

# Thinking about APS

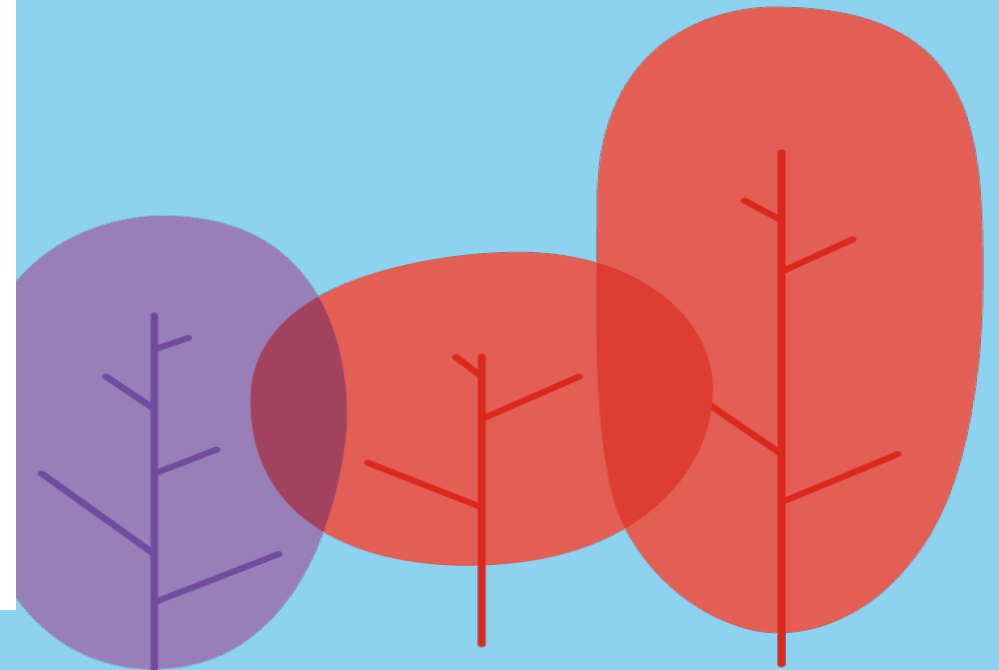
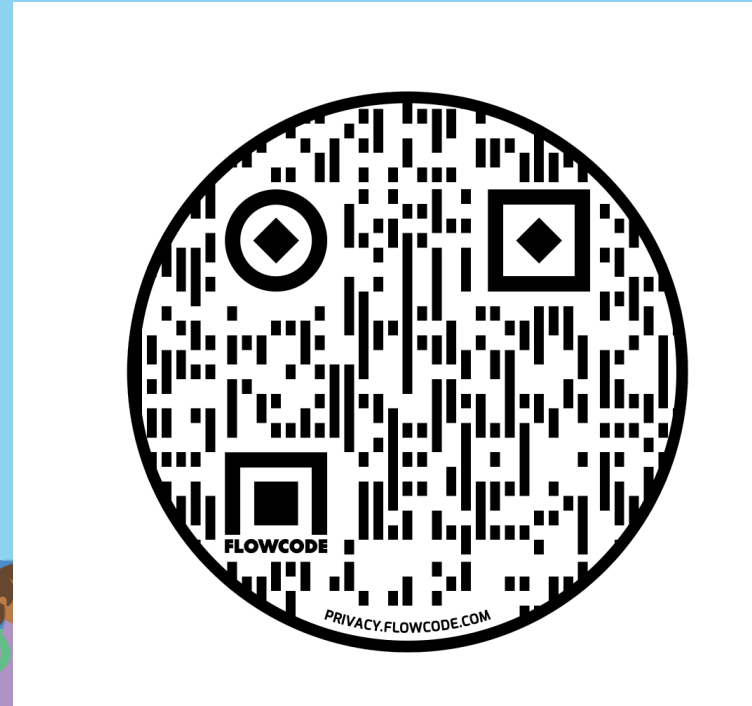
Watch this video or put camera on the QR code to jump to video:  
<https://screencast-o-matic.com/watch/cYXIIKMKso>

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Mr. John Pemberton

John works at the Birmingham Women's Children's Hospital as a Diabetes Specialist Dietitian, helping look after 300 children with Type 1 Diabetes, and 25 Children with Type 2 Diabetes. The bulk of his work involves empowering and educating Children and Young People and their families to self-manage diabetes. His current interests include the effective use of new technology (APS, CGM, pumps), re-establishing foundational principles (three balanced meals, regular activity and insulin timings) and how expectations drive change. He created the "CGM Academy" that teaches Dynamic Glucose Management in 2020, implemented a novel high HbA1c pathway in 2019, co-authored the ACDC CGM guidance in 2018, and implemented the KISS system for giving extra insulin for high fat and protein meals in 2017. His niche lies in developing easy to use interactive PDF tools that put the theory into practice. His most important jobs are being a top dad to Grace and Jude and trying to be a half decent husband to Dani.



By your side

# To discuss

- The different systems & their CE Mark
- Target ranges
- How the algorithms calculate and use
  - Insulin on board
  - Carbs on board
- How the algorithms work
- Key tips for onboarding and education
- How to manage high fat and protein meals
- How to use Exercise settings



# APS Systems

<https://hcp.medtronic-diabetes.co.uk/>



[https://www.airliquidehealthcare.co.uk/sites/homecare\\_uk/files/Control-IQ-Training-for-Clinical-Professionals-Module/story.html](https://www.airliquidehealthcare.co.uk/sites/homecare_uk/files/Control-IQ-Training-for-Clinical-Professionals-Module/story.html)



