ΕΛΛΗΝΙΚΗ ΕΤΑΙΡΕΙΑ
ΜΕΛΕΤΗΣ & ΕΚΠΑΙΔΕΥΣΗΣ
ΓΙΑ ΤΟΝ ΣΑΚΧΑΡΩΔΗ ΔΙΑΒΗΤΗ

Insulin management during exercise in Diabetes Mellitus type 1

Η ΤΕΧΝΟΛΟΓΙΑ ΣΤΟΝ ΣΑΚΧΑΡΩΔΗ ΔΙΑΒΗΤΗ

20-21/9/2024
THE MET HOTEL
ΘΕΣΣΑΛΟΝΙΚΗ

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In the old days, the advice was maybe you should avoid it. Just go for a walk.

Lack of evidence

Dysglycaemia :acute responses with high risk situations for patients.

Hypoglycemia fear

Hyperglycemia fear

Lack of training on exercise for Healthcare practitioners!!!

Types of individuals

Amateur / recreational simple gym	intermediate	Professional
Normal weight – Normal body fat “Normal” insulin sensitivity	Overweight – Obesity – Increased body fat ”Resistant” insulin sensitivity	Very low body fat ? Insulin sensitivity

Treatment regimes

MDI

CSII

MDI + CGM

HCL

Can we even consider exercising without a CGM device?

Types of exercise

Αεροβια ασκηση

χαμηλής έως υψηλής έντασης που εξαρτάται κυρίως από την αερόβια διαδικασία παραγωγής ενέργειας.

βασιζεται στο συστημα Ο2

Κυρια πηγη γλυκογονο, λιπη και γλυκοζη

Παρατεταμενη χρονικη περιοδος

τρέξιμο μεσαίων ή μεγάλων αποστάσεων, το τζόκινγκ, η κολύμβηση, η ποδηλασία, το ανέβασμα σκαλοπατιών και το περπάτημα.

Αναεροβια ασκηση

Εντονη ασκηση, μικρης διαρκειας

Βασιζεται στο συστημα ATP-CP και στο συστημα γαλακτικου οξεος

Κυρια πηγη φωσφοκρεατινη γλυκογονο

Αρση βαρων, δρομος διαρκειας 6 δευτερολεπτων
Δρομος μεχρι 800μ

Διάρκεια προσπάθειας	Πηγή ενέργειας
<30 δευτερολεπτα	ATP-CP
30-90 δευτερολεπτα	ATP-CP- γαλακτικο οξυ
90-180 δευτερολεπτα	Γαλακτικο +Ο2
>180 δευτερολεπτα	Ο2

Ταξινόμηση	Διάρκεια προσπάθειας	Πηγή ενέργειας
Αναεροβια ισχυς	1-10 δευτερολεπτα	ATP-CP
Αναεροβια ικανοτητα	20-45 δευτερολεπτα	ATP-CP + αναεροβια γλυκολυση
Ανοχη στο γαλακτικο οξυ	1-8 λεπτα	Ικανοτητα ανοχης μεγαλων ποσοτητων γαλακτικου οξεος
Αεροβια	10 λεπτα +	Ο2

Types of exercise

- Aerobic exercise is associated with decreasing glucose values, whereas brief, very high-intensity or anaerobic exercise is related to increasing glucose values

↓ glucose

↑ glucose

Critical timepoints for exercise

- Before
- During
- After

Risks

- Indeed, the glucose changes that occur during physical activity depend not only on **the doses of insulin** or the **amount of carbohydrates** consumed by an individual but also on the **type, intensity, and duration** of physical activity performed, the **patient's metabolic control** of diabetes, their **residual insulin secretion**, their **physical fitness**, and their own **knowledge of diabetes**

- A greater risk of ketoacidosis occurs in individuals treated with continuous subcutaneous insulin infusion (CSII) because **insulin pumps are often disconnected during sports**, especially team games, contact sports, or swimming. In addition, there is a **risk of damage to the infusion set**.

Lost???

Glucose management for exercise using continuous glucose monitoring (CGM) and intermittently scanned CGM (isCGM) systems in type 1 diabetes: position statement of the European Association for the Study of Diabetes (EASD) and of the International Society for Pediatric and Adolescent Diabetes (ISPAD) endorsed by JDRF and supported by the American Diabetes Association (ADA)

- **A lag time between** the glucose value in the vasculature and interstitial fluid does exist and, thus, influences sensor glucose measurement accuracy against blood glucose values . Moreover, other physiological changes during exercise, such as **alterations in blood flow rate, body temperature and body acidity, can theoretically have an impact on interstitial glucose- sensing accuracy**
- Thus, when assessing the accuracy of different interstitial glucose monitoring systems vs reference glucose, which is usually assessed by a median or mean absolute relative difference (MARD), a part of the difference should be **interpreted as lag time rather than inaccuracy**
- Additionally, other factors, like **local metabolic rate, sensor site , exercise type , vasoconstriction, potential interference with medications , the direction of glucose rate of change and baseline glucose level may influence lag time .**
- Also, the **glucose concentration**, per se, might have an impact on the **sensor accuracy**, as seen for isCGM, detailing a **lower MARD for hyperglycaemia and higher MARD for hypoglycaemia**
- **At** rest, a **lag time of ~5 min** is seen in healthy individuals , while, in situations of rapid glucose changes, it can increase to up to **12– 24 min or even longer during exercise**, as seen in people with type 1 diabetes . Depending on the CGM and isCGM device, the overall mean of all MARDs during different types of exercise in people with type 1 diabetes is ~13.63% (95% CI 11.41%, 15.84%)

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- CGM and isCGM devices may provide a different glucose reading compared with the actual SMBG, especially during exercise, and, thus, the sensor glucose value should be interpreted together with the corresponding trend arrow.
- mild-to-moderate aerobic exercise decreases glucose levels , whilst intense aerobic and anaerobic exercise and exercises with a load-profile similar to interval exercise stabilise or increase glucose levels, as seen in various experimental studies .
- Independent of the aforementioned groups (adults and children/adolescents), individuals who do not routinely exercise may face an increased risk of hypoglycaemia, as partially shown in a prospective observational study (C).
- Additionally, IAH , preceding episodes of hypoglycaemia (B) and advanced age (C) potentially increase the risk of hypoglycaemia during and after exercise.

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- following groups can be categorised:
- & Currently minimally exercising and/or high risk of hypoglycaemia
- & Currently moderately exercising and/or moderate risk of hypoglycaemia
- & Currently intensively exercising and/or low risk of hypoglycaemia

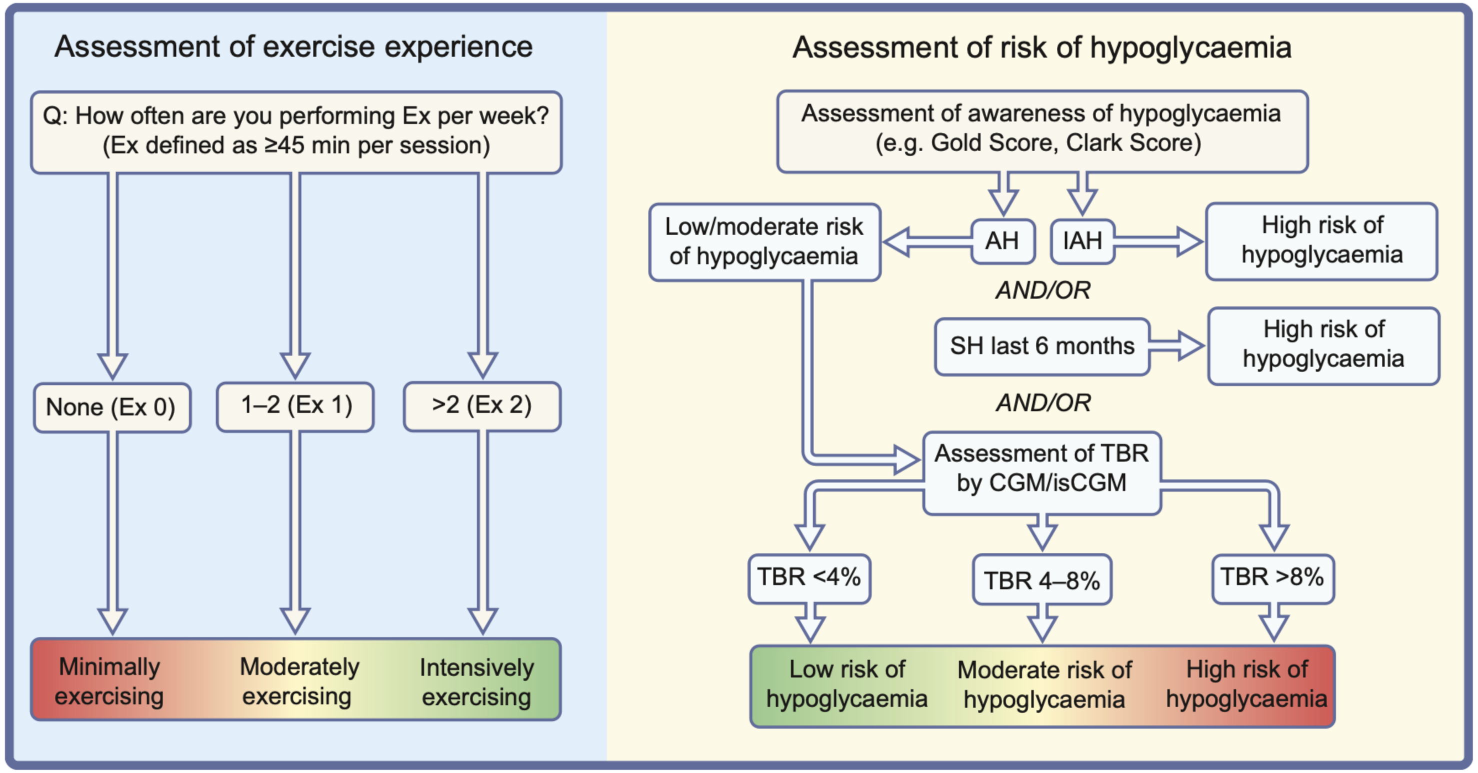

Fig. 2 Assessment of exercise experience and risk of hypoglycaemia. Exercise (Ex) represents how often people with type 1 diabetes are exercising with a duration ≥45 min per session per week. Assessment of risk of hypoglycaemia should be based on scoring systems for being aware of hypoglycaemia (AH) or showing IAH. In addition, if the scoring system reveals AH, the time below range (TBR; <3.9 mmol/l, <70 mg/dl) over the last 3 months should be evaluated to detail the degree of awareness. Furthermore, if an episode of severe hypoglycaemia (SH) occurred within the last 6 months, then there might be a high risk of hypoglycaemia during exercise. This figure is available as part of a downloadable slideset

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- To lower the risk of hypoglycaemia during prolonged exercise, **exercise should be initiated when mealtime insulin levels are low or about 90 min after the last carbohydrate- rich meal with a reduction in mealtime insulin [38] (D), [39] (D).** However, to achieve beneficial effects of exercise on overall glycaemic control, **exaggerated bolus insulin dose reductions should be avoided**
- Preparation in advance to exercise If a CGM or a second- generation isCGM device is used, **hypoglycaemic alerts might be set at the highest possible alarm lower threshold at the onset of exercise,** which is currently 5.6 mmol/l (**100 mg/dl**) [22] (D). This elevated hypoglycaemia alert setting is in **line with the expected delay between interstitial glucose and blood glucose when levels are dropping during prolonged exercise**
- The **rate-of-glucose-change alerts (dropping or rising) can be used to initiate an earlier action, such as a decrease or increase in basal insulin rate for those on continuous subcutaneous insulin infusion (CSII),** or a **change to glucose-rich or glucose-free fluids, depending on the direction of change.**
- Thirty to 60 min prior to the start of prolonged aerobic exercise (>30 min), to reduce hypoglycaemia risk, low glycaemic index carbohydrates can be consumed in those who do not reduce insulin dose, aiming to achieve pre-exercise sensor glucose targets.

