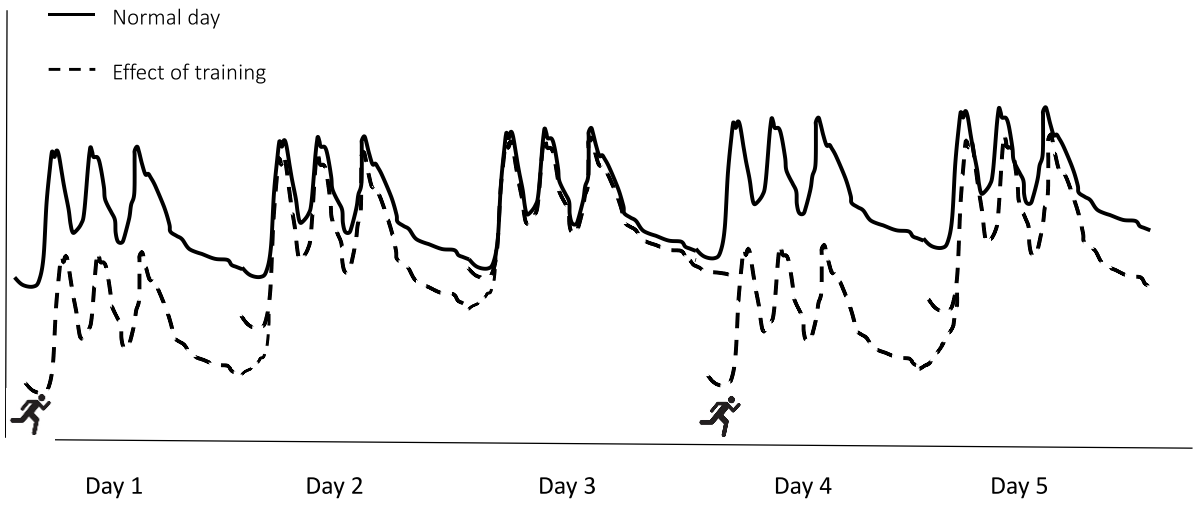
warm down
10 minutes warm
Down lowers by 1-2 mmol

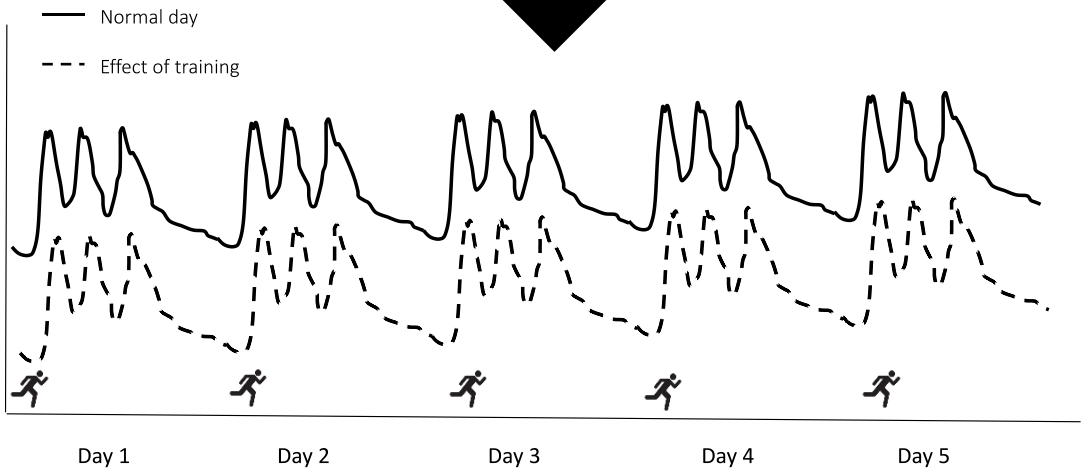
Glucose <4 →



10 sec sprint
Raises by 2-4 mmol
Protects from hypo for
30-40 minutes

Exercising 5 or more times a week helps with control after exercise





Option 2 & 3 – Answers

1. Hydration does not help lower glucose post exercise. False
2. Taking carbohydrate and protein within 1 & ½ hours after exercise can help prevent hypos after exercise. True
3. A nighttime snack of carbohydrate and protein can always prevent hypo overnight after exercise. False
4. Exercise can not help protect against hypo during the first hour after exercise. False
5. Exercising more regularly can simplify changes that need to be made after exercise. True

Summary 3 - options for managing glucose after exercise

Insulin - how do you alter it

MDI and Pump

- 50% of normal quick acting with meal prior to exercise if exercising within 2 hours of meal
- 50% of normal quick acting insulin for first 2 meals/snacks after
- 20% reduction night time background insulin or 20% reduction background for 6 hours when go to bed , If exercise after 4 pm or longer than 2 hours

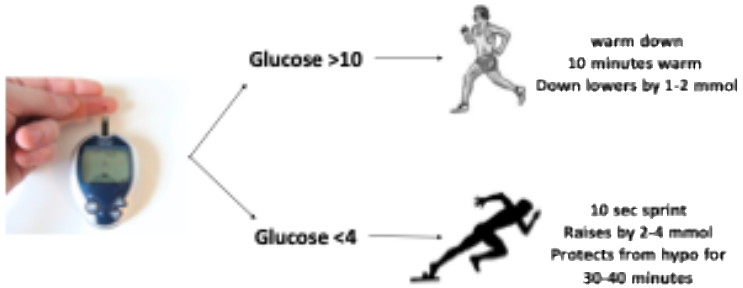
Closed Loop

- 25% less bolus for first meal
- Keep at exercise target for first few hours if prolonged exercise
- Return to normal set points overnight

Carbohydrate for exercise

Recovery	1 -1.2g/kg during the first hour
Before bed	Slow release carbohydrate

Exercise type and intensity



Match what changes can be made if exercise/ temp mode does not work

Medtronic hybrid closed loop
Omnipod 5 hybrid closed loop
CamAPS FX hybrid closed loop
Tandem T:Slim X2 with Control IQ
Medtrum Nano hybrid closed loop

Choose
Come out of closed loop
Increase personal target
Reduce basal rate
Weaker ICR
Weaker ISF
0.05u micro correction

Medtronic hybrid closed loop

E Temp Target can be set to 8.3 mmol/L from 30 mins to 24 hours (in 30 mins increments). At that interval NO Auto corrections are administered.

