Exercise in children and young people with type 1 Diabetes Mellitus – Paediatric Full Clinical Guideline

Reference no.: CH CLIN D11/Feb 21/v005

1. Introduction

To support the Derbyshire Children's Hospital Diabetes team in the management of children with Type 1 Diabetes Mellitus.

2. Aim and Purpose

The guideline applies to all children and young people with Type 1 Diabetes Mellitus under the care of the Derbyshire Children's Hospital Diabetes team who encounter variability in their blood sugars as a result of exercise. It aims to stabilise blood sugars during exercise and to optimise overall glycaemic control.

3. Definitions

4. Main body of Guidelines

Children and adolescents with diabetes experience fluctuations in their blood glucose with exercise. This can affect their overall glycaemic control as well as their sport performance.

Excursions in blood glucose will be affected by:

- Timing of exercise
- Duration and intensity of exercise
- Type of activity
- Frequency of exercise (e.g. regular or infrequent)
- Blood glucose level at the start
- Type and timing of food

There is the potential for:

- Hypoglycaemia during the exercise, shortly after or many hours/days later
- Hyperglycaemia during /immediately after the exercise.

An understanding of the reasons for these blood glucose excursions will enable the development of strategies with the individual to minimise the impact of exercise on glycaemic control as well as optimising sport performance.

The key to success is accurate record keeping of blood glucose, activity and food.

Section 1: Exercise physiology

Non diabetics
In these individuals moderate intensity exercise results in a reduction in insulin secretion and an increase in glucose counter regulatory hormones. This facilitates an increase in liver glucose production which matches skeletal muscle glucose uptake during exercise. The blood glucose remains stable.

Diabetics
In the individual with type 1 diabetes the pancreas is unable to regulate insulin levels in response to exercise. In addition there is the potential for counter regulatory failure. Individuals may experience either increases or decreases in blood glucose during exercise as explained below.

i. Over insulinisation and hypoglycaemia

This can occur as a result of:

- **Increased insulin absorption** with exercise (but not apparently with glargine) due to increased blood flow to subcutaneous and muscle and increased body temperature.

- The **inability to decrease plasma insulin levels** in response to exercise results in relative hyperinsulinaemia and impaired hepatic glucose production. This has a tendency to cause **hypos within 20-60 mins of exercise.**

- An exercise induced increase in **skeletal muscle insulin sensitivity for up to 48 hrs.**

  Since the increase in insulin action persists for several hours after the end of exercise there is **increased risk of hypoglycaemia for several hrs and in some individuals 1-2 days.**
  If the exercise is done regularly then there will be increased sensitivity even between training sessions and the total insulin dose can probably be lowered.

  Adolescents however who only exercise intermittently can have real difficulties in managing their basal insulins. This may be an issue on residential trips.

  Younger children tend to exercise every day to some extent which results in less post exercise fluctuations in blood glucose.

ii. Counter regulatory failure

- Previous hypos will blunt counter regulatory response to exercise so there will be a vicious cycle. Eg hypoglycaemia the day before exercise will put the individual at increased risk of further hypos.

- It should also be noted that the energy expenditure itself predisposes individual to **hypos for 24h after end** of exercise as insulin sensitivity remains elevated.

iii. Underinsulinisation and hyperglycaemia

- In individuals with poor glycaemic control, exercise can cause an additional increase in blood glucose and ketoacidosis, due to exaggerated hepatic glucose production and impairment in exercise-induced glucose utilization.

- Intense exercise may exacerbate this since increases in catecholamines and glucocorticoids will further exaggerate the elevations in BG concentrations and ketone production.

- Strenuous exercise should therefore be avoided if hyperglycaemia(>14 mmol/l) and ketonaemia

iv. High intensity exercise / resistance exercise

- High intensity exercise (85-90% maximal heart rate) impairs muscle glucose utilization due to dramatic elevations in catecholamines, free fatty acids and ketone bodies.

- The inability to release insulin to counteract these then results in increases in blood glucose. **This is usually transient and lasts as long as there are elevations in the counter regulatory hormones (ie 30-60 mins).**

- Some individuals can easily correct with an insulin bolus, others may be resistant to taking additional insulin following exercise since there will be a greater risk of late-onset post exercise hypoglycaemia in the next several hours particularly if the prior exercise bout was >30 min. High intensity interval training has been associated with a higher risk of nocturnal hypoglycaemia than continuous aerobic exercise.