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Before exercise

Table 1 Sensor glucose targets in advance of exercise in regard to different groups of people with type 1 diabetes

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],	Consider insulin correction[c],
			↘		
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)	↗		
			↘		
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)	↗		
			↘		
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	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]

Sensor glucose	Trend arrow	Increase in sensor glucose expected	Decrease in sensor glucose expected
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]	

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During exercise

Table 2 Sensor glucose targets during exercise in regard to different groups of people with type 1 diabetes

During 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			↑↗→↘↓	Stop Ex, Consider insulin correction, No restart of Ex	
>15.0 mmol/l (>270 mg/dl) AND ≤1.5 mmol/l blood ketones			↗↑	Consider insulin correction[c], Proceed all Ex	Proceed all Ex, Consider AE
			→	Consider insulin correction[c], Proceed all Ex	Proceed all Ex
			↘↓	Proceed 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)	↗↑	Proceed all Ex, Consider insulin correction[c]	Proceed all Ex
			→		
			↘↓	Proceed 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)	↗↑	Proceed all Ex	
			→		
			↘↓		
<7.0 mmol/l (<126 mg/dl)	<8.0 mmol/l (<145 mg/dl)	<9.0 mmol/l (<162 mg/dl)	↗↑	Proceed all Ex	
			→	~10 g CHO, Proceed all Ex[d]	~15 g CHO, Proceed all Ex[d]
			↘	~15 g CHO, Proceed all Ex[d]	~25 g CHO, Proceed all Ex[d]
			↓	~20 g CHO, Proceed all Ex[d]	~35 g CHO, Proceed all Ex[d]
<3.9 mmol/l (<70 mg/dl)			↑	Stop all Ex, Consider confirmatory SMBG, Individual amount CHO ingestion, Restart of all Ex possible[e]	
			↗		
			→		
			↘		
			↓		
<3.0 mmol/l (<54 mg/dl)			Stop all Ex, Confirmatory SMBG, Individual amount CHO ingestion, No restart of Ex		

Sensor glucose targets are detailed for the following groups in type 1 diabetes (T1D): intensively exercising and/or low risk of hypoglycaemia (Ex

A lower carbohydrate intake can be achieved during prolonged exercise if desired, but aggressive insulin dose adjustments are likely to be needed

- if sensor glucose **is rapidly increasing in the post-exercise phase (detected by CGM when using the rate-of-change alert), then an insulin correction can be considered (50% of typical correction dose)**

Table 4 General insulin therapy and carbohydrate recommendations for exercise in children and adolescents with type 1 diabetes

Type of therapy	Type/intensity of exercise Duration 30–45 min	Type/intensity of exercise Duration >45 min
MDI/CSII: mealtime bolus insulin dose reduction	−25% for mild aerobic −50% for moderate aerobic −50% for intense aerobic −25% for mixed aerobic/anaerobic Up to −50% post exercise	−50% for mild aerobic −75% for moderate aerobic −75% for intense aerobic −50% for mixed aerobic/anaerobic Up to −50% post exercise
MDI: basal insulin[a]	−20% for evening/late afternoon exercise	−20% for evening/late afternoon exercise −30 to −50% for all-day/unusual activities[a]
CSII: basal insulin rate	Up to −50% 90 min pre exercise Insulin pump suspension (<60 min) −20% for post-exercise night time[b]	Up to −80% 90 min pre exercise Insulin pump suspension (<60 min) −20% for post-exercise night time[b]
General CHO intake[c]	10–15 g CHO depending on IOB and sensor glucose level 1.5 g CHO per kg BW/h for intense exercise (regular IOB) 0.25 g CHO per kg BW/h for intense exercise (less IOB) 0.4 g CHO/kg BW pre-bed snack for evening/late afternoon exercise	10–15 g CHO depending on IOB and sensor glucose level 1.5 g CHO per kg BW/h for intense and/or long-lasting exercise (regular IOB) 0.25 g CHO per kg BW/h for intense exercise (less IOB) 0.4 g CHO/kg BW pre-bed snack for evening/late afternoon exercise

[a] Basal insulin dose might be reduced the day prior and on the day of all-day exercise

[b] Basal insulin rate might be reduced by 20% before bedtime if late afternoon/evening exercise was performed, depending on the duration and intensity of exercise

[c] Regular IOB, no/little insulin reduction has been performed; less IOB, moderate/high insulin reduction has been performed

BW, body weight; CHO, carbohydrates; CSII, continuous subcutaneous insulin infusion; IOB, insulin on board; MDI, multiple daily injections

Points to consider when using CGM/isCGM around exercise

Before exercise

- Know type, intensity and duration of exercise
- Consider timing of exercise
- Know how much insulin on board
- Target a sensor glucose range based on exercise routine and risk of hypoglycaemia accompanied by adequate trend arrow

During exercise

- Target sensor glucose ranges should be between 7.0 mmol/l and 10.0 mmol/l (126 mg/dl and 180 mg/dl) and slightly higher for those with an increased risk of hypoglycaemia
- At a glycaemic threshold of 7.0 mmol/l (126 mg/dl), accompanied by a horizontal trend arrow, 10–15 g of carbohydrates should be consumed; 15–25 g carbohydrates should be consumed immediately if accompanied by a (slightly) downward trend arrow; 20–35 g of carbohydrates should be consumed if accompanied with a downward trending arrow
- If sensor glucose levels are elevated (>15.0 mmol/l [>270 mg/dl]), monitor blood ketone levels, and an insulin correction may be performed (50% of individual’s regular correction factor)
- Exercise should be suspended in adults if the sensor glucose level reaches <3.9 mmol/l (<70 mg/dl) and, if below 3.0 mmol/l (54 mg/dl), then exercise should not be restarted

After exercise

- During the first 90 min following exercise, a sensor glucose range of 4.4 mmol/l to 10.0 mmol/l (80 mg/dl to 180 mg/dl) might be targeted and ~10–15 g carbohydrates should be consumed at the lower glucose limit based on the trend arrow
- If an insulin correction is applied due to high sensor glucose levels, then the regular correction factor might be reduced by up to 50%. CGM alarm should set at 4.4 mmol/l (80 mg/dl) and those using isCGM system should perform at least one scan during the night-time period

Insulin Management Strategies for Exercise in Diabetes

Βασική ινσουλίνη – Εντατικοποιημένο σχήμα

- However, with all 3 basal insulin types unadjusted for activity, mild hypoglycemia was relatively common either during the 30 minutes of exercise or soon after exercise was finished (21%–57% of patients, depending on the basal insulin used)

- Τα άτομα που «σπάνε» την δόση της βασικής σε πρωινη και βραδινη εχουν μεγαλυτερη ευελιξια
- Μπορούν να **μειωσουν την πρωινη δοση πριν την ασκηση** , αφηνοντας την βραδινη το προηγουμενο βραδυ ανεπηρεαστη

- Επισης μπορουν να **μειωσο**

- Γενικα η μειωση στην ινσο … ταν υπαρχει ασυνηθιστα **εντονη μερα για φυσικη δρ** … **g-distance run, or a cycling event)**

> For those individuals using ultra-long-acting insulin (i.e. degludec), basal adjustments for exercise **are generally not recommended**, since the glycemic impact will be prolonged. More research is needed to accommodate exercise in the era of ultra-long-acting basal insulins.

- **προσοχή στην degludec !**
- Αν η βασικη ινσουλινη δινεται μονο το βραδυ , τοτε αλλαγες συστηνοται το **βραδυ πριν την ημερα με εντονη φυσικη δραστηριοτητα.**
- Αν δινεται το πρωι τοτε αλλαγες γινονται **εκεινο το πρωι**

- In cases of prolonged aerobic activity, an additional reduction in **bedtime basal insulin by 10% to 20% after exercise**, when possible, should be implemented to protect against postexercise nocturnal hypoglycemia .
- In situations in which planned exercise occurs **1 to 3 hours after a meal, bolus insulin adjustments** are preferred for those receiving MDIs, since the impact on 24-hour BG levels will be minimal.

Insulin Management Strategies for Exercise in Diabetes

Βασική ινσουλίνη – Εντατικοποιημένο σχήμα

Table 4
Basal insulin adjustment strategies for patients receiving multiple daily injection therapy

	Single exercise bout (up to 60 minutes)	Unusually active day (≥90 minutes accumulated)
Aerobic: moderate-to-vigorous intensity continuous exercise	No reduction typically performed	20%–30% long-acting insulin reduction*
Resistance: weight lifting	No reduction typically performed	10%–20% long-acting insulin reduction*
Brief intense anaerobic (sprinting, powerlifting)	Not applicable: Exercise typically lasts only a few minutes	
Mixed: intermittent aerobic and anaerobic	No reduction typically performed	20%–30% long-acting insulin reduction*

Suggested starting points for basal rate reductions for various types and durations of exercise (not all recommendations have been formally tested). Basal rate adjustments for patients receiving multiple daily injections are appropriate if the planned activity is prolonged and the activity is performed either in the fasted state or several hours after a meal such that bolus insulin cannot be reduced (i.e. 3 or more hours). In all situations with multiple daily injection therapy, additional carbohydrates may be required, particularly if no basal rate adjustments are made. This summary table is based on studies conducted in patients with type 1 diabetes (21, 23, 44), but these suggestions may also be applied to patients with type 2 diabetes.