B Basal insulin adjusts every 5 mins based on SG values , avoiding post exercise highs if anaerobic or lows post aerobic exercise.

Medtronic hybrid closed loop – not working

If going hypo when exercise within 2 hrs of meal

- Adjust bolus reduction based on intensity
- 25% light intensity
- 50% moderate intensity
- 75% high intensity

If above does not work or hypo when exercising >2hr after meal

- Come out of close loop
- 80% reduced basal 90 minutes before
- Replace carbs

Omnipod 5 hybrid closed loop

Exercise mode

- Target raised to 8.3
- Reduced insulin deliver by 50%
- Limits micro-bolus corrections

Omnipod 5 hybrid closed loop – not working

If going hypo when exercise within 2 hrs of meal

- Adjust bolus reduction based on intensity
- 25% light intensity
- 50% moderate intensity
- 75% high intensity

If above does not work or hypo when exercising >2hr after meal

- Come out of close loop
- 80% reduced basal 90 minutes before
- Replace carbs

CamAPS FX hybrid closed loop

Ease off

- Can be preset
- No insulin give below 7.7 mmol/
- Target increased by 2.5 mmol/l (5.8 to 8.2)
- Reduced insulin given by 33%

CamAPS FX hybrid closed loop – not working

If going hypo when exercise within 2 hrs of meal

- Adjust bolus reduction based on intensity
- 25% light intensity
- 50% moderate intensity
- 75% high intensity

If going hypo when exercise > 2 hrs after meal

- Increase personal target, can go up to 11.0 – from DIY loops 8.9 works well

If above does not work or hypo when exercising >2hr after meal

- Come out of close loop

Tandem T:Slim X2 with control IQ

Exercise mode

- Target is 7.8-8.9 mmol/L
- Basal Insulin decreased if glucose predicted to be < 7.8 in next 30 min
- Basal Insulin suspended if glucose predicted to be < 4.4 in next 30 min
- Basal Insulin increased if glucose predicted to be >8.9 in next 30 min
- Correction bolus given if glucose predicted to be >10 in next 30 min

Tandem T:Slim X2 with control IQ – not working

Step 1 - Can set basal rate, ICR and ISF for exercise

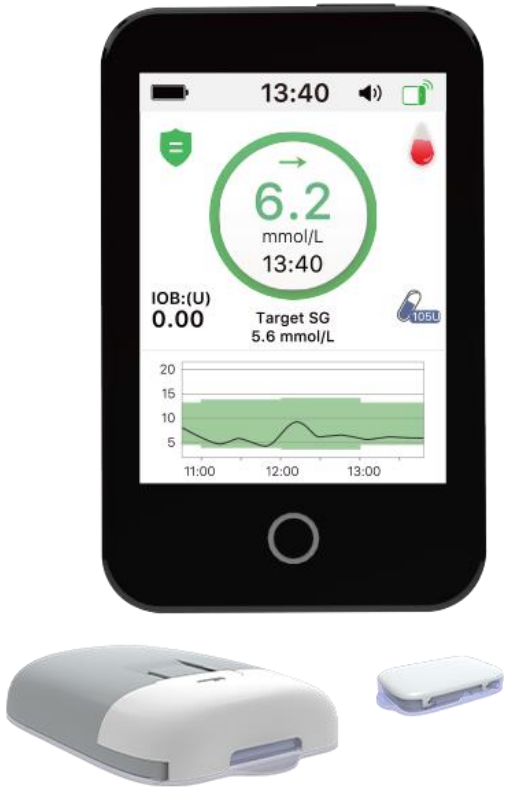
- Reduced 25% for mixed exercise
- Reduced 50% for aerobic exercise

Step 2 - Micro-bolus of 0.05units before exercise to stop bolus being given

Step 3 - Change bolus if exercising with 2 hours of meal

Step 4 - Come out of close loop

Exercise with Medtrum Nano



- Increases glucose target to 8.3 mmol/l (set at 5.6, 6.1 or 6.7 mmol/l)
- Does not turn off correction boluses but these are more conservative (not specifically defined)

Medtrum nano – not working

If going hypo when exercise within 2 hrs of meal

- Adjust bolus reduction based on intensity
- 25% light intensity
- 50% moderate intensity
- 75% high intensity