<https://camdiab.cdep.org.uk/>



<https://loopkit.github.io/loopdocs/>



<https://androidaps.readthedocs.io/en/latest/EN/>



<https://openaps.org/>



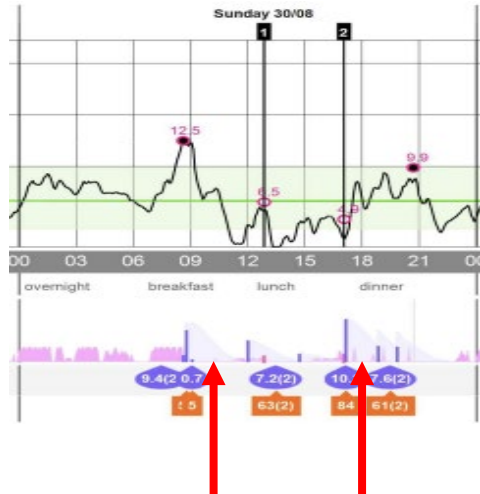

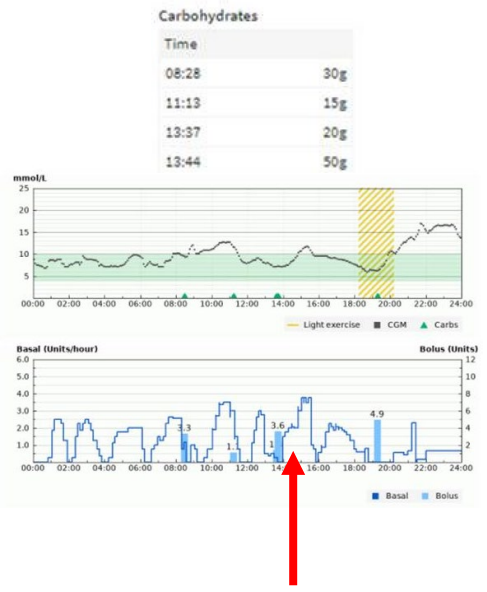
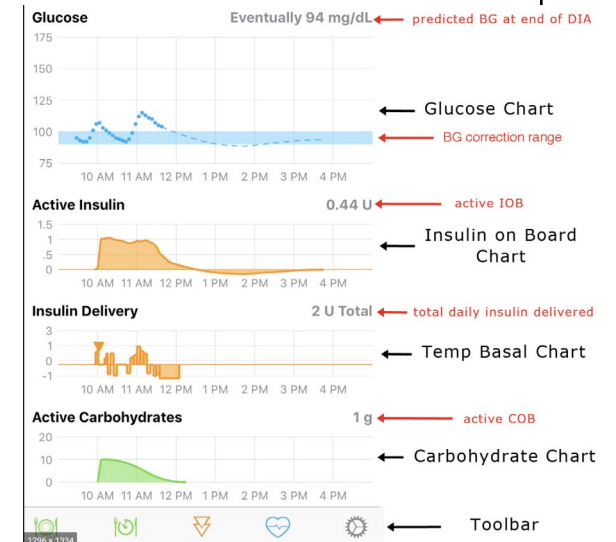
# The different systems with CE Mark

	670G – Auto Mode	780G – SmartGuard	T-Slim Control IQ	CamAPS FX
Where to get training?	<a href="https://hcp.medtronic-diabetes.co.uk/">https://hcp.medtronic-diabetes.co.uk/</a>	<a href="https://wwwp.medtronic.com/registration/application/noauth/index/1009?locale=en-GB">https://wwwp.medtronic.com/registration/application/noauth/index/1009?locale=en-GB</a>	<a href="https://www.airliquidehealthcare.co.uk/sites/homecare_uk/files/Control-IQ-Training-for-Clinical-Professionals-Module/story.html">https://www.airliquidehealthcare.co.uk/sites/homecare_uk/files/Control-IQ-Training-for-Clinical-Professionals-Module/story.html</a>	<a href="https://camdiab.cdep.org.uk/">https://camdiab.cdep.org.uk/</a>
What need	670G pump & consumables Guardian™ Sensor 3 Guardian™ 3 Link Transmitter Carelink account linked to centre Ascensia Contour Next Link 2.4	780G pump & consumables Guardian™ Sensor 3 Guardian™ 3 Link Transmitter (BLE) Carelink account linked to centre Roche Accu-Chek Guide Link Meter Patient: MiniMed Mobile APP Care partners (5): Carelink Connect APP	T-Slim x 2 pump & consumables Dexcom G6 sensor Dexcom G6 transmitter Control IQ algorithm Company started or HCP (Certification available) Diasend account linked to centre - optional	Dana Pump & consumables Dexcom G6 sensor Dexcom G6 transmitter Android phone CamAPS APP & paid subscription Diasend account linked to centre Certified trainers with number
CE Mark	7 years + 8u TDD NovoRapid, Humalog	7 years + 8u TDD NovoRapid, Humalog	6 years + Weight 25-140kg 10-100u TDD No pregnancy (Pump & Dexcom ok) NovoRapid & Humalog	1 year + Weight 10-300kg 5-300u TDD Dexcom licenced from 2yrs so clinical decision if using 1-2yrs NovoRapid, Humalog, Apidra, FiAsp

# Target levels

Variable	670G	780G	T-Slim Control IQ	CAMAPS FX	DIY
Target range	6.7mmol/l  Temp Target: 8.3mmol/l	5.5mmol/l Default 6.1mmol/l 6.7mmol/l  Temp Target: 8.3mmol/l	6.3-8.9mmol/L  Exercise Target: 7.8-8.9mmol/l  Sleep: 6.1-6.3mmol/l	Set at 5.8mmol/L  4.4 – 11.0mmol/L  Ease Off: Increases set target by 2.5mmol/l	User defined  3.5 – 14.0mmol/L  Exercise: User defined

# Active insulin and carbs on board

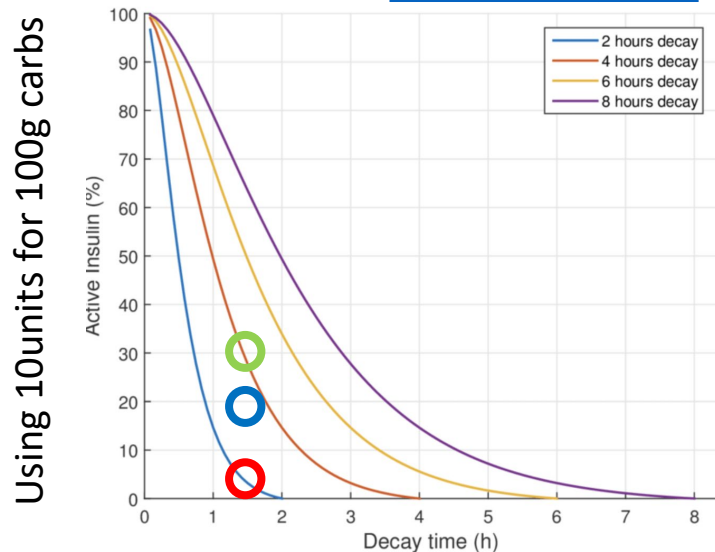
Variable	670G & 680G	T-Slim Control IQ	CamAPS FX	DIY
Active insulin	Active insulin 2-8 hrs: Counts food & correction	Control IQ fixed 5hrs: Counts food & correction	Algorithm sets Active insulin: Counts food & correction	DIY Active insulin user defined (1-8hrs): Counts food & correction
COB	No recognition of carbs on board	No recognition of carbs on board	Has recognition carbs on board	Carbs on board defined (1-8hours)
How uses IOB	Deducts IOB from basal to leave 0% for 60-90 minutes post meal. But after IOB has gone it will correct much earlier and aggressively.	Control IQ only reduces basal if predicted to go (does not subtract IOB). It uses IOB to subtract from corrections so takes 2-3 hrs post-meal before it corrects effectively.	Carbs on board are recognised so the algorithm can reduce or increase insulin as needed after meals as required.	Carbs on board are recognised so the algorithm can reduce or increase insulin as needed after meals, if set correctly!
	 <p>Screenshot of 670G/680G active insulin chart. The top chart shows glucose levels with peaks at 12.5, 1.5, and 9.9. The bottom chart shows basal rate and bolus. Red arrows point to IOB values: 9.4(2) 0.7, 7.2(2), 10, 7.6(2). Other values shown: 1.5, 63(2), 84, 61(2).</p>	 <p>Screenshot of T-Slim Control IQ active insulin chart. The top chart shows carbohydrates: 07:06 (32g), 11:49 (35g). The bottom chart shows basal rate and bolus. Red arrows point to basal rate values: 3.2, 0.5, 3.4, 0.2, 3.5, 3.1, 0.5, 3.6, 4.9.</p>	 <p>Screenshot of CamAPS FX active insulin chart. The top chart shows carbohydrates: 08:28 (30g), 11:13 (15g), 13:37 (20g), 13:44 (50g). The bottom chart shows basal rate and bolus. A red arrow points to a bolus value of 14.</p>	 <p>Screenshot of DIY active insulin chart. The top chart shows glucose levels with a predicted BG at end of DIA of 94 mg/dL. The bottom chart shows active insulin (0.44 U), insulin delivery (2 U Total), and active carbohydrates (1g). Annotations include: Glucose Chart, BG correction range, active IOB, Insulin on Board Chart, total daily insulin delivered, Temp Basal Chart, Carbohydrate Chart, and Toolbar.</p>