* This applies to long-acting (insulin glargine, detemir) and intermediate-acting (neutral protamine Hagedorn) insulins only. Patients on a split-dose basal insulin regimen can reduce the morning basal dose to protect against exercise-induced hypoglycemia and may lower the evening dose to further protect against nocturnal hypoglycemia. Doses of ultra-long-acting insulin (e.g. degludec) should not be adjusted for exercise.

Insulin Management Strategies for Exercise in Diabetes

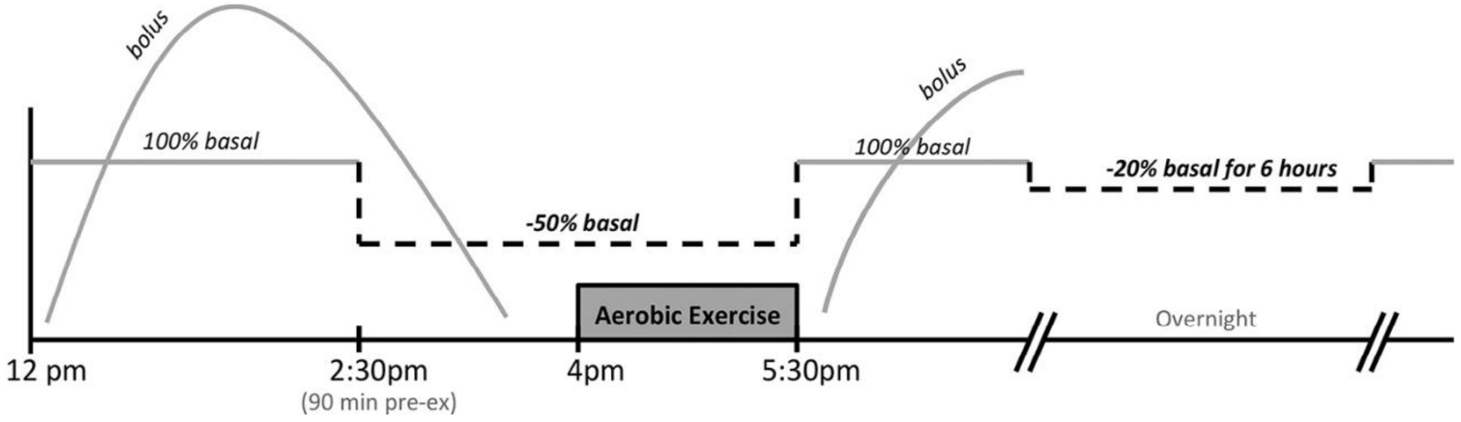


Figure 1. Basal rate insulin reductions for patients receiving a continuous subcutaneous insulin infusion. Basal rate reductions should be done well in advance of the planned exercise (~90 minutes before exercise) and generally last until the end of exercise. After aerobic exercise,~20% basal insulin reductions are recommended for 6 hours overnight (starting at bedtime) to help protect against nocturnal hypoglycemia.

Insulin Management Strategies for Exercise in Diabetes

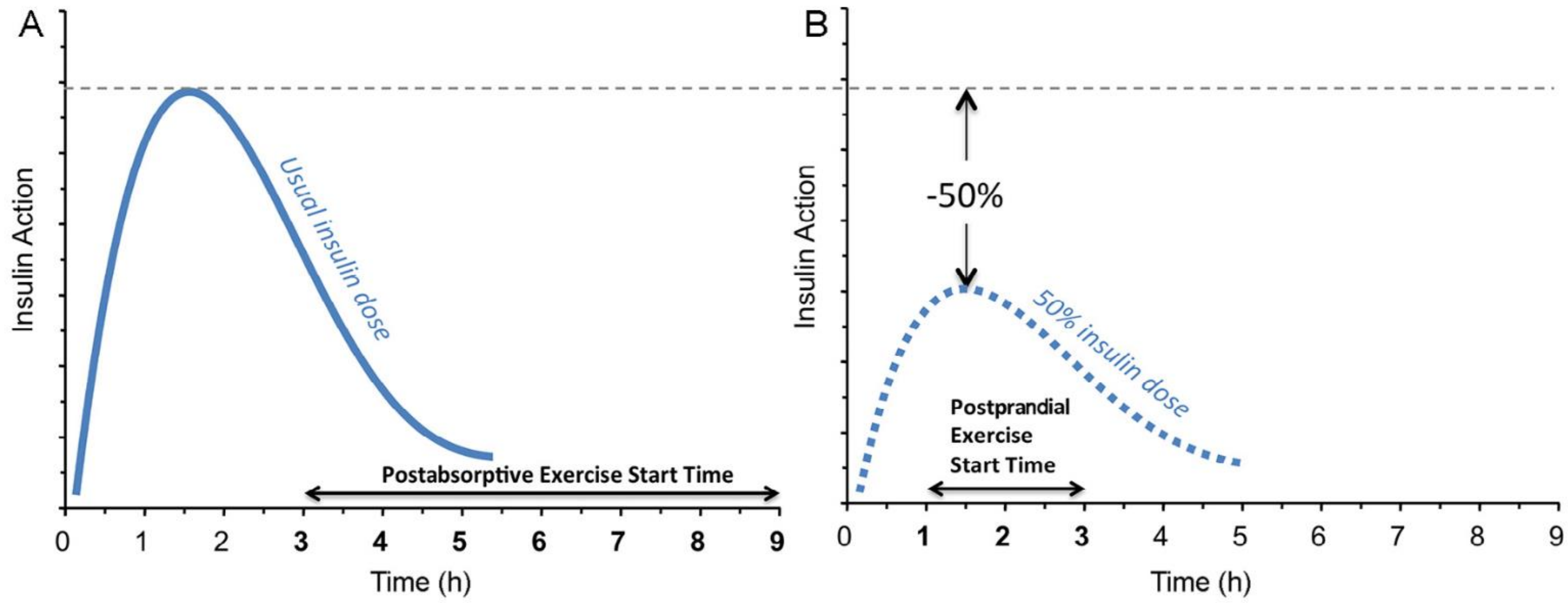


Figure 2. Bolus insulin adjustments based on the timing of exercise relative to mealtime. A, If the onset of exercise occurs 3 or more hours after a meal, generally, no bolus adjustments are made. B, If the start of exercise occurs 1 to 3 hours after a meal, generally, a 50% reduction in bolus insulin is required with the meal before exercise. These recommendations are applicable for aerobic exercise lasting >30 minutes.

Insulin Management Strategies for Exercise in Diabetes

Table 2
Bolus insulin adjustments for postprandial exercise

	Meal before exercise		Meal after exercise
	Exercise (~30 min)	Exercise (~60 min)	
Aerobic: moderate-to vigorous intensity continuous exercise	25%–50% bolus reduction	50%–75% bolus reduction	Up to 50% bolus reduction
Resistance: weight lifting	No reduction typically performed	25%–50% bolus reduction	No change in bolus
Brief intense anaerobic (sprinting, powerlifting)	Not applicable: Exercise typically lasts only a few minutes		Small (~50%) bolus correction if hyperglycemic*
Mixed: intermittent aerobic and anaerobic	~ 25% bolus reduction	~ 50% bolus reduction	Up to 50% bolus reduction

Suggested starting points for bolus insulin reductions for various types and durations of exercise (not all recommendations have been formally tested). These suggestions are for rapid-acting insulin only. Bolus insulin adjustments are typically made when the exercise is performed within 1 to 3 hours after a meal. Knowing the type of activity that is being performed will guide the bolus insulin adjustments, as described previously. This summary table is based on studies conducted in patients with type 1 diabetes who received prandial (bolus) insulin adjustments (2, 21, 28, 31–33, 38).

* Requires continued monitoring to help protect against postexercise hypoglycemia, particularly overnight.

Insulin Management Strategies for Exercise in Diabetes

Table 3
Basal insulin adjustment strategies for patients receiving continuous subcutaneous insulin infusion

	Exercise (~30 min)	Exercise (~60 min)	After exercise
Aerobic: moderate-to-vigorous intensity continuous exercise	50% basal reduction, performed 60–90 min before exercise) or 100% basal reduction at exercise onset*	50%–80% basal reduction performed 60–90 min before exercise) or 100% basal reduction at exercise onset*	20% basal reduction overnight from bedtime lasting 6 h
Resistance: weight lifting	No reduction typically performed	50% basal reduction, performed 60–90 min before exercise)	20% basal reduction overnight from bedtime for 6 h
Brief intense anaerobic (sprinting, powerlifting)	Not applicable: Exercise typically lasts seconds to minutes		No reduction typically performed†
Mixed: intermittent aerobic and anaerobic	100% basal reduction at exercise onset*	50% basal reduction, performed 60–90 min before exercise) or 100% basal reduction at exercise onset*	20% basal reduction overnight from bedtime for 6 h

Suggested starting points for basal insulin reductions for various types and durations of exercise (not all recommendations have been formally tested). Basal rate adjustments are typically made when the exercise is performed in the fasted state or several (3+hours) after a meal. For activities that occur soon after meals (within 3 hours), bolus insulin should be adjusted (see Table 2). Knowing the type of activity that is being performed will guide the basal rate adjustments, as described previously. This summary table is based on studies conducted in patients with type 1 diabetes (35, 37, 44, 45).