- Resistance exercise is associated with better glucose stability than continuous moderate intensity aerobic exercise; although resistance exercise could cause a modest rise in glycaemia in some individuals.

- Compared with aerobic exercise, a high intensity interval training session attenuates the decrease in glycaemia, as does resistance exercise done before aerobic exercise, possibly because of increased concentrations of counter regulatory hormones and various metabolites that restrict glucose disposal.

v. Competition stress, heat stress and hyperglycaemia

- The anticipatory stress of competition combined with competition stress can produce hyperglycaemia in situations which usually result in hypoglycaemia on regular training days.

- This is likely due to elevated levels of ‘stress’ (counter regulatory hormones) resulting in increased hepatic glucose production and decreased peripheral glucose uptake.

- The inability to increase insulin secretion may then result in hyperglycaemia.

- This may be particularly frustrating in team sports (eg basketball, hockey) with breaks in play. Frequent BG monitoring and small boluses of rapid acting insulin may be required.

- Training in warm climates may produce similar problems.

Section 2: contraindications and cautions for exercise

Elevated ketones

Blood ketones up to 1.4 mmol/l: restrict exercise to light intensity for less than 30 minutes and consider correction dose before starting exercise.
Blood ketones 1.5mmol/l or above: exercise is contraindicated. Correct with novorapid as per 'sick day rules' and identify cause. Commence exercise once ketones less than 0.5 mmol/l.
Blood ketones 3mmol/l or above: do not exercise and seek urgent help. Will need additional novorapid as per 'sick day rules'.

Recent hypoglycaemia
Severe hypoglycaemia in the past 24 hours (less than 2.9 mmol/l or requiring assistance from another individual): exercise is contraindicated because of substantially increased risk of a more serious episode during exercise.
If mild hypoglycaemia (2.9-3.9 mmol/l) the increased risk of recurrence must be taken into account .Blood sugars must be monitored and exercise that puts individual at increased risk avoided eg cycling, rock climbing, swimming, walking/running alone

Hypoglycaemia during exercise should lead to discontinuation of exercise to treat hypoglycaemia . Wait at least 45 minutes before recommencing. If severe hypoglycaemia then do not recommence exercise due to high risk of further hypoglycaemia

Section 3: Strategies to stabilise blood glucose during and after exercise (See appendix 1)

The 2 main strategies available to help stabilise BG concentrations during and after exercise are insulin adjustment and additional carbohydrates .

Monitoring
Frequent BG monitoring is essential so that **trends** in glycaemic responses can be identified.
A typical 'exercise diary' should record blood glucose, timing, duration and intensity of exercise as well as the strategies used to maintain the glucose levels.
Use this information to complete an exercise management plan for each exercise (see appendix) and modify according to trends in blood sugars.

.BG should be measured:

Before ...in some individuals 2-3 measurements at 30 min intervals
During...ideally every 30 mins
After…for several hours and before bed esp if strenuous.

Bed time blood sugar of <7mmol/l may predict nocturnal hypoglycaemia (controversial).

Consider CGMS if:
Variable blood sugars in response to exercise especially if 2 or more sports a week ; nocturnal hypoglycaemia, ; poor glycaemic control.

The 2 main strategies available are:

Insulin adjustment and additional carbohydrate

A. Insulin adjustment:

1. **Hypoglycaemia during aerobic exercise: reduction in pre exercise meal bolus**

   Reduction in the dose of fast acting insulin for the meal prior to exercise is advised if exercising within 120 minutes of the meal. There is greater need for reduction when the dose is within 1 hour of exercise and for more intense exercise. Reduction will not be required for anaerobic exercise

Recommended reduction in fast acting insulin (%)

Intensity of exercise	Duration: 30 mins	Duration: 60 mins
Low E.g. school PE/swimming	25%	50%
Moderate E.g. football, hockey	50%	75%
Heavy E.g. swimming training	75%	100%
anaerobic	No reduction	n/a

2. **Late hypoglycaemia: reduction in post exercise meal bolus**

   This could be avoided by reduction in post exercise boluses e.g. reduced insulin to carbohydrate ratio by 20-30%.

3. **Adjustments in basal insulin**

   For patients on multiple daily insulin injections, clinical observations and limited experimental data show that reduction of basal (as well as prandial) insulin concentrations before exercise reduces the risk of hypoglycaemia during and after the activity, but might promote hyperglycaemia at other points during the day. Therefore, reduction in the basal insulin dose for patients on multiple daily insulin injections should not be routinely recommended but can be a therapeutic option for those engaging in considerably more planned activity than usual (eg, camps or tournaments). In general, basal insulins with a short half life, such as insulin detemir, seem to lead to less hypoglycaemia in conjunction with exercise than do basal

insulins with a longer half-life, such as insulin glargine, although the mechanism through which this occurs is unclear.