# Active Insulin [IEEE control systems](#) 2018: 38(1):86-104

## 670G & 780G (2-8hr range)

Food insulin  
10 units

[IEEE control systems](#) 2018: 38(1)



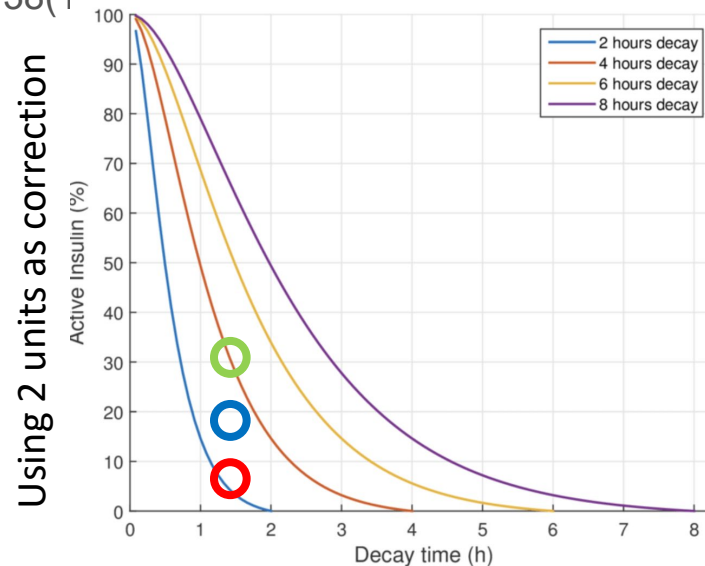
After 90 minutes if Active insulin at 2hrs (red circles), 3hrs (blue circles) & 4hrs (green circles):

- Food insulin = 0.5units (2hrs), 2.0 units (3hrs), 3.0units (4hrs)
- Correction = 0.1units (2hrs), 0.4 units (3hrs), 0.6units (4hrs)
- Total IOB = 0.6units (2hrs), 2.4 units (3hrs), 3.6units (4hrs)

At 90 mins the algorithm believes all 0.6units (2hrs), 2.4 units (3hrs), 3.6units (4hrs) will drop glucose. Therefore it deducts IOB from basal to prevent hypo. Results is very little basal 60mins (2hrs) 90mins (3hrs) 120mins (4hrs) after eating.

If the algorithm wants to correct a high glucose level at 90 minutes all 0.6units (2hrs), 2.4 units (3hrs), 3.6units (4hrs) will be deducted. Results very little correction 60mins (2hrs) 90mins (3hrs) 120mins (4hrs) after eating, but aggressive corrections after that.

Correction insulin  
(including basal adjustments)  
2 units

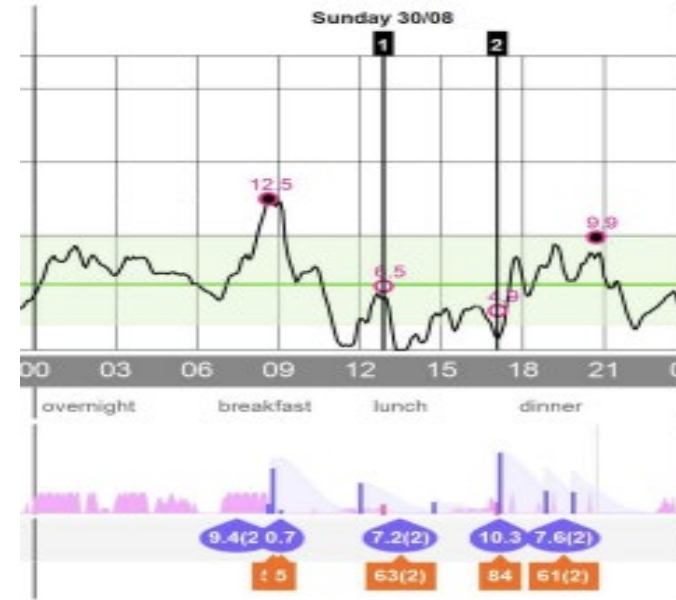


### Key education:

- Never set active insulin more than 3hrs:
  - 2 hours aggressive
  - 2 ½ hours normal
  - 3 hours safe
- ICR needs making more aggressive (10-20%) on starting closed loop to cover the missed basal from IOB after meal insulin.
- Round down with carb counting to prevent hypos as basal cannot be reduced soon after eating as basal will be at or close to 0%.
- Bolus 15-20min pre-meal to prevent post-meal glucose spikes.
- Algorithm not not effective for preventing hypos if exercise is within 60-90 mins of eating as basal will be close to 0%.
- Algorithm will manage high fat and protein well with normal 100% of carbs bloused for upfront and the algorithm it will deal with the delayed glucose rise from fat and protein later.

# 670G: How the algorithm works

Variable	670G
algorithm works	<p>Algorithm does not use manual set basal rates, <b>so changing basal rates will not impact Auto Mode</b></p> <p>Algorithm uses TDD to calculate ISF, Auto basal umin and umax, requires minimum 48 hours to enter Auto Mode but data is updated every night at midnight for ISF and recalculate umin and umax every 6-12 days using median values.</p>
Preventing lows with basal	Algorithm predicts below low target level the basal insulin is reduced or stopped.
Preventing highs with basal	If Algorithm predicts above the target level the basal insulin is increased.





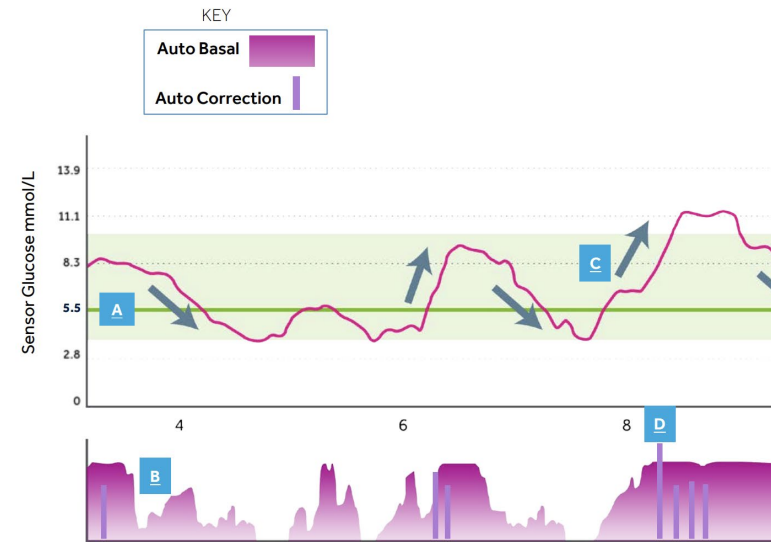
# Key education points – 670G



- Active Insulin:
  - 2 hours aggressive
  - 2 ½ hours normal
  - 3 hours safe
- Advise will target for 6.7mmol/L so HbA1c will likely not be lower than 50mmol/mol & TIR 60-70% not >70%
- ICR 10-20% more aggressive on Auto Mode initiation
  - Round down carb counting
- Bolus 15-20min pre-meals
- Suspend insulin delivery when take off & restart when back on
- Three monthly updates:
  - For manual mode: basal rates & ISF
  - For Auto Mode: Weight, ICR, Active Insulin Time
- Exercise:
  - Set Temp Target 90 minutes before activity
  - Meals within 90 mins of exercise
    - Start Temp Target 90mins before exercise
    - Reduce carbohydrate entered for meal bolus's (25-50%)
    - Pre-bolus 15-20min and accurate carb counting
    - Drip feed quick acting glucose during exercise, not all before
  - Reduce carbs entered into bolus wizard for meals after longer duration exercise (25-50%)
  - Keep the pump on at all times if possible, suspend if taking off
- High fat and protein:
  - Enter all carbs but **do not add extra insulin**
  - Let the algorithm take care of the delayed glucose rise
  - If hypo in 3 hours after meal, next time only enter for 75% of carbs