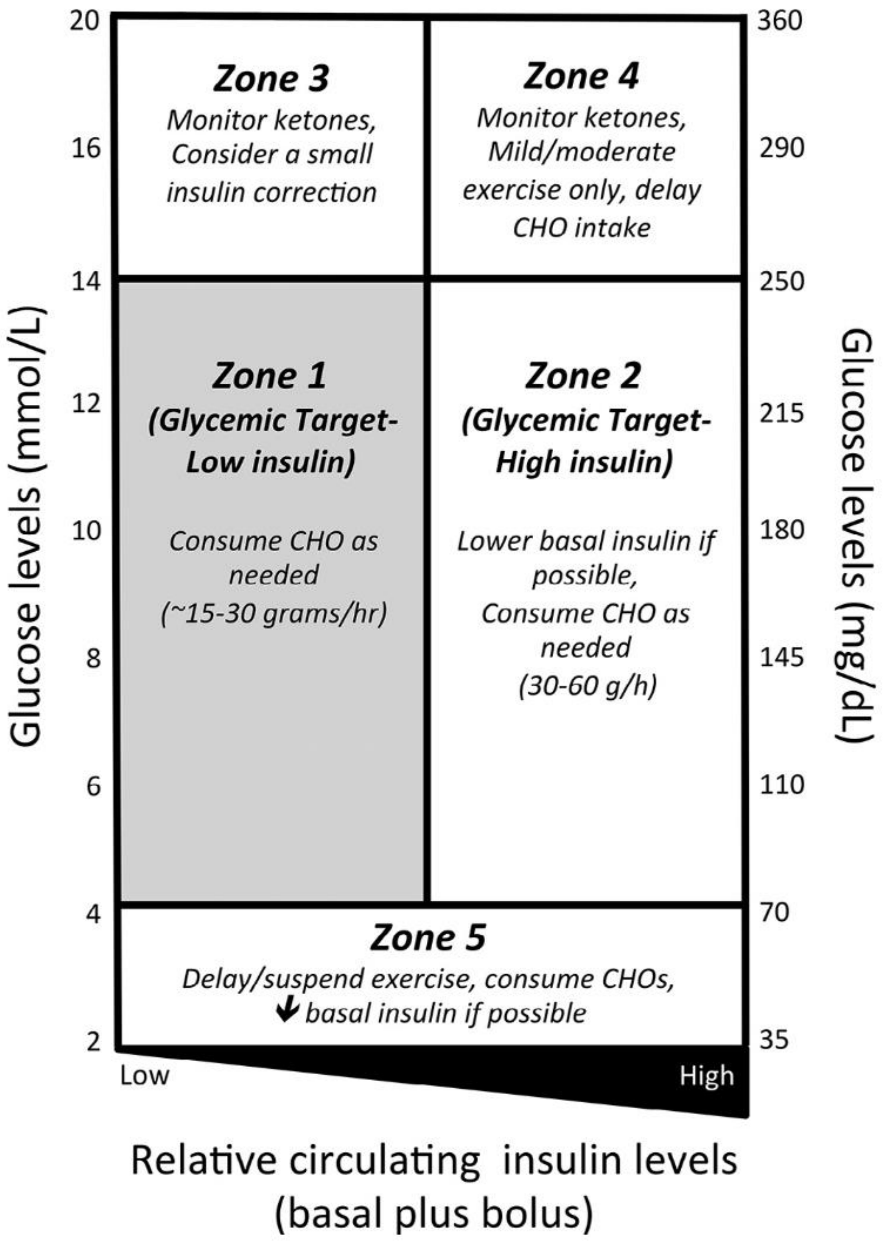
* Carbohydrate may be required, since insulin levels may not drop fast enough during the activity.

† Postexercise hyperglycemia should be treated with a bolus insulin correction rather than a basal rate change.

Insulin Management Strategies for Exercise in Diabetes

Zones 1 to 5 represent BG ranges and relative insulin levels at the start of exercise and suggested strategies for safe performance of exercise (e.g. monitor ketone levels, delay exercise, consume carbohydrates, lower basal insulin if possible).

- Zone 1 (i.e. BG in targeted range, low insulin) is suitable for prolonged aerobic exercise and for anaerobic and mixed exercise.
- Zone 2 (i.e. BG in targeted range, high insulin) is suitable for prolonged aerobic exercise but typically requires some carbohydrate feeding and/or basal insulin reductions if possible (patients receiving continuous subcutaneous insulin infusion only). Anaerobic and mixed exercise can be initiated.
- Zone 3 (i.e. high BG levels, low insulin) requires ketone monitoring before exercise and insulin administration if ketones are elevated above trace level. Exercise should be avoided until control is re-established.
- Zone 4 (i.e. high BG levels, high insulin) also requires ketone monitoring to confirm that ketones are low before start of moderate-intensity aerobic exercise. (Note: Circulating insulin concentrations may be lower than estimated levels because of infusion-set blockage in patients receiving continuous subcutaneous insulin infusion).
- Zone 5 (i.e. hypoglycemia with or without elevated insulin levels) requires carbohydrate feeding before the start of exercise (~15–30 g, depending on the amount of insulin in the circulation). **In all of these zones, close BG monitoring is advised.**



Use of continuous glucose monitoring for sport in type 1 diabetes

- Additional recommendations: If first-time exercise, there is a prolonged hypoglycaemia risk so the basal rate should be reduced for the entire night using temporary basal rate setting;
  if on MDI the long -acting dose should be reduced that day/ night. Hypoglycaemia risk is also higher if exercise is carried out on sequential days, or there was a hypoglycaemic event on the day preceding exercise. Alcohol also increases the risk of hypoglycaemia.
- If hyperglycaemia is encountered post-exercise (especially likely if moderate-intensity/high -intensity exercise at the anaerobic/lactate threshold), a cool-down over 20–30 min will reduce the need to give a correction bolus.
- A 10 s sprint done before and/or during low/moderate -intensity exercise will elevate glucose levels and reduce the risk of hypoglycaemia during or after exercise.

Insulin adjustments

Pre-exercise	Timing of exercise	Action
MDI	≤90 min after meal	Reduce pre-meal insulin bolus, 25%–50% if<90 min exercise, 50% if>90 min exercise
	>90 min after meal	Do not adjust bolus, may need to consume extra Carbohydrate
Pump	≤90 min after meal	Reduce pre-exercise insulin dose or use temporary basal rate for 30–90 min pre-exercise
	>90 min after meal	Do not reduce bolus, temporary basal rate only
During exercise	MDI	Replenish with Carbohydrate as needed
	Pump	Use temporary basal rate, for example, 50%
After exercise	MDI	Reduce long-acting insulin dose
	Pump	Reduce basal rate for 4 hours from bedtime

Continued

Εφαρμογή στην πράξη?

Reduction in insulin degludec dosing for multiple exercise sessions improves time spent in euglycaemia in people with type 1 diabetes: A randomized crossover trial

Aims: To compare the time spent in specified glycaemic ranges in people with type 1 diabetes (T1D) during 5 consecutive days of moderate-intensity exercise while on either 100% or 75% of their usual insulin degludec (IDeg) dose.

Materials and Methods: Nine participants with T1D (four women, mean age 32.1 ± 9.0 years, body mass index 25.5 ± 3.8 kg/m^2, glycated haemoglobin 55 ± 7 mmol/mol (7.2% ± 0.6%) on IDeg were enrolled in the trial. Three days before the first exercise period, participants were randomized to either 100% or 75% of their usual IDeg dose. Participants exercised on a cycle ergometer for 55 minutes at a moderate intensity for 5 consecutive days. After a 4-week wash-out period, participants performed the last exercise period for 5 consecutive days with the alternate IDeg dose. Time spent in specified glycaemic ranges, area under the curve and numbers of hypoglycaemic events were compared for the 5 days on each treatment allocation using a paired Students' *t* test, Wilcoxon matched-pairs signed-rank test and two-way ANOVA.

Results: Time spent in euglycaemia over 5 days was greater for the 75% IDeg dose versus the 100% IDeg dose (4008 ± 938 minutes vs. 3566 ± 856 minutes; P = 0.04). Numbers of hypoglycaemic events (P = 0.91) and time spent in hypoglycaemia (P = 0.07) or hyperglycaemia (P = 0.38) was similar for both dosing schemes.

Conclusions: A 25% reduction in usual IDeg dose around regular exercise led to more time spent in euglycaemia, with small effects on time spent in hypo- and hyperglycaemia.

Reduction in insulin degludec dosing for multiple exercise sessions improves time spent in euglycaemia in people with type 1 diabetes: A randomized crossover trial

TABLE 2 Comparison of the entire 5 days of exercise in the 100% insulin degludec (IDeg) and 75% IDeg dosing period for glycaemic ranges, area under the curve for hyperglycaemic, euglycaemic, hypoglycaemic ranges, hypoglycaemic events, coefficient of variation for glycaemia, carbohydrate consumption and insulin administration

Overall	100% IDeg	75% IDeg	*P*
$Time_{euglycaemia}$, min	3566 ± 856	4008 ± 938	0.04
$Time_{euglycaemia}$, %	57 ± 14	62 ± 15	0.16
$Time_{hypoglycaemia}$, min	240 (128-465)	270 (90-683)	0.07
$Time_{hypoglycaemia}$, %	3.6 (1.9-7.9)	4.0 (1.3-10)	0.10
$Time_{serious\ hypoglycaemia}$, min	45 (0-105)	30 (0-233)	0.15
$Time_{serious\ hypoglycaemia}$, %	0.7 (0-1.7)	0.4 (0-3.5)	0.30
$Time_{hyperglycaemia}$, min	2440 ± 1094	2187 ± 1046	0.38
$Time_{hyperglycaemia}$, %	38 ± 16	33 ± 16	0.23
$Time_{serious\ hyperglycaemia}$, min	195 (0-420)	165 (23-405)	0.36
$Time_{serious\ hyperglycaemia}$, %	2.8 (0-7.3)	2.7 (0.4-5.9)	0.64
$AUC_{euglycaemia}$	11 310 ± 3190	12 772 ± 3214	0.08
$AUC_{hypoglycaemia}$	121 ± 106	153 ± 138	0.09
$AUC_{serious\ hypoglycaemia}$	107 (0–248)	65 (0–600)	0.30
$AUC_{hyperglycaemia}$	5893 ± 3092	5332 ± 3024	0.52
$AUC_{serious\ hyperglycaemia}$	374 (0-1259)	192 (7-846)	0.84
Hypoglycaemic events per participant over 5 days, n	4.7 ± 2.9	4.8 ± 3.4	0.91
$CV_{glycaemia}$, %	39 ± 7	40 ± 7	0.57
Prandial insulin used, IU	73 ± 40	72 ± 32	0.89
Correction insulin used, IU	17 ± 10	20 ± 10	0.31
Prandial carbohydrates, g	648 ± 115	739 ± 237	0.10
Correction carbohydrates, g	259 ± 114	219 ± 112	0.17

Abbreviations: AUC, area under the curve; CV, coefficient of variation; IDeg, insulin degludec.