Residential camps: Reduce basal insulin by 20-25% the night before, during trip, 1-2 days after.

Infrequent exercise eg done less than every 3 days: Consider using changing to twice a day basal insulin eg detemir. Reduce evening dose after exercise by 10-20% if issues with nocturnal hypoglycaemia after exercise. If issues with hypoglycaemia during: reduce morning basal insulin by 10-20% before the exercise.

4. **Hyperglycaemia**

   If this occurs during training or competition this may require additional fast acting insulin aiming to correct to a blood glucose of 10 mmol/l.

5. **Site of injection**

   Injecting insulin well away from an exercising muscle may also minimise the risk of hypoglycaemia.

6. **CSII**
   Aerobic exercise: reduce basal by 50%-80% 60-90 minutes before and during or remove). Run 90% basal 7-12 hours after.

   Anaerobic: run 110% basal 30 minutes before to 60 minutes after.

   Do not suspend the pump for more than 2 hours.

B. Carbohydrate Adjustments

Carbohydrate is the favoured fuel for sports activity to help maintain glycaemia and to replenish muscle glycogen stores post exercise.

Carbohydrate intake should account for approximately 60% of total calorie intake for diabetics that exercise regularly and at a high level. Complex carbohydrates should be encouraged i.e. whole grains, cereals, rice and pasta, however non milk extrinsic sugars can be used to maintain adequate blood sugars during intense exercise i.e. the use of isotonic sports drinks. For those who exercise less frequently, carbohydrate should account for at least 50% of total calorie intake as per general healthy eating guidelines and non milk extrinsic sugars should not exceed 11% of total carbohydrate intake.

Carbohydrate requirements vary considerably depending on the time, duration and intensity of the exercise.

1. Meal before exercise

Prior to competition or strenuous training, a nutritious meal containing carbohydrate, fat and protein should be consumed to maximise energy stores. This meal can be eaten 3-4 hours before to allow for adequate digestion and to minimise circulating novorapid..

Typically, 6-10g carbohydrate/kg body weight/day may be needed to maintain blood glucose and replace muscle glycogen. Therefore, for a child weighing 38kg, daily carbohydrate requirements are 228 – 380g (912 – 1520kcal from carbohydrate).

2. Blood glucose concentrations before exercise commencement and recommended glucose management strategies

The carbohydrate intakes shown below aim to stabilise glycaemia at the start of exercise.
Blood glucose at the start of exercise must also be viewed within a wider context. Factors
to consider include directional trends in glucose (if using CGM) and insulin concentrations, patientsafety, and individual patient preferences based on experience. Carbohydrate intake will need to be higher if circulating insulin concentrations are high at the onset of exercise. Anaerobic and high intensity interval training can be started at a lower blood glucose (5-7 mmol/l) than aerobic (7-10 mmol/l)

Starting glycaemia below target (<5 mmol/L)

Ingest 10–20 g of glucose before starting exercise.
Delay exercise until blood glucose is more than 5 mmol/L and monitor closely for hypoglycaemia.

Starting glycaemia near target (5–6·9 mmol/L)

- Ingest 10 g of glucose before starting aerobic exercise.
- Anaerobic exercise and high intensity interval training sessions can be started.

Starting glycaemia at target levels (7–10 mmol/L)

- Aerobic exercise can be started.
- Anaerobic exercise and high intensity interval training sessions can be started, but glucose concentrations could rise.

Starting glycaemia slightly above target (10·1–15·0 mmol/L)

- Aerobic exercise can be started.
- Anaerobic exercise can be started, but glucose concentrations could rise.

Starting glycaemia above target (>15 mmol/L)

- If the hyperglycaemia is unexplained (not associated with a recent meal), check blood ketones. If blood ketones are modestly elevated (0.6-1.4 mmol/L), exercise should be restricted to a light intensity for only a brief duration (<30 min) and a small corrective insulin dose might be needed before starting exercise. If blood ketones are elevated (≥1.5 mmol/L), exercise is contraindicated and glucose management should be initiated rapidly as per sick day rules.
- Mild to moderate aerobic exercise can be started if blood ketones are low (<0.6 mmol/L)

Blood glucose concentrations should be monitored during exercise to help detect whether glucose concentrations increase further. Intense exercise should be initiated only with caution as it could promote further hyperglycaemia.