If above does not work or hypo when exercising >2hr after meal

- Come out of close loop
- 80% reduced basal 90 minutes before
- Replace carbs

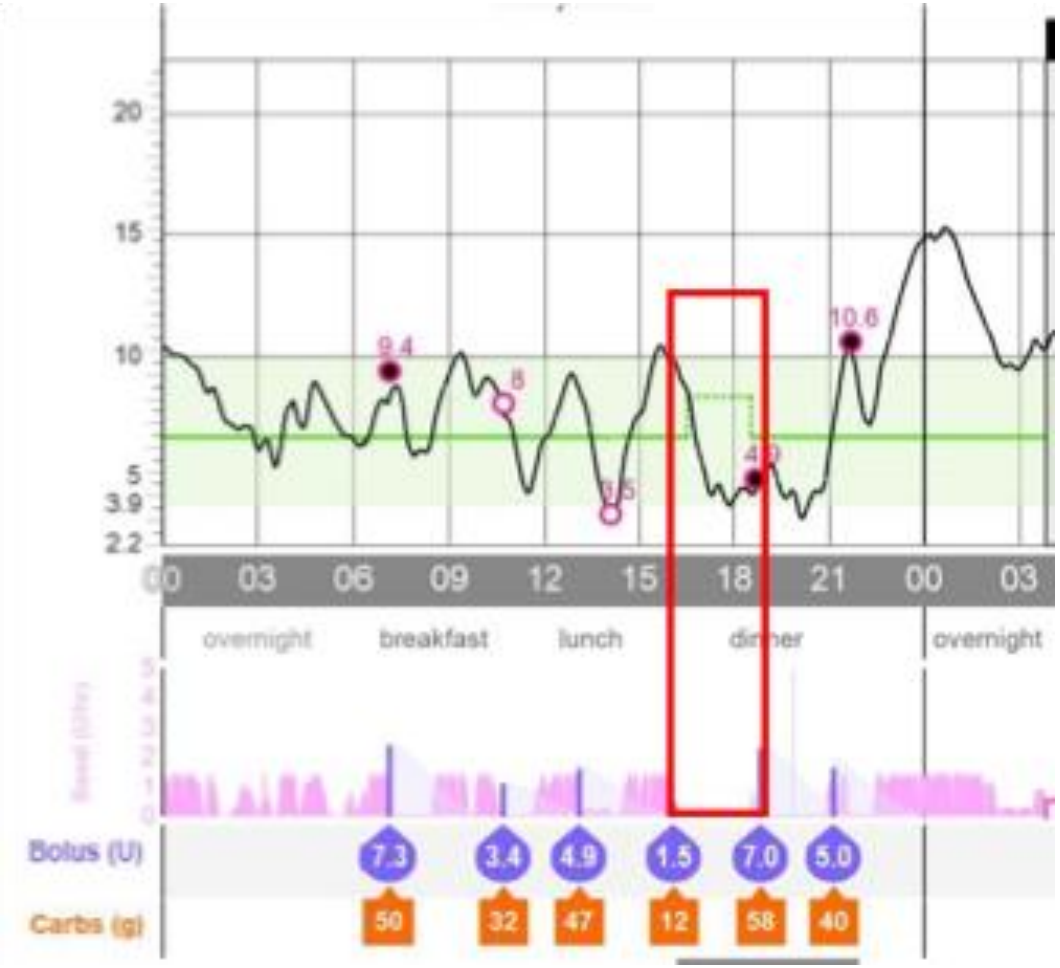
Match what changes can be made if exercise/ temp mode does not work

Medtronic hybrid closed loop	Come out of closed loop
Omnipod 5 hybrid closed loop	Come out of closed loop
CamAPS FX hybrid closed loop	Increase personal target
Tandem T:Slim X2 with Control IQ	Reduce basal rate, Weaker ICR, Weaker ISF, 0.05u micro correction, come out of closed loop
Medtrum Nano hybrid closed loop	Come out of closed loop

Final questions

1. After 2 hours of exercise in exercise mode glucose might rise significantly after.
2. A bolus of 50% of missed basal may need to be given after exercise
3. When drinking alcohol
   a) Glucose target can remain at 5- 7 mmol/l.
   b) Exercise mode can be used to help manage glucose when drinking.
   c) If glucose is above 10 mmol/l then insulin bolus should be given in the normal manner for food and alcohol.

Beware of long suspensions and negative insulin on board



There is a risk of prolonged insulin suspension >120 min:

- Ketones usually not an issue
- Post-exercise BG rise can be significant

Solutions

If causing problems:

- Stop activity mode halfway through
- Bolus 50% of usual basal every hour
- CamAPS can use Boost after exercise
- Other systems: 50% missed basal as a bolus on reconnection after exercise
- Golden hour snack with a reduced bolus will help compensate

Advice for alcohol

Having more than 4 units of alcohol?

Put exercise/activity mode before going out and until 11am the next day

- **CamAPS Fx = Ease Off (2-3 mmol/L higher target and ~30% relaxation of algorithm)**
- **T-slim = Activity mode and Alcohol 50% profile (8.3 mmol/L target & 50% reduction basal, ICR, ISF)**
- **OP5 = Activity mode (8.3 mmol/L target and ~50% relaxation of algorithm)**
- **780G = Temp Target (8.3 mmol/L and no autocorrect) or maybe manual mode (50% temp basal rate)**

Aim to keep the glucose between 7-10 mmol/L

If glucose is less than 7 mmol/L have 10-15g of fast acting carbs

Enter half the carbs for alcoholic drinks containing carbs and food if glucose more than 10.0 mmol/L

Have a sensible person following your glucose readings

Have fast acting glucose on you and by the side of your bed

Apply trial and error – start low (alcohol units) and go slow (increasing alcohol units)

Final questions

1. After 2 hours of exercise in exercise mode glucose might rise significantly after. True
2. A bolus of 50% of missed basal may need to be given after exercise. True
3. When drinking alcohol
   a) Glucose target can remain at 5- 7 mmol/l. False
   b) Exercise mode can be used to help manage glucose when drinking. True
   c) If glucose is above 10 mmol/l then insulin bolus should be given in the normal manner for food and alcohol. False

Conclusion - 1

Adapted from: Diabetes Spectr. 2023 May;36(2):127-136
Diabetologia: https://doi.org/10.1007/s00125-024-06308-z
Hormone Research in Paediatrics: https://doi.org/10.1159/000542287