Assessment of Safety and Glycemic Control During Football Tournament in Children and Adolescents With Type 1 Diabetes—Results of GoalDiab Study

- **189 children with type 1 diabetes** from 11 diabetes care centers, in Poland, participated in a football tournament in 3 age categories: 7–9 (21.2%), 10–13 (42.9%), and 14–17 (36%) years

- Results: The median level of blood glucose before the matches was 6.78 (4.89–9.39) mmol/L, and after the matches, it was 7.39 (5.5–9.87) mmol/L (P = .001).
- There were **no episodes of severe hypoglycemia or ketoacidosis**.
- The number of episodes of low glucose value (blood glucose ≤3.9 mmol/L) was **higher** during the tournament versus 30 days before: 1.2 (0–1.5) versus 0.7 (0.3–1.1) event/person/day, P < .001.
- Lactate levels increased during the matches (2.2 [1.6–4.0] mmol/L to 4.4 [2.6–8.5] mmol/L after the matches, P < .001)

Assessment of Safety and Glycemic Control During Football Tournament in Children and Adolescents With Type 1 Diabetes—Results of GoalDiab Study

Table 1 Glycemic Control Among 83 Children in the Preceding 30 Days and During the Football Tournament (N = 83)

	30 d prior	Throughout tournament	Day 1	Day 2
Blood glucose level, mmol/L	8.33 (7.72–9.72)	7.43 (6.54–8.59)*	7.61 (6.56–8.53)	7.48 (6.41–8.63)
Number of episodes of level 1 hypoglycemia/person/day	0.7 (0.3–1.1)	1.2 (0–1.5)*	1 (0–2)*	1.6 (0–1.6)*
0	5 (8.3%)	12 (14.5%)	26 (31.3%)	34 (41.0%)
0–2	54 (90.0%)	41 (49.4%)	19 (22.9%)	25 (30.1%)
>2	1 (1.7%)	30 (36.1%)	38 (45.8%)	24 (28.9%)
Number of episodes of level 2 hypoglycemia/person/day	0.17 (0.03–0.3)	0 (0–0.6)*	0 (0–1.0)	0 (0.0–0.8)
0	10 (16.7%)	46 (55.4%)	59 (71.1%)	62 (74.7%)
0–2	50 (83.3%)	34 (41.0%)	19 (22.9%)	34 (41.0%)
>2	0 (0.0%)	3 (3.6%)	5 (6.0%)	7 (8.4%)
Blood glucose levels from CGM system, mmol/L	n/a	7.94 (7.22–8.90) n = 66	8.03 (6.76–8.81) n = 66	8.0 (7.01–8.84) n = 66
Blood glucose levels from FGM system, mmol/L	n/a	7.64 (6.89–9.08) n = 42	7.53 (6.85–8.6) n = 42	7.56 (6.51–9.16) n = 42

Abbreviations: CGM, continuous glucose monitoring; FGM, flash glucose monitoring; n/a, not available. Note: Data presented as median (interquartile range) and n (%) for available data (n).

*$P < .001$ versus 30 days prior.

Assessment of Safety and Glycemic Control During Football Tournament in Children and Adolescents With Type 1 Diabetes—Results of GoalDiab Study

Users of CSII were disconnected from the pump.
The protocol followed was

<100mg/dl	**10-25 g CHO (depending on body weight)**
100-150 mg/dl	**To advice on carbohydrate consumption check active insulin + glucose trend arrows**
>250 mg/dl	**Corrective dose of insulin reduced by 50%**
>250 mg/dl	**Beta ketone testing If >0.6 mmol/L not allowed to play and correction bolus and drink water !**

Hydration is key!!!

- **Ketone meters**
- **Hydration**
- The knowledge and skills in the use of insulin pumps, the calculation of active insulin, and deciding the amount of additional carbohydrates needed were extremely necessary.
- The rise in glucose **during 30 minutes of activity** was statistically significant but perhaps not surprising given the nature of activity (relatively brief, fairly intensive, and above the lactate threshold in nature) nor **clinically relevant**.
- Taking into account the element of competition, hyperglycemia seemed more likely. Insulin therapy during such intense and difficult-to-predict physical activity is much **easier** in athletes treated with a **personal insulin pump** ; these were used by over 80% of players in GoalDiab.
- **No mentioning of the carbohydrates consumed** !
- The study also attempted to determine the intensity and nature of the effort during the football tournament. **On the basis of measured lactates, the effort seems to be moderate aerobic–anaerobic.** Moreover, the presented results confirm that **mixed activity is associated with glucose stability**
- In any case, elevation in lactate levels during matches is **lower** than expected during efforts such as resistance training and high-intensity interval training in early adolescents

Efficacy of Carbohydrate Supplementation Compared With Bolus Insulin Dose Reduction Around Exercise in Adults With Type 1 Diabetes: A Retrospective, Controlled Analysis

Table 1

Efficacy of different glycemic management concepts during exercise in T1D

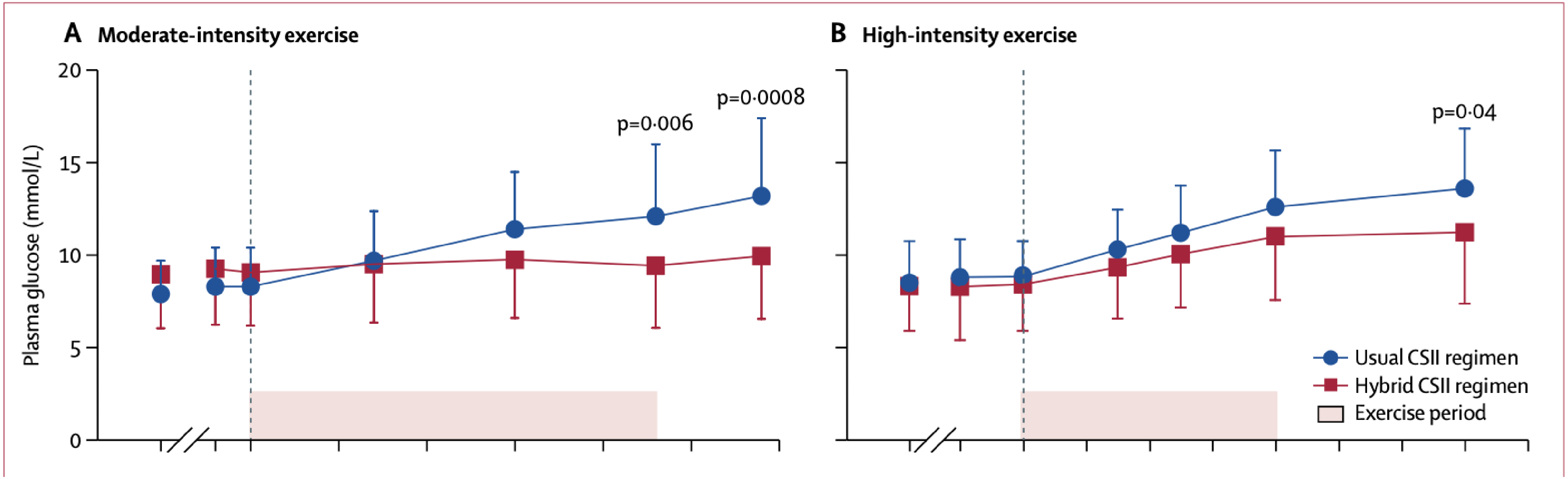
	Group A	Group B	Group C	p value *
Number of events, hypoglycemia	0 of 9 †	4 of 9 ‡	4 of 9 §	0.05
Time of hypoglycemia (min)	0§	0 (0–9)	12 (0–12) §	0.01
Time of euglycemia (min)	49 (28–49)	30 (12–36)	23 ± 12.2	0.10
Time of hyperglycemia (min)	0 (0–21)	6 (0–9)	0 (0–6)	0.41
Time of hypoglycemia (%)	0 §	0 (0–27)	22 ± 18 §	0.01
Time of euglycemia (%)	100 (57–100)	71 (47–86)	62 ± 27	0.37
Time of hyperglycemia (%)	0 (0–43)	14 (0–21.5)	0 (0–14.5)	0.43
Participants' consumed CHO (n)	7 of 9	0 of 9	0 of 9	
Time until reaching hypoglycemia (min)	–	33 ± 11.5	31.5 ± 9	0.83
CHO consumed per participant (g)	20.8 ± 6.7	–	–	
Total CHO treatments	14	–	–	

Group A: glycemic target 7.0mmol/L with supplementation 15-20 g CHO

Group B: reduction of bolus insulin by 50% in last meal

Group C: control

Flexible insulin therapy with a hybrid regimen of insulin degludec and continuous subcutaneous insulin infusion with pump suspension before exercise in physically active adults with type 1 diabetes (FIT Untethered): a single-centre, open-label, proof-of-concept, randomised crossover trial



Flexible insulin therapy with a hybrid regimen of insulin degludec and continuous subcutaneous insulin infusion with pump suspension before exercise in physically active adults with type 1 diabetes (FIT Untethered): a single-centre, open-label, proof-of-concept, randomised crossover trial

	Usual CSII regimen	Hybrid CSII regimen	Mean difference (95% CI)	p value*
Moderate-intensity exercise (n=24)				
Time in blood glucose range of 4–10 mmol/L, min	143 (126)	230 (124)	86 (61 to 147)	0·005
Percentage of time in blood glucose range of 4–10 mmol/L	40% (35)	64% (35)	24% (7 to 41)	0·005
Time in hyperglycaemia, min	215 (127)	128 (126)	–87 (–148 to –26)	0·005
Percentage of time in hyperglycaemia	60% (35)	36% (35)	–24% (–41 to –7)	0·005
Time in hypoglycaemia, min	2 (8)	3 (9)	0·4 (–5 to 5)	0·83
Percentage of time in hypoglycaemia	0·6% (2·1)	0·7% (2·5)	0·1% (–1·3 to 1·5)	0·86
Mean glucose concentration, mmol/L†	11·1 (2·9)	9·3 (2·7)	–1·8 (–3·0 to –0·6)	0·004
Number of hypoglycaemic events	2	2	..	..
High-intensity exercise (n=24)				
Time in blood glucose range of 4–10 mmol/L, min	179 (97)	239 (115)	60 (11 to 109)	0·01
Percentage of time in blood glucose range of 4–10 mmol/L	50% (27)	66% (32)	17% (3 to 31)	0·01
Time in hyperglycaemia, min	178 (97)	117 (117)	–61 (–111 to –12)	0·01
Percentage of time in hyperglycaemia	49% (27)	32% (33)	–17% (–31 to –3)	0·01
Time in hypoglycaemia, min	4 (9)	5 (14)	–1 (–5 to 8)	0·71
Percentage of time in hypoglycaemia	1·0% (2·1)	1·3% (3·9)	0·4% (–1·4 to 2·2)	0·71
Mean glucose concentration, mmol/L†	10·5 (1·9)	9·0 (2·5)	–1·5 (–2·6 to –0·4)	0·006
Number of hypoglycaemic events	4	3	..	..