3. Carbohydrate intake during exercise to prevent hypoglycaemia

During aerobic exercise 0.5-1.5g carbohydrate/kg body weight/hour can be consumed to a maximum of 60g carbohydrates. Isotonic sport drinks are ideal for this.

Appendix 3 gives recommendations for use of isotonic sports drinks in a variety of sports and are appropriate to use when no alteration to basal/bolus insulin has been made.

4. Prevention of Nocturnal hypoglycaemia due to elevated insulin sensitivity - Increased risk especially with afternoon activity and if alcohol consumption.

Aim to eat within 90 minutes of the end of exercise.
Reduce meal bolus by 50%.

Bedtime snack: low GI, carbohydrate 1g/kg, protein 0.3g/kg without insulin. Any additional carbohydrates give 50% of usual novorapid dose.

5. References (including any links to NICE Guidance etc.)

www.runsweet.com (Dr Ian Gallen, Mark Riddell, Francesca Annan)

Type 1 diabetes and vigorous exercise: applications of exercise physiology to patient management. Riddell at al 2006

ISPAD clinical practice consensus Guidelines 2014 Exercise in children and adolescents with diabetes.

Exercise management in type 1 diabetes: a consensus statement, www.thelancetcom/diabetes-endocrinology January 23 2017

6. Documentation Controls

Development of Guideline:	Dr Julie Smith
Consultation with:	Lead Clinician
Approved By:	Paediatric Guidelines Group, Women and Children's Division, 23rd February 2021
Review Date:	Feb 2024 Extended to June 2024
Key Contact:	Dr Julie Smith

7. Appendices –

Appendix 1: exercise types

Anaerobic exercise results in higher intensity of muscular contraction that produces lactic acid.

Examples: sprinting, hockey, gymnastics, racquets sports that have short bursts of sprinting eg squash, sprinting positions in football and rugby.

At risk of: Hyperglycaemia during exercise
Delayed hypoglycaemia

Aerobic exercise results in lower intensity of muscular contraction and carbohydrate, fat and some proteins are used as the energy source.

Examples: long distance running, cycling, long distance swimming, football

At risk of: hypoglycaemia during and after exercise

Resistance (strength) training
Primarily anaerobic exercise

Examples: free weights, weight machines, body weight or elastic resistance bands
Associated with better glucose stability than moderate aerobic activity. Resistance training before aerobic training may prevent hypoglycaemia.

High intensity interval training
Alteration between brief periods of vigorous activity and recovery at low to moderate intensity

Promotes the increased oxidative capacity of skeletal muscle and attenuates the rates of glycogen breakdown which might protect against hypoglycaemia after exercise, though glucose levels may rise during.

Appendix 2 : carbohydrate snacks to be eaten before exercise to avoid hypoglycaemia during exercise, amount given depends on starting blood glucose and type of exercise

Before/during exercise	10g	15g	20g
Isotonic sport drink 6g/100ml	200 ml	300ml	400ml
Jaffa cake	1	1.5	2
Dried apricots	3	4	6
raisins	1box	1.5 box	2 box
Jelly babies	3	*4*	6

Appendix 3: use of isotonic sports drinks during to avoid hypoglycaemia during exercise.

Aim to give 0.5-1.5g/kg/hr – maximum 60 g

Isotonic sports drinks contain 6g CHO per 100ml
Examples: Lucozade Sport, Powerade

Carbohydrate intake with various types of exercise using isotonic sports drinks

	Body weight		
Activity	**20kg**	**40kg**	**60kg**
	ml. isotonic* sports drink per 20minutes of continuous exercise number in brackets = grams of carbohydrate		
Basketball	170 (10)	330 (20)	500 (30)
Cycling 10km/h	85 (5)	130 (8)	200 (12)
Cycling 15km/hr	120 (7)	200 (12)	330 (20)
Ice skating	200 (12)	330 (20)	500 (30)
Running	200 (12)	330 (20)	500 (30)
8km/h	250 (15)	330 (20)	500 (30)
12km/h	170 (10)	330 (20)	500 (30)
Football	100 (6)	200 (12)	330 (20)
Swimming 30m/min	130 (8)	250 (15)	330 (20)
Breast stroke	85 (5)	170 (10)	250 (15)
Tennis	120 (7)	200 (12)	330 (20)
Walking	100 (6)	200 (12)	330 (20)
4km/h	85 (5)	130 (8)	170 (10)
6km/h	130 (8)	170 (10)	200 (12)

E.g. 20kg child should consume 120ml every 20minutes of tennis.
60kg child should consume 330ml every 20minutes of tennis.
40kg child should consume 200ml every 20minutes of football.