	Before exercise		Immediately before	During Exercise	After exercise	
	Activity mode	**Meal insulin**	**Carbohydrate**	**Carbohydrate**	**Activity target**	**Post exercise meal insulin**
Plan execution	Start 1-2 hours before	Meal within 2 hours of exercise	At start	Every 20-30 min		
>15.0mmol/L using starting plan	Off	No reduction	<7.0 mmol/L carbohydrate **10-20g**	<7.0 mmol/L carbohydrate **3-12g per 30 min**	Off	No reduction
Starting plan	**On**	**-25%**			**Off**	**-25%**
<5.0mmol/L using starting plan	On	-50%			On for 6 hours	-50%

Conclusion 2

Variable	780G	T-Slim Control IQ	CAMAPS FX	Omnipod 5	Medtrum Nano
Included in EASD/ISPAD consensus? (Number of published Exercise RCTs)	✓ (10)	✓ (4)	✓ (2)	✓ (1)	X (0)
Usual Glucose Target	User defined 5.5 (Default),6.1, 6.7mmol/L	Treatment value 6.3-8.9mmol/L Target for corrections 6.1	User defined 4.4 – 11.0 mmol/L Default 5.8mmol/l	User defined 6.1-7.2mmol/L	User defined 5.6, 6.1, 6.7mmol/L
Activity glucose targets	Temp Target: 8.3mmol/l & no auto correction	Exercise Mode: Treatment range 7.8-8.9mmol/l **Autocorrections still happen & target 6.1**	Ease Off: Increases set target by 2.5mmol/l *(effectively reduces insulin delivery by ~30%)*	Activity mode: Increases set target to 8.3mmol/L & reduces basal delivery *(effectively reduces insulin delivery by ~50%)*	Exercise mode: Increases set target to 8.3mmol/L* **Autocorrections still happen** (more conservative) ** "not stated and defined exactly"*
Adjustable parameters	ICR AIT PGT	ICR ISF Basal	ICR PGT (ISF *bolus only*)	ICR PGT (AIT & ISF *bolus only*)	ICR ISF PGT
Pros for exercise	Autocorrections stopped Can remove	Can have multiple profiles for basal rates, carb ratios and correction factor to influence algorithm Can remove	Can adjust PGT for exercise as well as Ease Off (can personalise) Ease Off relaxes algorithm Can remove	Exercise mode relaxes algorithm by half and reduces insulin delivery	Unable to comment – no experience
Cons for exercise (can generally be managed with some extra considerations)	Target may still be too high Short AIT – algorithm may be too aggressive	Autocorrections continue	Ease off alone may not be enough of an increase in target	Cannot remove	Unable to comment – no experience
	May not adjust quick enough for rapid changes in activity levels (e.g. activity camp) Insulin levels at the start of exercise will vary each time				

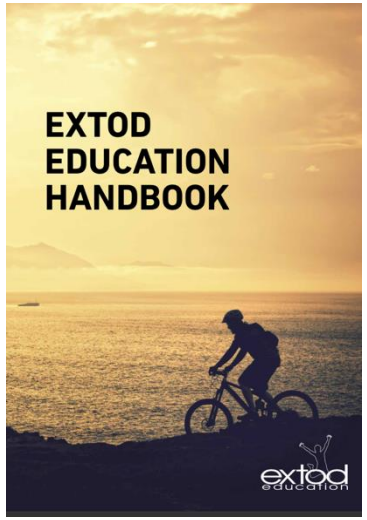
Further information

Websites

EXTOD website
www.extod.org

Other sites
https:// Runsweet.com
https://theglucoseneverlies.com
https://www.digibete.org

Face to face training



EXTOD Education
Local team can be trained

EXTOD

EXTOD Health Care Professionals Annual Conference Tuesday 26th and Wednesday 27th November 2024, Radisson BluHotel, Edinburgh

On line training

The Open University

EXTOD Education remote
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NHS Somerset NHS Foundation Trust