# 780G How the algorithms

Variable	780G
algorithm works	<p>Algorithm does not use manual set basal rates, <b>so changing basal rates will not impact Auto Mode SmartGuard (780G).</b></p> <p>Algorithm uses TDD to calculate ISF, Auto basal umin and umax, requires minimum 48 hours to enter SmartGuard™ but data is updated every night at midnight for ISF and recalculate umin and umax every 6-12 days using median values.</p> <p><b>PID algorithm which uses real-time information:</b> Current SG, How far SG is from the set target, How long SG has been away from target, How rapidly SG has been changing Estimated total insulin (Basal and Bolus) Auto basal rate up and down every 5 minutes aiming for a glucose level of 5.5mmol/l (Default 780G)</p>
Preventing lows with basal	Algorithm predicts below low target level the basal insulin is reduced or stopped.
Preventing highs with basal	If Algorithm predicts above the target level the basal insulin is increased.
Preventing highs with auto corrections	780G only: If auto basal is at max delivery and above 6.7mmol/L auto correction applied if required after active insulin calculation.



## SUMMARY

- A** Selection between the default setting of 5.5 mmol/L, and 6.1 mmol/L or 6.7 mmol/L.
- B** Basal insulin adjusts every 5 mins based on SG values
- C** The auto correction target is set at 6.7 mmol/L
- D** Auto corrections delivered every 5 minutes if max basal reached and SG is above 6.7 mmol/L, as determined by the algorithm. NO automatic corrections if Temp Target is set.

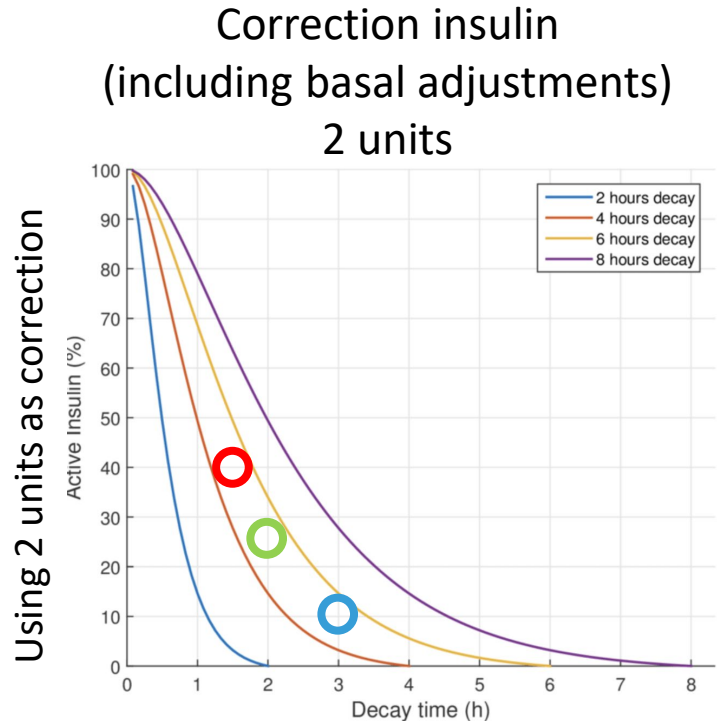
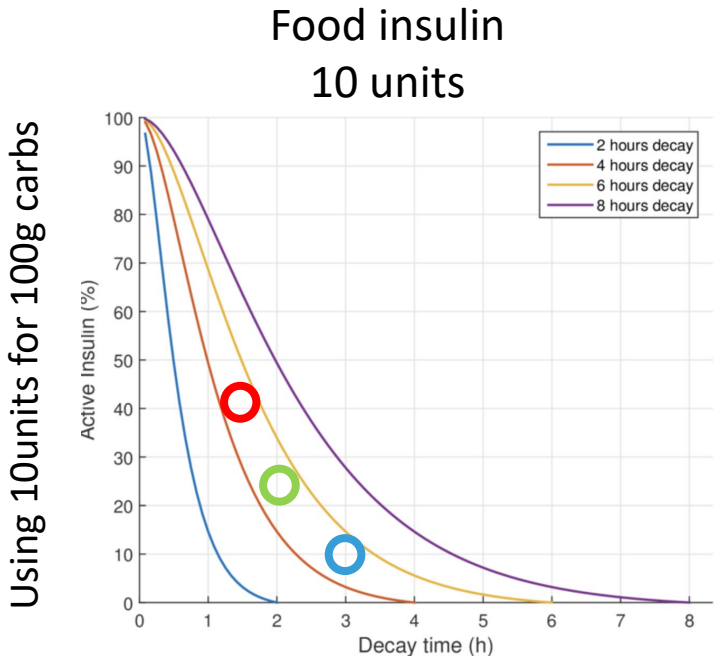


# Key education points – 780G



- Active Insulin:
  - 2 hours aggressive
  - 2 ½ hours normal
  - 3 hours safe
- Set target at 5.5mmol/L so HbA1c will likely HbA1c 48mmol/L & TIR >70%
- ICR 10-20% more aggressive on Auto Mode initiation
  - Round down carb counting
  - Bolus 15-20min pre-meals
- When offered Safe Bolus is offered (predicted to go low) at meal times:
  - All IOB will be deducted from the suggested bolus for the carbs to be eaten
  - Remember you are eating carbs and the negative correction may be to big.
- Suspend insulin delivery when take off & restart when back on
- Three monthly updates:
  - For manual mode: basal rates & ISF
  - For SmartGuard: Weight, ICR, Active Insulin Time
- Exercise:
  - Set Temp Target 90 minutes before activity
  - Meals within 90 mins of exercise
    - Start Temp Target 90mins before exercise
    - Reduce carbohydrate entered for meal bolus's (25-50%)
    - Pre-bolus 15-20min and accurate carb counting
    - Drip feed quick acting glucose during exercise, not all before
  - Reduce carbs entered into bolus wizard for meals after longer duration exercise (25-50%)
  - Keep the pump on at all times if possible, suspend if taking off
- High fat and protein:
  - Enter all carbs but **do not add extra insulin**
  - Let the algorithm take care of the delayed glucose rise
  - If hypo in 3 hours after meal, next time only enter for 75% of carbs

# T-Slim Control IQ: Set at 5 hours



After 90mins (red circles), 120mins (green circles) 180 mins (blue circles):

- Food insulin = 4.0units (90mins), 2.5units (120mins), 1.0units (180mins)
- Correction = 0.8units (90mins), 0.5units (120mins), 0.2units (180mins)
- Total IOB = 4.8units (90mins), 3.0units (120mins), 1.2units (180mins)
- The algorithm only reduces basal if glucose is predicted to go low and NOT based on IOB, so **basal runs post-meal**
- All IOB is deducted from basal or auto-corrections so almost no correction until at least 2-3hrs after eating a large carb meal.
- If the glucose level is below target at meal-time and there is IOB, the pump will offer a negative correction– **DON'T accept it as you want insulin for the carbs!**