Flexible insulin therapy with a hybrid regimen of insulin degludec and continuous subcutaneous insulin infusion with pump suspension before exercise in physically active adults with type 1 diabetes (FIT Untethered): a single-centre, open-label, proof-of-concept, randomised crossover trial

clinic

	Usual CSII regimen	Hybrid CSII regimen	Mean difference (95% CI)	p value*
Moderate-intensity exercise (n=24)				
Time in blood glucose range of 4–10 mmol/L, min	143 (126)	230 (124)	86 (61 to 147)	0·005
Percentage of time in blood glucose range of 4–10 mmol/L	40% (35)	64% (35)	24% (7 to 41)	0·005
Time in hyperglycaemia, min	215 (127)	128 (126)	–87 (–148 to –26)	0·005
Percentage of time in hyperglycaemia	60% (35)	36% (35)	–24% (–41 to –7)	0·005
Time in hypoglycaemia, min	2 (8)	3 (9)	0·4 (–5 to 5)	0·83
Percentage of time in hypoglycaemia	0·6% (2·1)	0·7% (2·5)	0·1% (–1·3 to 1·5)	0·86
Mean glucose concentration, mmol/L†	11·1 (2·9)	9·3 (2·7)	–1·8 (–3·0 to –0·6)	0·004
Number of hypoglycaemic events	2	2	..	..
High-intensity exercise (n=24)				
Time in blood glucose range of 4–10 mmol/L, min	179 (97)	239 (115)	60 (11 to 109)	0·01
Percentage of time in blood glucose range of 4–10 mmol/L	50% (27)	66% (32)	17% (3 to 31)	0·01
Time in hyperglycaemia, min	178 (97)	117 (117)	–61 (–111 to –12)	0·01
Percentage of time in hyperglycaemia	49% (27)	32% (33)	–17% (–31 to –3)	0·01
Time in hypoglycaemia, min	4 (9)	5 (14)	–1 (–5 to 8)	0·71
Percentage of time in hypoglycaemia	1·0% (2·1)	1·3% (3·9)	0·4% (–1·4 to 2·2)	0·71
Mean glucose concentration, mmol/L†	10·5 (1·9)	9·0 (2·5)	–1·5 (–2·6 to –0·4)	0·006
Number of hypoglycaemic events	4	3	..	..

Flexible insulin therapy with a hybrid regimen of insulin degludec and continuous subcutaneous insulin infusion with pump suspension before exercise in physically active adults with type 1 diabe… open-label, proo…

Home

	Usual CSII regimen	Hybrid CSII regimen	Mean difference (95% CI)	p value*
Moderate-intensity exercise (n=23)				
Time in blood glucose range of 4–10 mmol/L, min	213 (108)	236 (95)	25 (–10 to 60)	0·16
Percentage of time in blood glucose range of 4–10 mmol/L	59% (30)	66% (26)	7% (–3 to 17)	0·16
Time in hyperglycaemia, min	133 (113)	113 (97)	–25 (–60 to 10)	0·17
Percentage of time in hyperglycaemia	37% (31)	31% (27)	–7% (–17 to 3)	0·17
Time in hypoglycaemia, min	14 (39)	11 (28)	–2 (–15 to 11)	0·74
Percentage of time in hypoglycaemia	3·9% (10·8)	3·2% (7·8)	–0·6% (–4·1 to 2·9)	0·74
Mean blood glucose concentration, mmol/L†	9·1 (2·5)	8·8 (1·9)	–0·4 (–1·2 to 0·4)	0·26
Number of hypoglycaemic events	15 (over 55 sessions)	12 (over 55 sessions)	..	..
High-intensity exercise (n=22)				
Time in blood glucose range of 4–10 mmol/L, min	242 (99)	266 (95)	25 (–3 to 53)	0·09
Percentage of time in blood glucose range of 4–10 mmol/L	67% (27)	74% (26)	7% (–1 to 15)	0·09
Time in hyperglycaemia, min	108 (103)	78 (95)	–30 (–60 to –0)	0·048
Percentage of time in hyperglycaemia	30% (29)	22% (27)	–8% (–17 to –0)	0·048
Time in hypoglycaemia, min	11 (24)	16 (39)	5 (–5 to 15)	0·34
Percentage of time in hypoglycaemia	3·0% (6·7)	4·4% (10·8)	1·3% (–1·4 to 4)	0·34
Mean blood glucose concentration mmol/L†	8·7 (2·1)	8·1 (2·2)	–0·5 (–1·1 to –0·0)	0·10
Number of hypoglycaemic events	23 (over 75 sessions)	16 (over 69 sessions)	..	..
All exercise sessions (n=23)				
Time in blood glucose range of 4–10 mmol/L, min	230 (104)	253 (96)	23 (–1 to 46)	0·055
Percentage of time in blood glucose range of 4–10 mmol/L	64% (29)	70% (27)	6% (–0 to 13)	0·055
Time in hyperglycaemia, min	119 (108)	94 (97)	–25 (–48 to –2)	0·04
Percentage of time in hyperglycaemia	33% (30)	26% (27)	–7% (0 to 13)	0·04
Time in hypoglycaemia, min	12 (31)	14 (35)	2 (–6 to 10)	0·61
Percentage of time in hypoglycaemia	3·4% (8·6)	4% (10)	0·5% (–1·7 to 2·7)	0·61
Mean glucose concentration (mmol/L)†	8·8 (2·3)	8·4 (2·1)	–0·4 (–0·9 to 0·1)	0·10
Number of hypoglycaemic events	38 (over 130 sessions)	28 (over 124 sessions)	..	..

Practical Aspects and Exercise Safety Benefits of Automated Insulin Delivery Systems in Type 1 Diabetes

TABLE 1 AID Strategies to Decrease IOB and/or Maintain Glucose Levels for Planned and Unplanned/Spontaneous Exercise

Strategy	Description
Strategies for planned exercise	
Combination strategy	Set exercise target before onset of exercise (optimally 1–2 hours in advance) *and* reduce mealtime bolus insulin 1–3 hours before exercise.*
Set exercise target	Set exercise target before onset of exercise (optimally 1–2 hours in advance).
Reduce mealtime bolus insulin	Reduce mealtime bolus insulin 1–3 hours before exercise.*
Use manual mode and temp basal settings	Exit automated mode and use manual mode with recommended 50–80% basal insulin reduction set 90 minutes before exercise; may require additional carbohydrate feeding before exercise.
Check blood glucose	Perform fingerstick blood glucose check† and/or check CGM trend arrows and determine a plan of action for exercise.
Check IOB	Check IOB and determine a plan of action for exercise.
Strategies for unplanned/spontaneous exercise	
Carbohydrate feeding	Eat carbohydrates at exercise onset or during exercise.‡
Insulin pump suspension	Suspend insulin delivery at exercise onset and resume it at the end of exercise.
No change	Leave usual AID settings with no changes for exercise.

*If exercise is likely to occur 1–3 hours after a meal, a reduction in the mealtime bolus may be compensated by increased insulin delivery by the AID system, still resulting in increased IOB during exercise. †Fingerstick blood glucose checks may not be needed before exercise but may be suitable during rapid changes in glucose during exercise because of the potential increase in CGM lag time (29,31). ‡Additional carbohydrate feeding may be required during unplanned/spontaneous exercise, particularly in situations with higher IOB.

TABLE 3 Exercise Targets and Settings for Available AID Systems

AID System	Sensor and Pump Technology	Standard Glucose Target, mg/dL	Exercise Glucose Target, mg/dL	Exercise Target Terminology	Additional Information
MiniMed 670G/770G (Medtronic)	Guardian Sensor 3 CGM sensor and 670G or 770G insulin pump	120	150	Temp Target	Program for duration of time; will automatically deactivate at the end of the programmed time period
MiniMed 780G (Medtronic)	Guardian Sensor 4 CGM sensor and 780G insulin pump	100, 110, or 120	150	Temp Target	Program for duration of time; will automatically deactivate at end of the programmed time period; Temp Target disables the automated bolus feature
Control-IQ (Tandem)	Dexcom G6 CGM sensor and t:slim X2 insulin pump	112–160	140–160	Exercise Activity (up to six personal profiles can be created with personalized basal doses, insulin-to-carbohydrate ratios, and insulin sensitivity factors for use with Exercise Activity)	Manual start/stop—cannot program a duration of time; exercise mode suspends insulin delivery at a higher predicted glucose than standard mode but delivers insulin for usual hyperglycemic targets; overrides programmed sleep mode unless exercise mode switched off
CamAPS FX (CamDiab)	Dexcom G6 CGM sensor and Dana RS or Dana-i insulin pump	105 (customizable)	Customizable	Ease-Off or Planned Ease-Off	Program for duration of time; will automatically deactivate at the end of the programmed time period
Omnipod 5 (Insulet)	Dexcom G6 CGM sensor and Omnipod Pod insulin pump	110, 120, 130, 140, or 150 (customizable throughout the day)	150	Activity	During activity feature, automated insulin delivery is decreased, calculated IOB is increased, and maximum insulin delivery is restricted; enable for 1–24 hours; will automatically deactivate at end of enabled time period
OpenAPS algorithm (OpenAPS, AndroidAPS, FreeAPS X)	Variety of systems	Customizable	Customizable	Ability to change/scale all insulin delivery parameters (aggressiveness of automation) and targets	Program for duration of time or schedule for specific time; will automatically deactivate at the end of the programmed or scheduled time period
Loop algorithm (Loop, FreeAPS)	Variety of systems	Customizable	Customizable	Ability to change/scale all insulin delivery parameters (aggressiveness of automation) and targets	Program for duration of time or schedule for specific time; will automatically deactivate at the end of the programmed or scheduled time period

CONTINUED FROM P. 130

TABLE 3 Exercise Targets and Settings for Available AID Systems

AID System	Sensor and Pump Technology	Standard Glucose Target, mg/dL	Exercise Glucose Target, mg/dL	Exercise Target Terminology	Additional Information
Insulin-only bionic pancreas (Beta Bionics)	Dexcom G6 CGM and iLet bionic pancreas	Usually 120; can be changed by ±10	Can increase target to 130	No specific feature	Target is changed manually; no automatic deactivation

Updated and modified from refs. 13 and 16. *Received CE-marked approval in the European Union and United Kingdom and approval in Canada, Australia, and New Zealand. †Received CE-marked approval in the European Union and United Kingdom; only commercially available in Europe. ‡Received U.S. Food and Drug Administration clearance; only commercially available in the United States. APS, artificial pancreas system.