Benefits of regular exercise

"Running is bad for my knees.
***Not running* is bad for everything else!"**

Extra questions 1 a

True or False

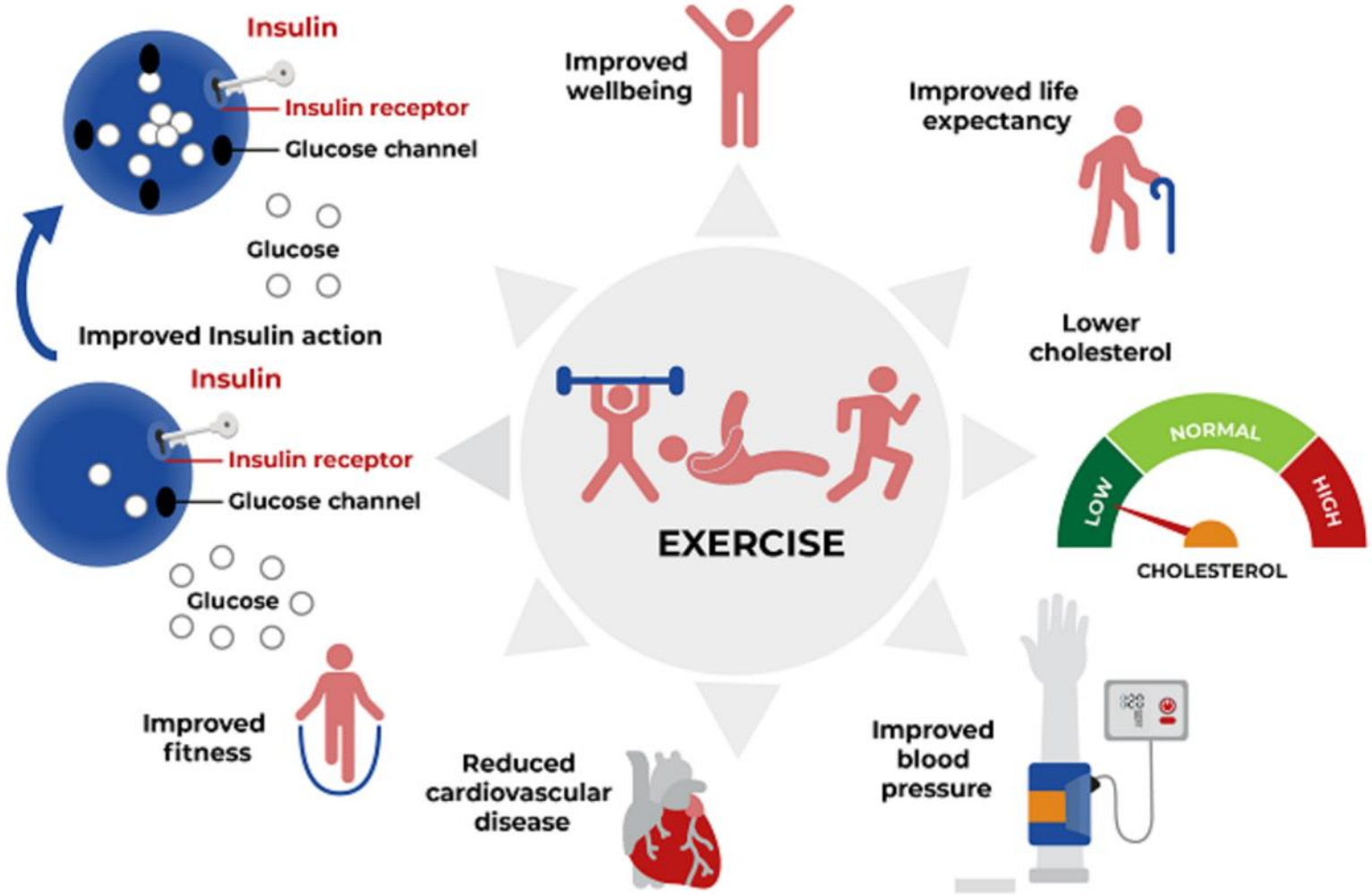
1. In people **with Type 1 diabetes** regular exercise has been shown to
   a) Reduce cardiovascular disease.
   b) Improve HbA1c in children and adults.
   c) Improve life expectancy
   d) Have no effect on rates of retinopathy and neuropathy
   e) Help prevent the development of nephropathy

Extra questions 1 b

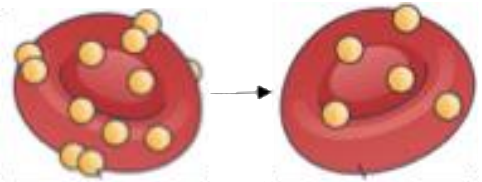
True or False

1. Current guidelines recommend that adults with T1D should aim to achieve the following:
    a. At least 150 minutes of moderate-intensity aerobic activity per week
    b. Anaerobic (strength) exercises on two occasions per week
    c. Flexibility exercises on two occasions per week
    d. Breaking up sedentary time
2. Adults with T2D are half as active as matched peers
3. Adults with T1D are half as active as matched peers

What are the benefits of exercising regularly?



What are the benefits of exercising regularly?



Lower HbA1c – only in children

Reduced retinopathy

Reduced Nephropathy

Reduced Neuropathy

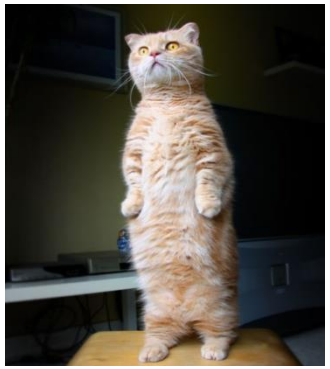
What are the recommendations for exercise?