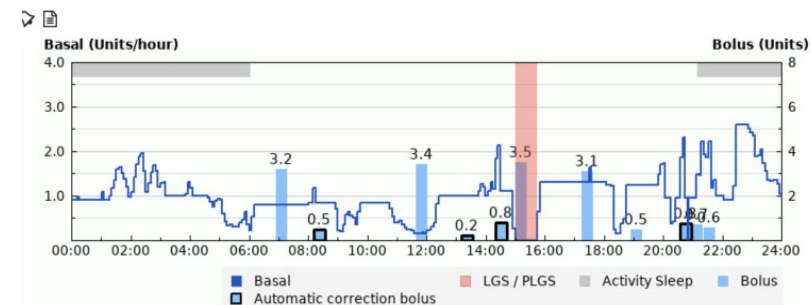
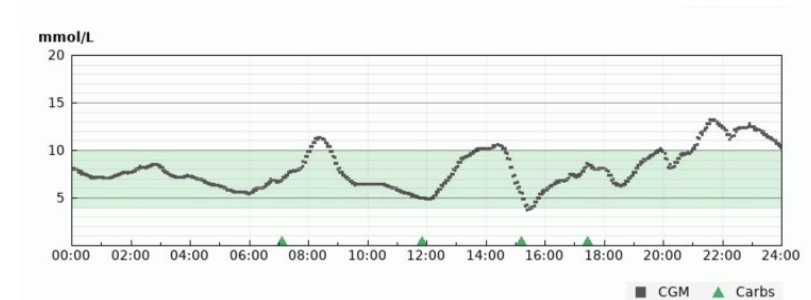
**Key education:**

- Do not make ICR more aggressive on initiation as basal will continue to run post meals.
- Must explain that accurate carb counting and giving insulin 15-20mins pre meal is **ESSENTIAL**, as 2-3hr post-meal corrections are hindered by the way IOB is calculated.
- Round up carb counting if unsure as corrections post-meal are hindered by IOB calculations
- Do not need to reduce carbs entered into the bolus calculator **too much** if within 90 mins of exercise as basal can still be reduced after eating if predicted to go low.
- Will still need to increase insulin for high fat & protein and usual an extended bolus.

# Control IQ: How the algorithms works?

Variable	T-Slim Control IQ
algorithm works	<p><b>Control IQ uses manually inputted basal rates</b> to adjust up and down from. So adjusting these at reviews will help improve how it works.</p> <p>Control IQ Algorithm uses weight, insulin sensitivity from personal profile and the current glucose level, trend and IOB.</p> <p>Manually set basal rate up and down every 5 minutes according to calculations aiming for a glucose level of 6.3-8.9mmol/l.</p>
Preventing lows with basal decrease	Control IQ predicts below the low target level the basal insulin is reduced or stopped.
Preventing highs with basal increase	Control IQ algorithm predicts above the target level the basal insulin is increased.
Preventing highs with auto corrections	Control IQ Algorithm predicts above the target level and going above 10.0mmol/L an auto correction is delivered.

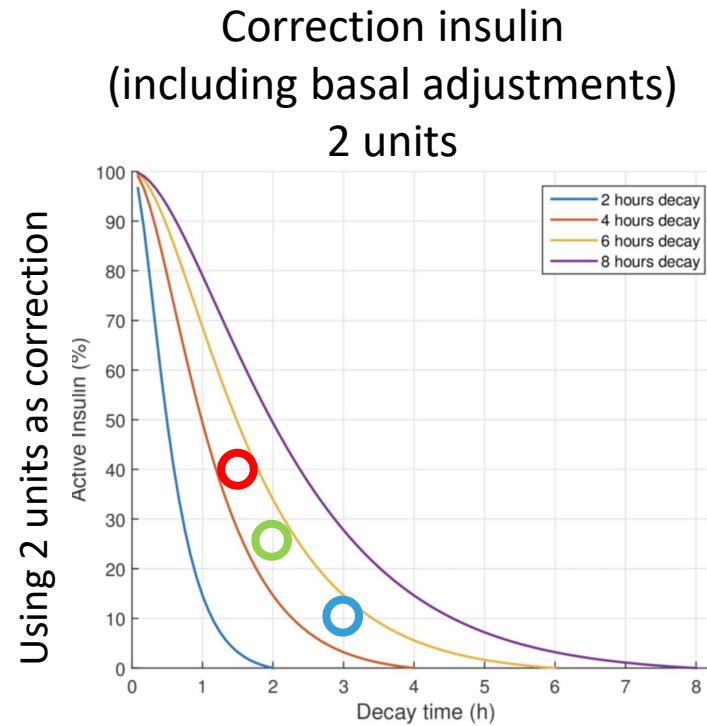
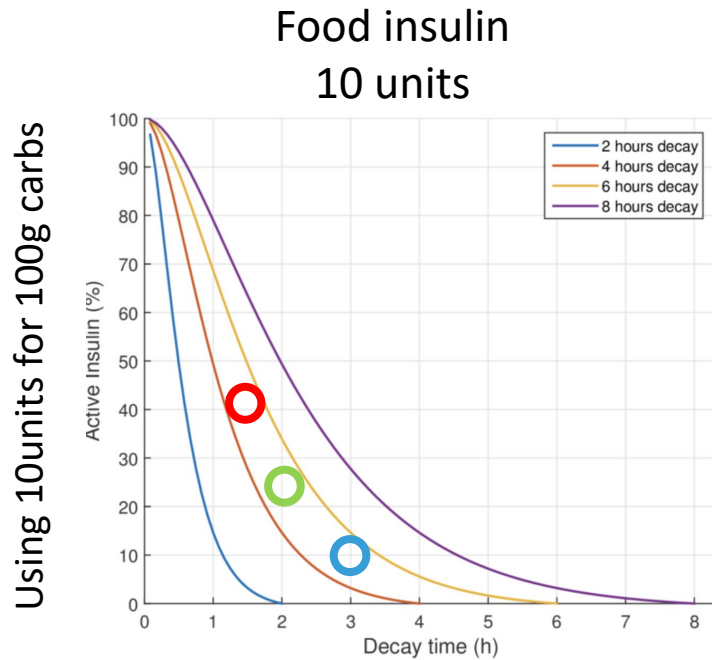
Predicted glucose in 30 min (mmol/l)	Action	How varies in exercise/sleep mode
>10	Autocorrection given hourly 60% bolus calc using ISF, glucose & IOB Never more than 1hr since last bolus. Can go on top of extended. Max 6u	Auto corrections not given in sleep mode
8.9-10	Increases basal Never above C-IQ Max (not personal setting but calc using basal,ISF,IOB & glucose. Never above 15u/hr or 50% TDD in 2hrs)	Adjustments start at 6.6 in sleep mode
6.3-8.9	Maintains	6.1-6.6 mmol/l sleep
3.9-6.3	Reduces basal	3.9-6.7 mmol/l exercise
<3.9	Suspends basal insulin Boluses continue. Restarts at lower basal rate when BGs predicted to be over 3.9 mmol/l in 30 mins	<4.4 mmol/l exercise



# Key education points – T-Slim x 2 Control IQ



- Get basal rates close to needs before starting Control IQ then set Insulin Profiles on initiation:
  - Normal – usual settings
  - 50% lower - All settings reduced by 50%
  - 25% lower – All setting reduced by 25%
  - 25% higher- High Fat & protein or illness all setting more aggressive by 25%
- Set sleep schedule for tighter control overnight 6.1-6.3mmol/l
- Insulin dosing:
  - Pre-bolus 15-20 min's
  - If unsure of carb counting round up
- If below target at meal time with IOB don't accept negative IOB correction
- Suspend insulin delivery when take off & restart when back on
- Three monthly updates:
  - For manual mode: basal rates, ISF, ICR, Active insulin 2.5-3hrs
  - For Control IQ : Update standard profile: basal rates, ICR, ISF. Then update all profiles from % changes from normal profile
- Exercise:
  - Set Exercise Target 90 minutes before activity
  - Meals within 90 mins of exercise
    - Set profile 25% lower or 50% lower before meal
    - Pre-bolus 15-20min and accurate carb counting
    - Drip feed quick acting glucose during exercise, not all before
  - Set 25% lower after exercise for for 90 mins after activity
  - Keep the pump on at all times if possible, suspend if taking off
- High fat and protein (2 options):
  - Create a + 25% profile and put on for 6 hours before bolus for 100% carbs via extended wave 50/50 over 2 hours.
  - Increase carbs by 40% (Carbs x 1.4) and do a extended wave 50/50 over 2 hours.