Performance of Omnipod Personalized Model Predictive Control Algorithm with Moderate Intensity Exercise in Adults with Type 1 Diabetes

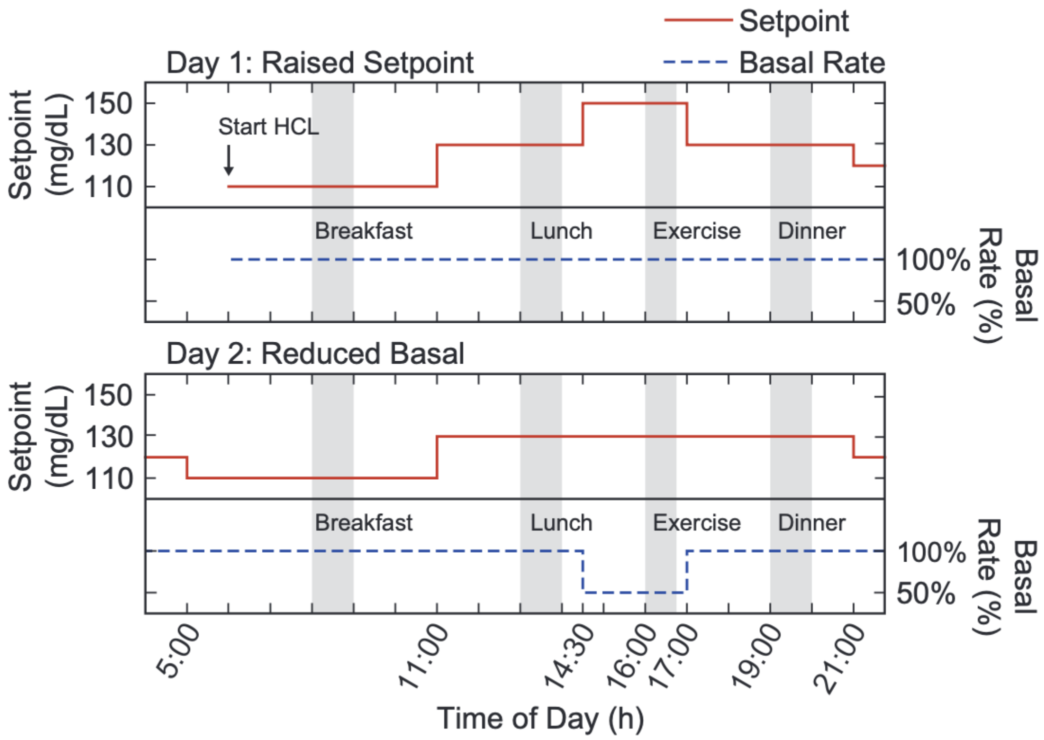


FIG. 1. Representation of the algorithm input settings of glucose set point (mg/dL) and basal rate (% of usual rate) on each study day with exercise. On study day 1, the glucose set point was raised to 150 mg/dL 90 min before exercise start (approximate timing indicated by gray bar labeled Exercise), whereas the basal rate was maintained at 100% of the usual rate (top panel). On study day 2, the basal rate was decreased to 50% of the usual rate 90 min before exercise, whereas the glucose set point was maintained at 130 mg/dL (bottom panel). On both days, the glucose set point was set to 110 mg/dL in the early morning (05:00 h), increased to 130 mg/dL in the late morning (11:00 h), and lowered to 120 mg/dL in the late evening (21:00 h). The approximate meal times are indicated by gray bars labeled with meal type. On Study day 3, the glucose set point was set to 110 mg/dL in the early morning (05:00 h), and HCL ended ∼5 h after breakfast (not shown). HCL, hybrid closed loop.

Performance of Omnipod Personalized Model Predictive Control Algorithm with Moderate Intensity Exercise in Adults with Type 1 Diabetes

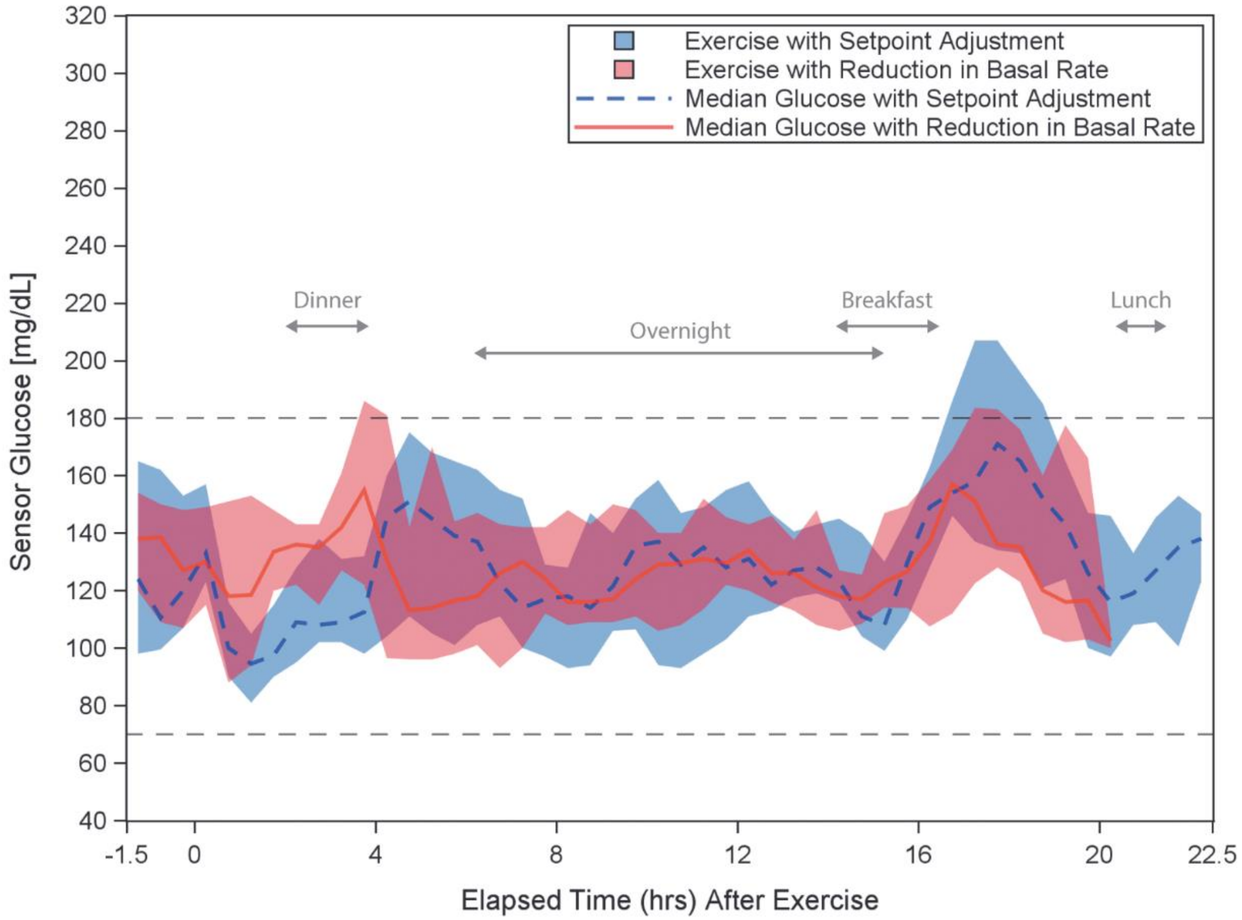


FIG. 2. Comparison of the glycemic response for the 12 participants for the 24 h period beginning 90 min before exercise start with glucose set point increase or reduction in basal rate. Median sensor glucose response is plotted for the 12 participants for 24 h after algorithm glucose set point increase (dashed blue line) or basal rate decrease (solid red line). The shaded area represents the IQR. Exercise start times ranged from 15:43 h to 16:48 h. The approximate ranges of time for dinner, the overnight period, breakfast, and lunch are labeled on the graph. The study ended ∼20 h after the start of exercise on day 2 and, therefore, the basal rate adjustment data series is limited to 20 h on the graph. The target range of 70–180 mg/dL is indicated by black dashed lines. IQR, interquartile range.

Performance of Omnipod Personalized Model Predictive Control Algorithm with Moderate Intensity Exercise in Adults with Type 1 Diabetes

TABLE 5. SUPPLEMENTAL CARBOHYDRATES AND HYPOGLYCEMIA AROUND EXERCISE

	Raised set point			Reduced basal		
Time period	*Subjects with supplemental CHO, n*[a]	*Subjects with BG <70 mg/dL, n*	*CHO per subject (range, g)*	*Subjects with supplemental CHO, n*[a]	*Subjects with BG <70 mg/dL, n*	*CHO per subject (range, g)*
Before exercise (90 min)	5	1	25–40	5	0	16–27
During exercise (~40 min)	1	0	12	0	0	—
Exercise end to dinner	4	2	12–20	3	1	14–17
Dinner to overnight	2	1	32–38	1	0	17
Overnight (23:00–07:00 h)	0	0	—	0	0	—

[a]Supplemental CHOs are defined as CHO ingested without a corresponding insulin bolus. Includes participants consuming supplemental CHOs as treatment for capillary BG <70 mg/dL, as well as for other reasons such as participant request or to qualify for exercise with capillary BG >120 mg/dL. For supplemental CHO consumption not associated with a capillary BG <70 mg/dL, subjects were counted if they consumed at least 12 g of CHO within a period of 15 min or less.

BG, blood glucose; CHOs, carbohydrates.

TABLE 3. GLYCEMIC OUTCOMES PRE-EXERCISE AND FOR THE SHORT-TERM (2 H) RESPONSE TO EXERCISE

Mean glucose, mg/dL	*Raised set point*	*Reduced basal*
Pre-exercise	140 ± 59	136 ± 26
90 min period before exercise start		
During exercise	140 ± 32	132 ± 26
Period from exercise start to end		
Postexercise	100 ± 19	122 ± 35
60 min period after exercise end		
During and postexercise	113 ± 17	128 ± 26
2 h period from exercise start		

Results are sensor glucose values, mean ± SD; SI conversion factor to convert glucose to mmol/L, multiply by 0.0555.

TABLE 4. GLYCEMIC OUTCOMES FOR THE EXTENDED (12 H) RESPONSE TO EXERCISE

	Raised set point	*Reduced basal*
Mean glucose, mg/dL	127 ± 24	131 ± 18
Percentage time in glucose range, %		
<54 mg/dL	0.7 ± 1.5	0 ± 0
	0.0 (0.0–0.3)	0.0 (0.0–0.0)
<70 mg/dL	1.4 ± 2.7	1.6 ± 3.0
	0.0 (0.0–1.7)	0.0 (0.0–2.1)
70–180 mg/dL	88.9 ± 17.6	89.1 ± 11.3
>180 mg/dL	9.7 ± 18.1	9.2 ± 11.8
≥250 mg/dL	0.9 ± 3.2	0.4 ± 1.0

Results are sensor glucose values, mean ± SD, or median (IQR); 12 h period measured from the start of exercise; SI conversion factor to convert glucose to mmol/L, multiply by 0.0555.