150 minutes per week of

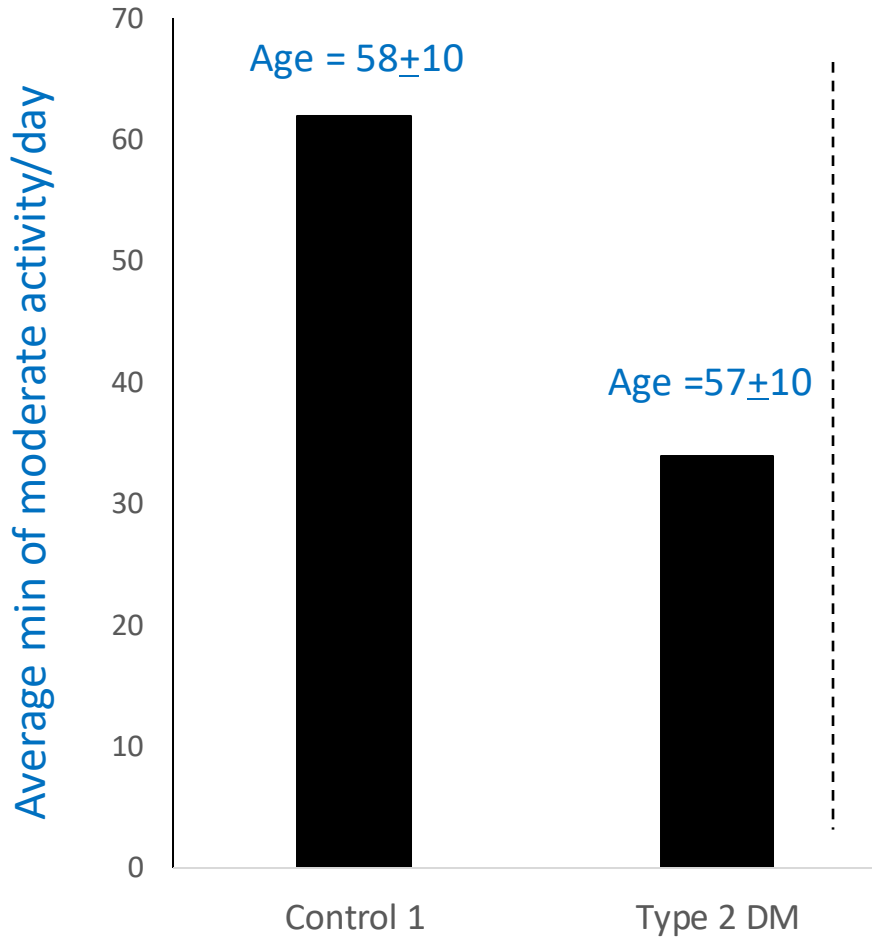
moderate to vigorous aerobic activity

Resistance training
three times a week

Reduce sitting time – try to get up three times per hour



How active are people with T1D?



On average half as active as matched healthy person

S.L Cichosz et al 2014

Extra answers 1 a

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Extra answers 1 b

True or False

1. Current guidelines recommend that adults with T1D should aim to achieve the following:
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2. Adults with T2D are half as active as matched peers True
3. Adults with T1D are half as active as matched peers True

Summary 5

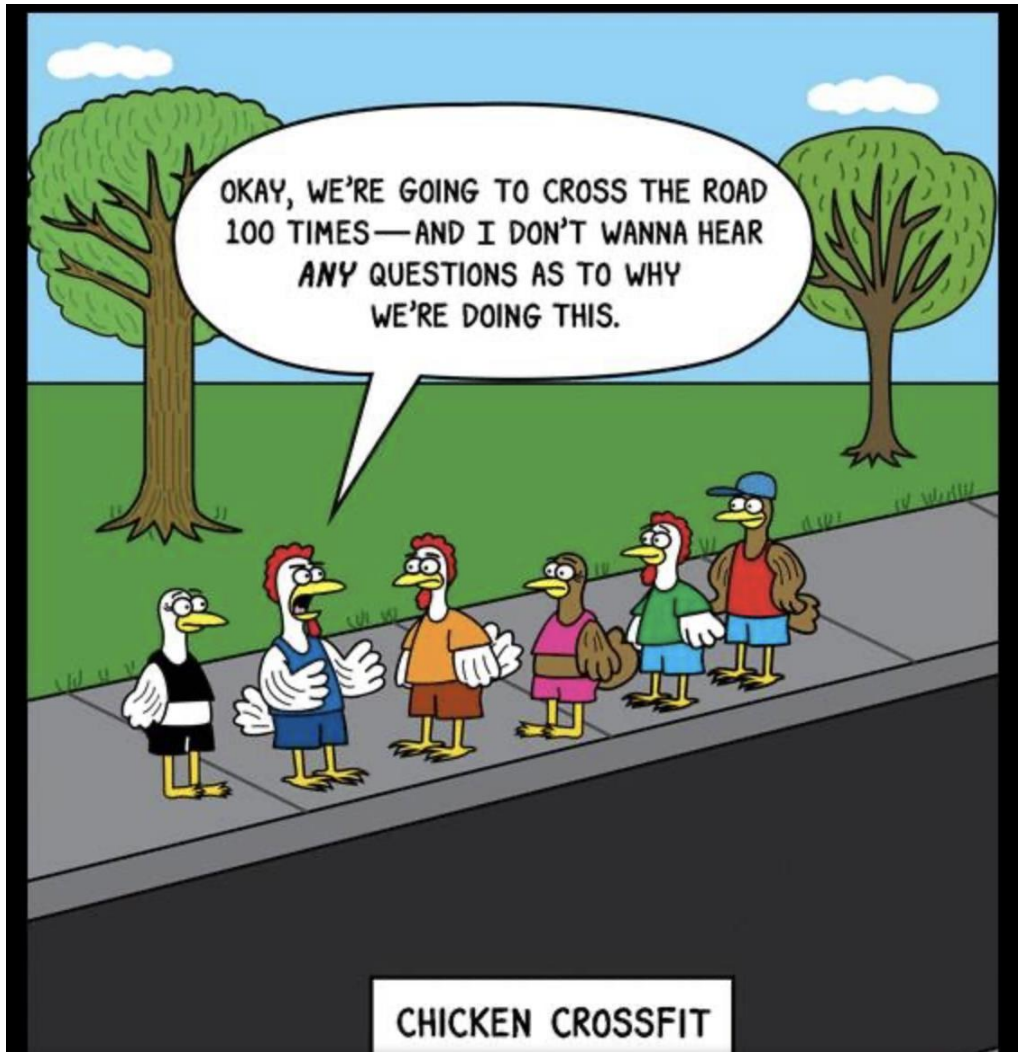
In people with T1D regular exercise

- Improves insulin resistance and glucose control
- Reduces lipids and blood pressure
- Extends life and improves well being
- Aids in preventing microvascular complications

But people with T1D

- Are 50% less active than their peers
- Often do not reach recommended exercise levels

Barriers to exercise?



Extra questions 2

True or False

1. Worry about hypoglycaemia is a common barrier to exercise.
2. HCPs are seen as being knowledgeable and a common place that people with T1D get exercise knowledge from.
3. Coaches and teachers are not helpful.
4. Stigma and Bias can be seen but is not common.