If Active insulin at roughly 5 hrs: after 90mins (red circles), 120mins (green circles) 180 mins (blue circles):

- Food insulin = 4.0units (90mins), 2.5units (120mins), 1.0units (180mins)
- Correction = 0.8units (90mins), 0.5units (120mins), 0.2units (180mins)
- Total IOB = 4.8units (90mins), 3.0units (120mins), 1.2units (180mins)

Algorithm recognises carbs on board and deducts from IOB, so only correction insulin is deemed as IOB when deciding if to:

- Reduce insulin if predicting of going below target.
- Increase insulin if predicting going above target.

### Key education

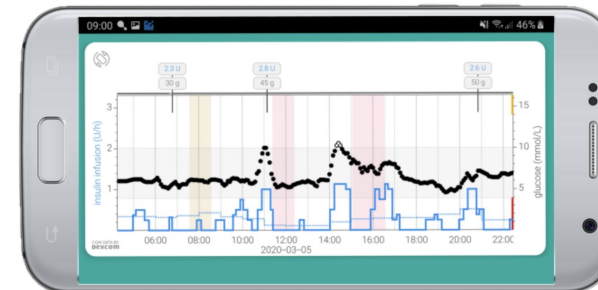
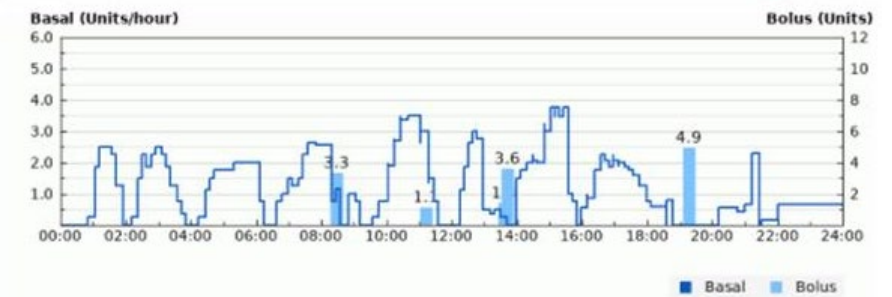
- Do not make ICR more aggressive on initiation.
- Must explain that accurate carb counting and giving insulin 15-20mins pre meal is **ESSENTIAL**
- The Algorithm is more effective for preventing exercise hypos in 90 mins after eating and the user will need to only need a smaller reduction in carbs entered.
- Algorithm will manage high fat and protein well with normal 100% of carbs bloused for upfront and the algorithm it will deal with the delayed glucose rise from fat and protein later.

# CamAPS FX: How the algorithm works

Variable	CamAPS FX
algorithm works	<p>Algorithm does not use manually set basal rates. It uses extended boluses every 10-12 minutes to adjust the insulin. <b>so changing basal rates will not impact auto mode.</b></p> <p>Algorithm uses body weight, TDD from last 5 days, learned insulin needs from previous days, current glucose level/trend &amp; carbs on board</p> <p>Extended boluses every 10-12 minutes according to the algorithms calculations aiming for a glucose level of 5.8mmol/l</p>
Preventing lows with basal	If Algorithm predicts below the low target level the Extended bolus insulin is reduced or stopped.
Preventing highs with basal	If Algorithm predicts above the target level the extended bolus is increased.
Preventing highs with auto corrections	If Algorithm predicts above the target level and going high fast a more aggressive extended bolus is delivered.

Carbohydrates

Time	Carbs
08:28	30g
11:13	15g
13:37	20g
13:44	50g





# Key education points – CAMAPS FX

- Start with target at 5.5mmol/L:
  - HbA1c will likely HbA1c 48mmol/L
  - TIR >70%

- Accurate carb counting
  - Bolus 15-20min pre-meals

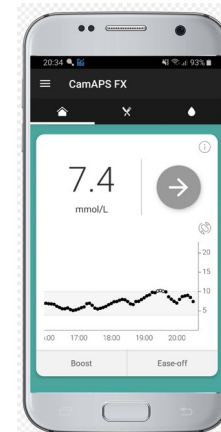
- Suspend insulin delivery when take off & restart when back on

- Three monthly updates:
  - For manual mode: basal rates & ISF
  - For Auto Mode: Weight, ICR,

- Exercise:
  - Set **Ease Off** 90 minutes before activity
  - Meals within 90 mins of exercise
    - Start Ease Off 90mins before exercise
    - Reduce carbohydrate entered for meal bolus's (25%)
    - Pre-bolus 15-20min and accurate carb counting
    - Drip feed quick acting glucose during exercise, not all before
  - Reduce carbs entered into bolus wizard for meals after longer duration exercise (25%)
  - Keep the pump on at all times if possible, suspend if taking off

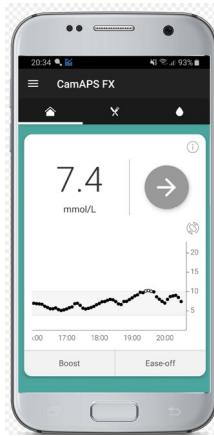
- **Boost:**
  - Increases insulin doses by 30%
  - Illness, stress, school holidays
  - Don't give manual corrections if using Boost

- High fat and protein:
  - Enter all carbs but **do not add extra insulin**
  - Let the algorithm take care of the delayed glucose rise
  - If hypo in 3 hours after meal, next time only enter for 75% of carbs