These are estimates of carbohydrate utilisation and are appropriate to use where no alteration to basal/bolus insulin has been made. In practice smaller volumes may be required.

Foods high in carbohydrate can be used rather than sports drinks especially when volumes are high i.e. 60kg child playing basketball.

1 x jelly baby = 4.6g CHO; 1 x fruit pastille = 2.5g CHO;
1 x jelly bean = 2.6g CHO; 14g box raisins = 10g CHO.

As an alternative to commercially available products, isotonic sports drinks can easily made at home:

Example 1	Example2	Example 3
50g sugar 1 litre warm water 1g (pinch) salt Sugar free squash to flavour	200ml cordial or non sugar free squash 800ml water 1g (pinch) salt	500ml unsweetened fruit juice (e.g. orange/apple) 500ml water 1g (pinch) salt

Appendix 4: Examples of mixed snacks to be eaten at bedtime to avoid nocturnal hypoglycaemia (carbohydrate 1g/kg, protein 0.3g/kg)

Cereal with milk
Yogurt with sprinkling of cereal or mixed seeds/nuts
bread with a variety of fillings – ham, chicken, cheese, tuna with salad
Peanut butter on toast
Yogurt or fruity/nutty cereal bar
Baked beans on slices of toast
Bagel and banana
Cheese and crackers

Appendix 5

Exercise Management Plan **Name** Derby Teaching Hospitals NHS
NHS Foundation Trust

Sport **Time** **Wt** **Date**

Plan to avoid: hypo during /hypo after/night time hypo/ high blood sugar during/high blood sugar after (delete as appropriate)
Check blood sugar before exercise, every 30 minutes during and at end. If exercise more intense or longer than usual check at 2-3 am.

Insulin adjustment

If within two hours of a meal, reduce Novorapid dose at previous meal by 25-75% depending on duration, intensity, previous experience
Pumps: 50% basal 60-90 mins before, and during (or remove). Run 90% basal 7-12 hrs after. Anaerobic 110% basal 30 mins before to 60 mins after
Basal insulin reduce by 10%-20% eg if twice a day and if exercise less than every 3 days

Extra carbohydrates before exercise

Blood sugar before sport	<4mmol	4.0 –4.9mmol/l	5.0- 6.9 mmol/l	7-15 mmol/l	>15.0 mmol/l
Action	Treat hypo Start exercise once above 5.0 mmol/l	10-20 g carbohydrate Start exercise once above 5.0mmol/l	10g carbs before aerobic Start anaerobic or IHit	Start aerobic Start anaerobic or IHIE but blood sugars may rise	If hyperglycaemia is not explained eg not associated with recent meal check ketones* Consider 1/3 usual correction

* - if Ketones above 0.5mmol/l follow sick day rules and do not begin exercise until ketones less than 0.5 mmol/l.

Extra carbohydrates during exercise

Check blood sugar every 30 minutes
Additional carbs 0.5-1.5g/kg/hr depending on blood sugar, intensity and whether circulating insulin. Max 60g
Anaerobic exercise and blood sugar > 14 mmol/l, check ketones consider small correction with novorapid with caution.

After exercise: actions to replenish glucose stores and prevent night time hypo

No meal due within next hour	Have mixed snack within 1 hour of finishing exercise : carb (0.5g- 1g/kg) and protein (0.3g/kg) snack Start with 1/2 of usual novorapid dose. Don't correct or cautious correction
Next meal	Novorapid dose for meal reduce by 50% Novorapid dose for correction- cautious with correction
Supper if exercise earlier in day	Have mixed snack: carb (1g/kg) and protein (0.3g/kg) snack without insulin If additional carbs eaten given 50% of usual dose for additional carbs. Don't correct /cautious correction

Examples of extra carbohydrates

Before/during exercise	10g	15g	20g		Post exercise snack
Isotonic sport drink 6g/100ml	200 ml	300ml	400ml		Standard porridge oats (not sachet) made with milk
Jaffa cake	1	1.5	2		Wholemeal bread with a meat filling
Dried apricots	3	4	6		Crackers (24g) with humous or cream cheese
raisins	1box	1.5 box	2 box		Toast with baked beans or peanut butter
Jelly babies	3	4	6		Plain yohgurt