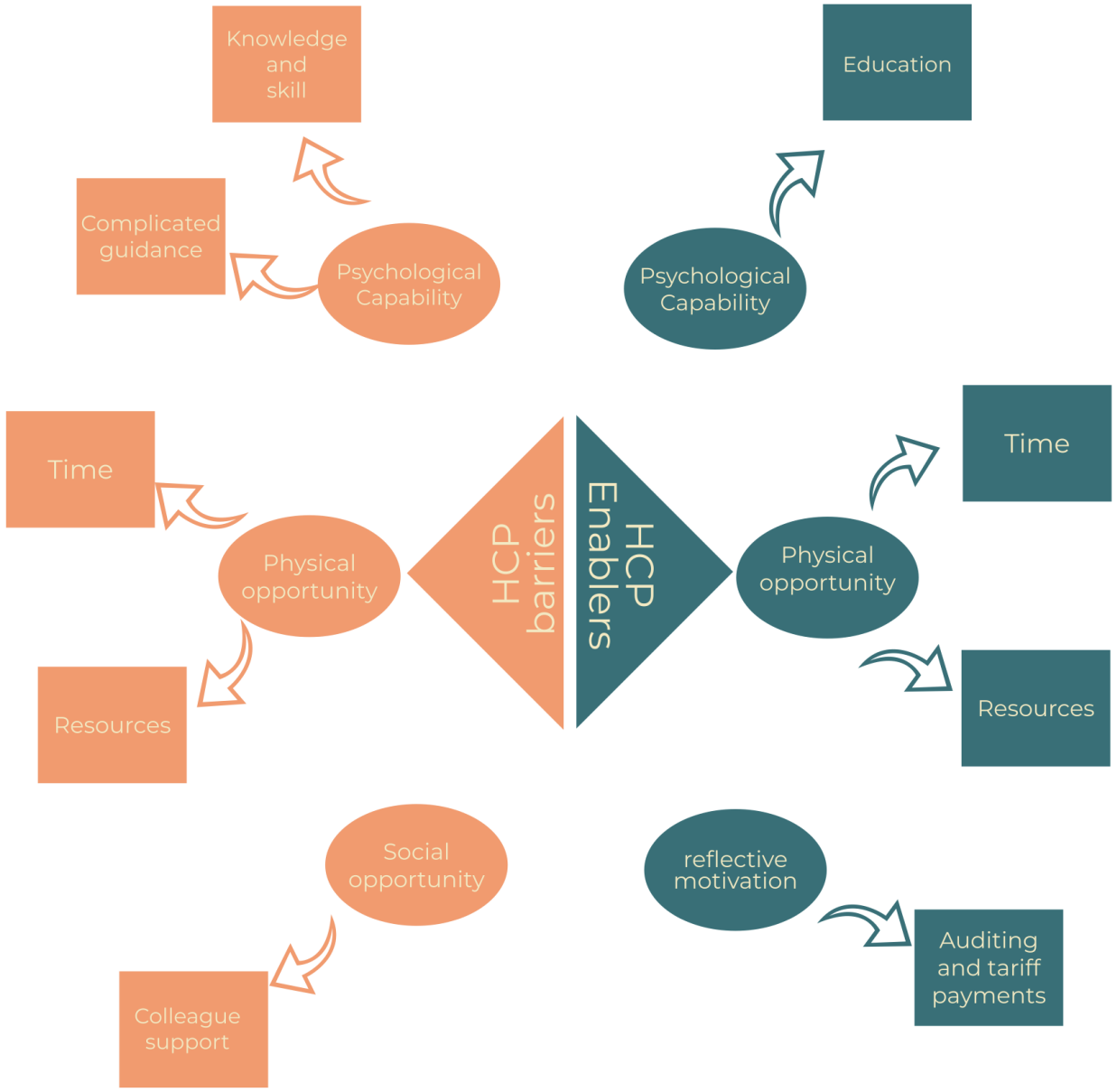
Barriers in adults with new-onset and established T1D

New onset T1D	Established T1D
• Hypoglycaemia (both actual and fear of) • Lack of knowledge/confidence in managing diabetes • Advice from healthcare professionals to stop exercising • Planning (e.g. checking blood glucose) • Feeling overwhelmed by diagnosis.	• Loss of control of diabetes • Lack of knowledge on the management of diabetes for exercise