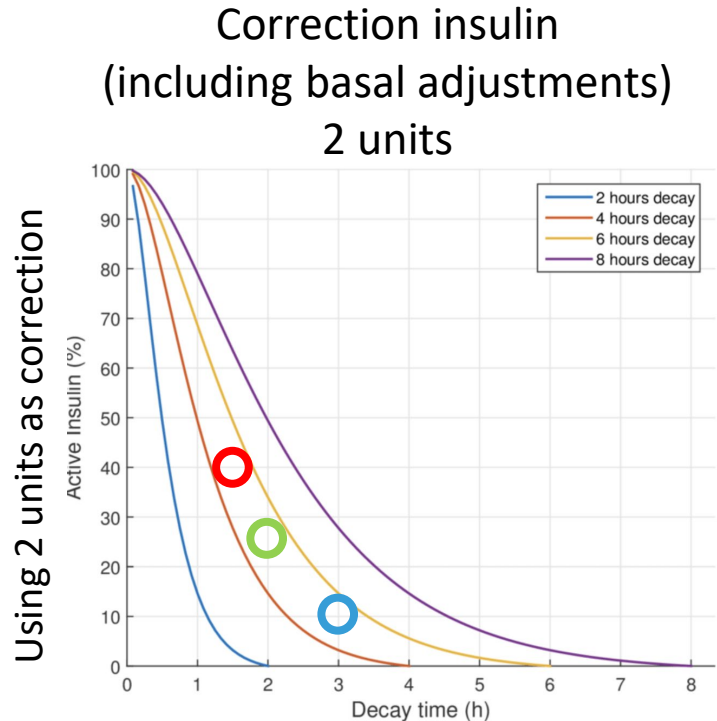
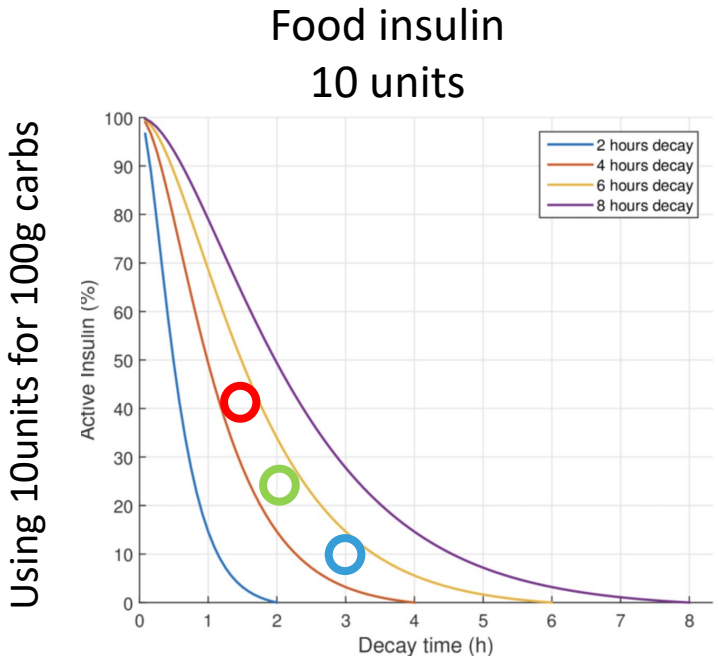


# Key education points – CAMAPS FX

- For children under 6yrs old:
  - If starting TDD <10u, to avoid hypos while system initiates:
    - Set target at 10.0mmol/l & lower proactively every 2 days
    - Consider underestimating TDD by 20%
    - Consider advice to treat downward CGM arrows with BG <5 during the day
  - If TDD reduces considerably on system:
    - Diluted insulin at U10 may improve glycaemia, and is easier for interpretation of downloads and settings adjustments (rather than using U25 or U50 dilution).
    - Practicalities of diluting insulin?



# DIY (Range 1-8 hrs)



If Active insulin at 5 hrs: after 90mins (red circles), 120mins (green circles) 180 mins (blue circles):

- Food insulin = 4.0units (90mins), 2.5units (120mins), 1.0units (180mins)
- Correction = 0.8units (90mins), 0.5units (120mins), 0.2units (180mins)
- Total IOB = 4.8units (90mins), 3.0units (120mins), 1.2units (180mins)

Algorithm recognises carbs on board based on carb absorption time set and deducts from IOB, so only correction insulin and possibly a little bit of food insulin is deemed as IOB when deciding if to:

- Reduce insulin if predicting of going below target.
- Increase insulin if predicting going above target.

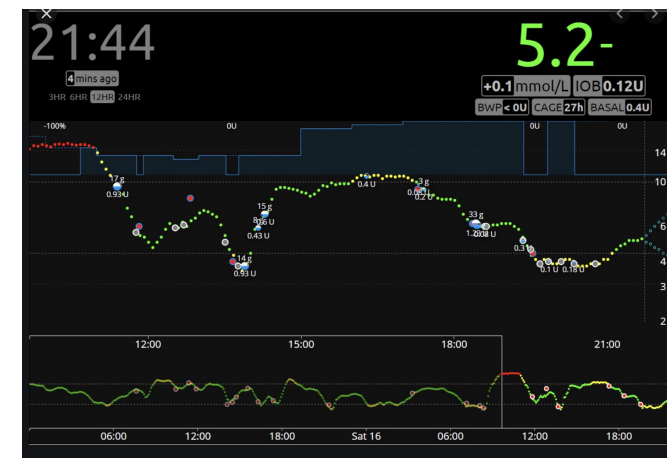


**Key education:**

- Council against short active insulin times of 2-3 hours – High risk of hypoglycaemia. Setting at 5 hours is suggested as the algorithms recognises carbs on board
- Do not make ICR more aggressive on initiation.
- The Algorithm is more effective for preventing exercise hypos in 90 mins after eating and the user will only need to slightly reduce carbs entered into bolus calculator.
- The user must have a good knowledge of absorption times of different meals.
- Algorithm will manage high fat and protein well with 100% of carbs bloused for upfront and the algorithm will deal with the delayed glucose rise from fat and protein later

# DIY: How the algorithms works?

Variable	DIY
algorithm works	<p><b>DIY uses manually inputted basal rates</b> to adjust up and down from. So adjusting these at reviews will help improve how it works.</p> <p>Algorithms use weight, insulin sensitivity from previous TDD and the current glucose level, trend and IOB and carbs on board</p> <p>Manually set basal rate up and down every 5 minutes according to calculations aiming for user defined glucose level</p>
Preventing lows with basal	Algorithm predicts below low target level the basal insulin is reduced or stopped.
Preventing highs with basal	Algorithm predicts above the target level the basal insulin is increased.
Preventing highs with auto corrections	Algorithm predicts above the target level and going high fast a more aggressive corrections (variety of ways)



# Key education points – DIY

- Get basal rates close to needs before starting DIY then set Insulin Profiles on initiation:
  - 50% lower - All settings reduced by 50%
  - 25% lower – All setting reduced by 25%
  - 25% higher- High Fat & protein or illness all setting more aggressive by 25%
- Insulin dosing:
  - Pre-bolus 15-20 min's
  - Accurate carb counting
- Suspend insulin delivery when take off & restart when back on
- Three monthly updates:
  - For manual mode: basal rates, ISF, ICR, Active insulin 2.5-3hrs
  - For auto mode: Update standard profile: basal rates, ICR, ISF. Then update all profiles

- Exercise:
  - Set Exercise Target 90 minutes before activity
  - Meals within 90 mins of exercise
    - Set profile 25% lower or 50% lower before meal
    - Pre-bolus 15-20min and accurate carb counting
    - Drip feed quick acting glucose during exercise, not all before
  - Set 25% lower after exercise for for 90 mins after activity
  - Keep the pump on at all times if possible, suspend if taking off
- High fat and protein:
  - Enter all carbs but **do not add extra insulin**
  - Let the algorithm take care of the delayed glucose rise
  - If hypo in 3 hours after meal, next time only enter for 75% of carbs



# 3 Star – Comparison- horse for courses

Variable	670G	780G	Control IQ	CamAPS FX	DIY
CE Mark indication	**	**	**	***	
Accessibilty to people with diabetes	***	***	***	**	*
Accuracy of sensor & calibrations needed	*	*	***	***	***
Target Level flexibility		**	*	***	***
Correcting glucose peaks after meals	** (2-3hrs AI)	*** (2-3hrs AI)	*	**	**
High fat and protein meal management	** (2-3hrs AI)	*** (2-3hrs AI)	*	**	**
Exercise management flexibility	*	*	***	**	***
Caregiver remotely reviewing glucose and insulin	*	***	**	**	**

# High fat and protein what the research says

- 96g carbs + 50g fat + <10g protein vs. same meal but 10g fat:
  - **42% Extra insulin** (-17% - 108%)
  - 5-10hrs to digest
  - (Wolpert *et al.*, 2013)
- Avocado Study: 45g carbs + 60g fat + <10g protein vs. same meal & up to 20g fat
  - **21% Extra insulin** (-28% - 35%)
  - 50/50 over 105mins
  - (Bell *et al.*, 2020)
- Pizza Study: 50g carb + 44g fat + 36g protein vs. same meal but 4g fat & 9g protein
  - **65% Extra insulin** (17%-124%)
  - 30/70 over 2 ½ hrs
  - (Bell *et al.*, 2016)
- **On average** for high fat meal (>40g) with at least 30g carbs needs (Bell *et al* 2015):
  - Extra 40% insulin
  - Split 50/50 over 2hours ish
- APS study showed HFHP (>35g each) meal needed 39% extra insulin over 5 hours
  - Gingras, *et al* Diabetes Obes Metab. 2018 Nov;20(11):2695-2699.