The future is here

Continuous Glucose Monitors and Activity Trackers to Inform Insulin Dosing in Type 1 Diabetes: The University of Virginia Contribution

Simulation study

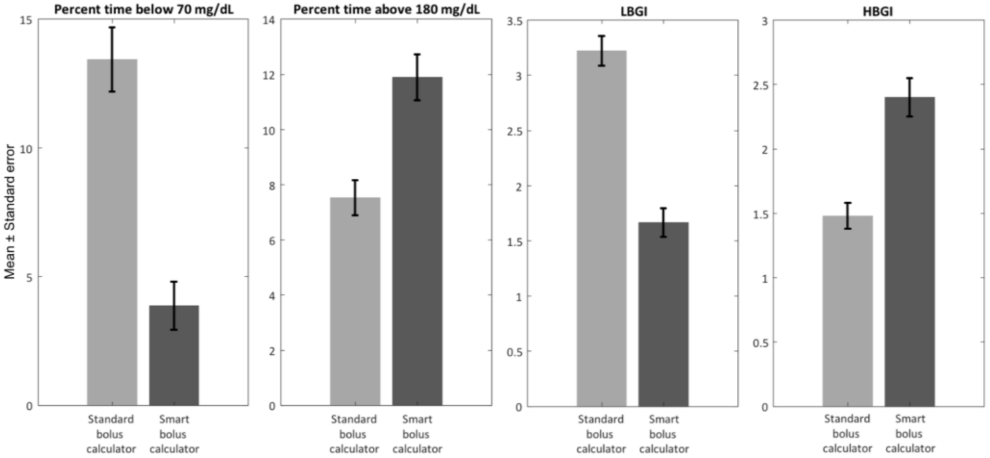


Figure 5. *Study 2 results*: Summary of postprandial GV indices obtained with the use of the standard (light gray) and smart (dark gray) bolus calculator following a 1-hour aerobic exercise session.

Abstract: *Objective*: Suboptimal insulin dosing in type 1 diabetes (T1D) is frequently associated with time-varying insulin requirements driven by various psycho-behavioral and physiological factors influencing insulin sensitivity (IS). Among these, physical activity has been widely recognized as a trigger of altered IS both during and following the exercise effort, but limited indication is available for the management of structured and (even more) unstructured activity in T1D. In this work, we present two methods to inform insulin dosing with biosignals from wearable sensors to improve glycemic control in individuals with T1D. *Research Design and Methods*: Continuous glucose monitors (CGM) and activity trackers are leveraged by the methods. The first method uses CGM records to estimate IS in real time and adjust the insulin dose according to a person's insulin needs; the second method uses step count data to inform the bolus calculation with the residual glucose-lowering effects of recently performed (structured or unstructured) physical activity. The methods were tested in silico within the University of Virginia/Padova T1D Simulator. A standard bolus calculator and the proposed "smart" systems were deployed in the control of one meal in presence of increased/decreased IS (*Study 1*) and following a 1-hour exercise bout (*Study 2*). Postprandial glycemic control was assessed in terms of time spent in different glycemic ranges and low/high blood glucose indices (LBGI/HBGI), and compared between the dosing strategies. *Results*: In Study 1, the CGM-informed system allowed to reduce exposure to hypoglycemia in presence of increased IS (percent time < 70 mg/dL: 6.1% versus 9.9%; LBGI: 1.9 versus 3.2) and exposure to hyperglycemia in presence of decreased IS (percent time > 180 mg/dL: 14.6% versus 18.3%; HBGI: 3.0 versus 3.9), tending toward optimal control. In Study 2, the step count-informed system allowed to reduce hypoglycemia (percent time < 70 mg/dL: 3.9% versus 13.4%; LBGI: 1.7 versus 3.2) at the cost of a minor increase in exposure to hyperglycemia (percent time > 180 mg/dL: 11.9% versus 7.5%; HBGI: 2.4 versus 1.5). *Conclusions*: We presented and validated in silico two methods for the smart dosing of prandial insulin in T1D. If seen within an ensemble, the two algorithms provide alternatives to individuals with T1D for improving insulin dosing accommodating a large variety of treatment options. Future work will be devoted to test the safety and efficacy of the methods in free-living conditions.

Algorithm that delivers an individualized rapid-acting insulin dose after morning resistance exercise counters post-exercise hyperglycaemia in people with Type 1 diabetes

- No hypoglycemia
- Peak glucsoe at after 20 min of exercise
- The magnitude of decline from peak blood glucose concentrations to 125 min after exercise was statistically greater for the insulin session (3.3 1.0 vs 1.3 0.4 mmol/l; P = 0.015)
- Individualized nadir blood concentrations were significantly lower for the insulin session than the no-insulin session (9.9 1.1 vs. 12.4 1.5 mmol/l; P = 0.035).

Aims To develop an algorithm that delivers an individualized dose of rapid-acting insulin after morning resistance exercise to counter post-exercise hyperglycaemia in individuals with Type 1 diabetes.

Methods Eight people with Type 1 diabetes, aged 34 ± 7 years with HbA_{1c} concentrations 72 ± 12 mmol/mol (8.7 ± 1.1%), attended our laboratory on two separate mornings after fasting, having taken their usual basal insulin the previous evening. These people performed a resistance exercise session comprising six exercises for two sets of 10 repetitions at 60% of the maximum amount of force that was generated in one maximal contraction (60% 1RM). In a randomized and counterbalanced order, the participants were administered an individualized dose of rapid-acting insulin (2 ± 1 units, range 0–4 units) immediately after resistance exercise (insulin session) by means of an algorithm or were not administered this (no-insulin session). Venous blood glucose concentrations were measured for 125 min after resistance exercise. Data (mean ± SEM values) were analysed using ANOVA ($P \leq 0.05$).

Results Participants had immediate post-resistance exercise hyperglycaemia (insulin session 13.0 ± 1.6 vs. no-insulin session 12.7 ± 1.5 mmol/l; $P = 0.834$). The decline in blood glucose concentration between peak and 125 min after exercise was greater in the insulin exercise session than in the no-insulin session (3.3 ± 1.0 vs. 1.3 ± 0.4 mmol/l: $P = 0.015$). There were no episodes of hypoglycaemia (blood glucose <3.9 mmol/l).

Conclusions Administration of rapid-acting insulin according to an individualized algorithm reduced the hyperglycaemia associated with morning resistance exercise without causing hypoglycaemia in the 2 h post-exercise period in people with Type 1 diabetes.

Diabet. Med. 33, 506–510 (2016)

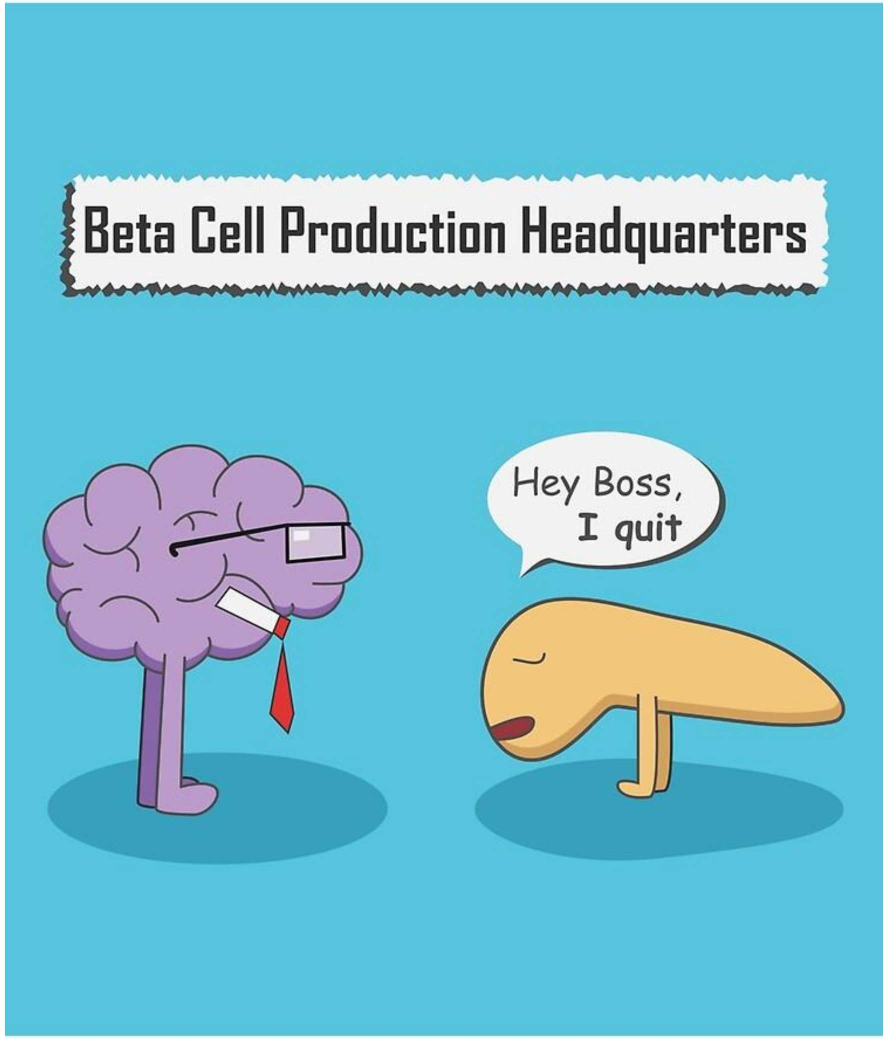
Turner D, Luzio S, Gray BJ, Bain SC, Hanley S, Richards A, Rhydderch DC, Martin R, Campbell MD, Kilduff LP, West DJ, Bracken RM. Algorithm that delivers an individualized rapid-acting insulin dose after morning resistance exercise counters post-exercise hyperglycaemia in people with Type 1 diabetes. Diabet Med. 2016 Apr;33(4):506-10. doi: 10.1111/dme.12870. Epub 2015 Aug 25. PMID: 26220149.

Take home messages

- Train our patients
- Train ourselves
- Collaborate closely with our patients
- Use technology

Προσοχή!

- Εφιστούμε την προσοχή των ατόμων με διαβήτη για τους περιορισμούς των συστημάτων νέας τεχνολογίας και συνιστούμε την παρακολούθηση και επιβεβαίωση της γλυκαιμίας με μέτρηση από το δάχτυλο.


Beta Cell Production Headquarters
Hey Boss, I quit