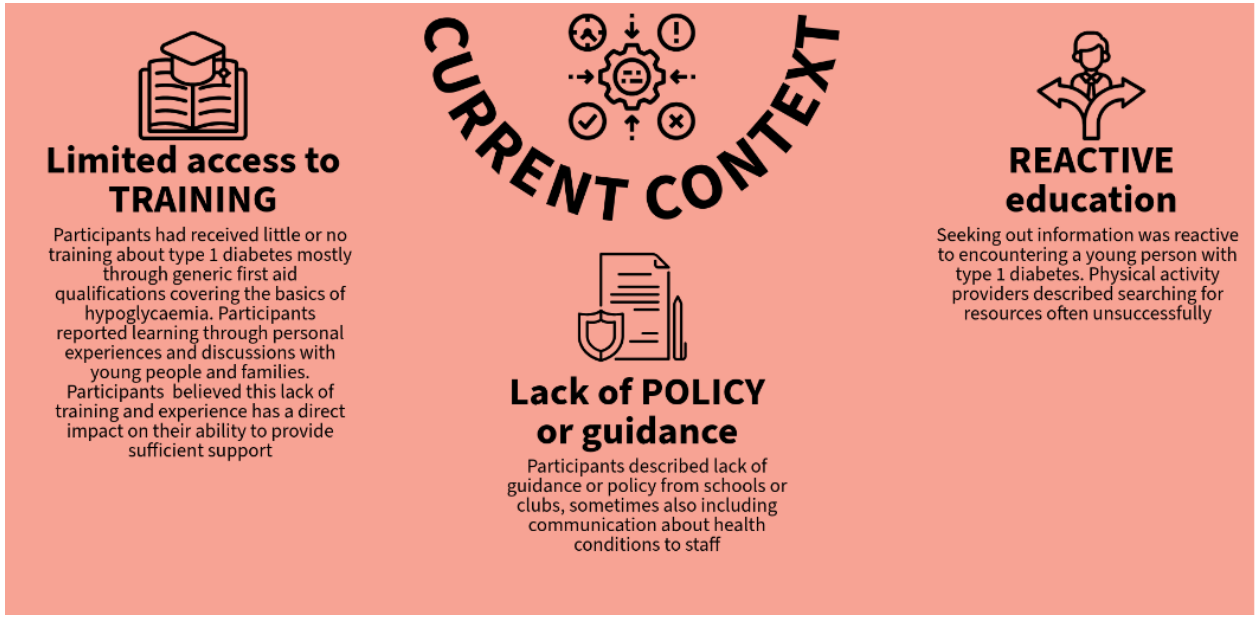
Kennedy 2018, Lascar 2014

HCPs barriers and enables to promoting exercise

Cockcroft, E et al. *BMC Pediatr* **23**, 131 (2023)

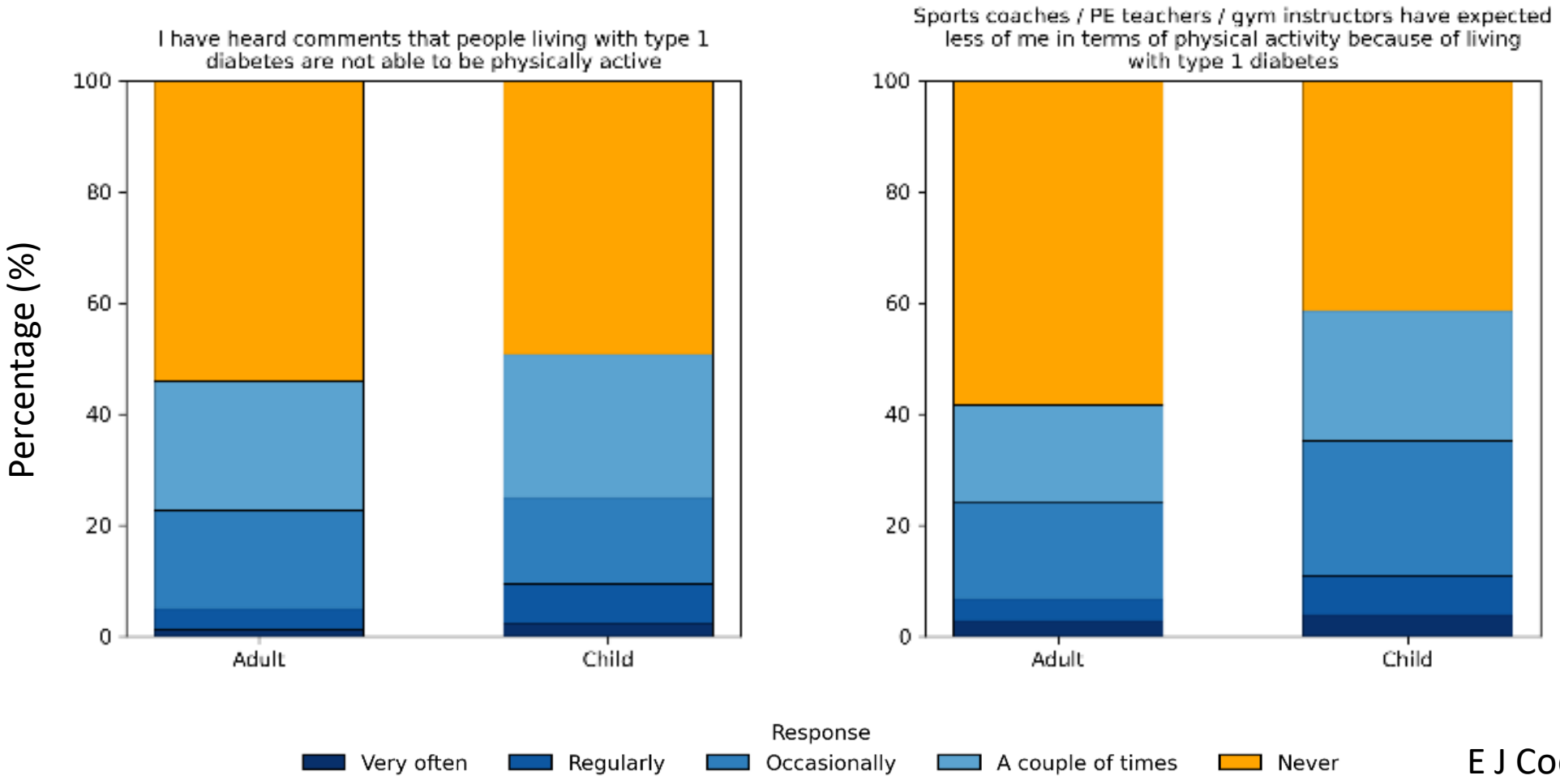


Barriers for teachers and coaches



Cockcroft, E et al. In review

Experience of stigma



Stigma and negative comments were reported by nearly three-quarters of both groups

E J Cockcroft et al – in review

Extra answers 2

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Summary 2


Lack of coach/teacher knowledge
Cost & access to facilities
Parental support
Lack of support in physical-activity settings
Social connection
Insufficient time to exercise
Stigma & stereotyping
Improved health and well-being
Fun & enjoyment
Not a habbit
Lack of motivation
Escape from T1D
Fear of hypo- & hyperglycaemia
Own knowledge
Low energy
Glucose management
Complexity & unpredictability of diabetes
Lack of informative resources
Capability
Opportunity
Motivation
Individual
Interpersonal
Organisational
Community
Public policy