# High fat and protein – From extended bolus to APS

- Example: 100g carb meal with >40g fat requires 40% extra insulin split 50/50 over 2 hours:
  - $100\text{g} \times 1.4 = 140\text{g}$  to enter into bolus calculator
  - If ICR is  $1\text{u}:10\text{g} = 14\text{units}$
  - Split 50/50 = 7 units upfront & 7 units over 2 hours
  - $7\text{units} = 70\%$  of the actual carbs ( $100\text{g} / 10\text{units}$ )
  - The remaining 7 units: 3.5 units for hr, 3.5units second hr.
  - During the first hour the APS give no extra insulin due to IOB therefore the first hrs (3.5units) extended would need to go in upfront
  - This makes  $7.0 + 3.5 = 10.5$  upfront, which is just about the same amount as if giving all carbs ( $100\text{g} / 10\text{units}$ ) upfront and letting the APS algorithm deal with the delayed rise.



# High fat and protein – From extended bolus to APS

APS systems:

- For Medtronic, CAMAPS FX & DIY:
  - Bolus for 100% of the carbs upfront and let the algorithm deal with the delayed glucose rise
    - If go hypo in first 3 hours first time: bolus for 75% of carbs next time.
- For Control IQ due to active insulin fixed at 5 hours and lots of IOB for 2-3hrs there are two options:
  - Create a + 25% profile and put on for 6 hours before bolus for 100% carbs via extended wave 50/50 over 2 hours.
  - Increase carbs by 40% (Carbs x 1.4) and do a extended wave 50/50 over 2 hours.

# Exercise and APS



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## Review

## Glucose Control During Physical Activity and Exercise Using Closed Loop Technology in Adults and Adolescents with Type 1 Diabetes

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**Table 3**

Open vs closed loop diabetes management strategies for exercise

	Open loop	Closed loop
Contraindications	<ul style="list-style-type: none"> <li>Recent severe hypoglycemia (i.e. loss of consciousness, seizure or inability to self-treat)</li> <li>Significant hyperglycemia (&gt;15.0 mmol/L)</li> <li>Ketones (<math>\geq 1.5</math> mmol/L)</li> </ul>	
Before exercise meal bolus	<ul style="list-style-type: none"> <li>Meal bolus &gt;3 h before exercise: Usual bolus with or without correction</li> <li>Meal bolus &lt;1–3 h before exercise: Reduce bolus by:               <ul style="list-style-type: none"> <li>25% for light exercise</li> <li>50% for moderate aerobic exercise</li> <li>75% for heavy aerobic exercise</li> </ul> </li> </ul>	
Before exercise basal adjustment	50% to 80% reduction 90 min before exercise and/or Pump suspension at exercise start	Exercise target 1–2 h earlier and/or If pump disconnected, should be suspended
Before exercise CHO (if glucose <7.0 mmol/L)	<ul style="list-style-type: none"> <li>&lt;5.0 mmol/L: 10–30 g CHO</li> <li>5.0–6.9 mmol/L: 10 g CHO (aerobic)</li> </ul>	<ul style="list-style-type: none"> <li>As per open loop<sup>*</sup></li> <li>Give &lt;10 min before exercise</li> </ul>
Before exercise CHO (if glucose 7.0–10.0 mmol/L)	0 g CHO	
Before exercise CHO (if glucose >10.0 mmol/L)	0 g CHO <ul style="list-style-type: none"> <li>10.1–15.0 mmol/L: Start exercise (aerobic)</li> </ul>	
Before exercise meal bolus	Ketones <0.6 mmol/L (mild to moderate exercise) Ketones 0.6–1.4 mmol/L (light/short-duration exercise)	
Before exercise basal adjustment	0% to 50% bolus reduction	Usual bolus/slight reduction (<25%)
	20% basal reduction for 6 h at bedtime	Exercise target off <sup>†</sup>


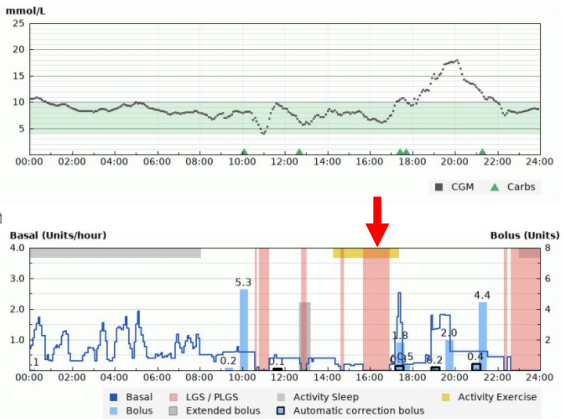
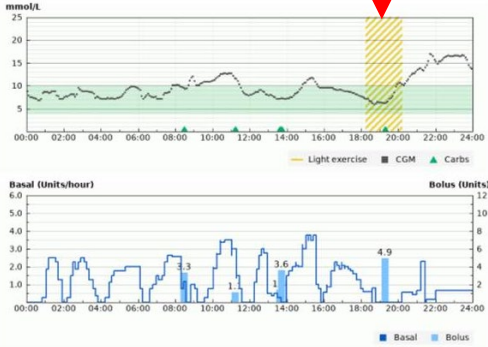
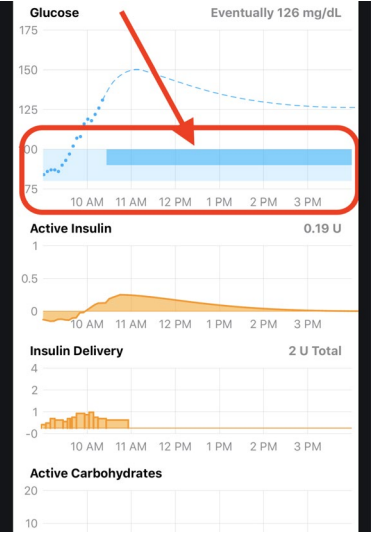
CHO, carbohydrate; h, hours; min, minutes.

Note: Modified from Riddell et al (13).

\* Denotes less CHO may be required with closed loop (~10 to 20 g).

† Denotes that, if patients are at high risk of hypoglycemia after exercise (e.g. prolonged aerobic or mixed activity), consider continuing exercise target for several hours after activity or overnight.

# What settings will help for exercise?

Variable	670G & 780G	T-Slim Control IQ	CamAPS FX	DIY
<b>Exercise</b>	<p><b>Temp target 8.3mmol/L</b></p> <p>Effective if exercise more than 90 minutes after eating if Active insulin is set at 2-3 hours</p> <p>Temp target must be set 90 minutes before activity.</p> <p>Effective for preventing hypos after activity by extending up to 6 hours after.</p> <p>Will need to reduce carbs (25-50%) entered into bolus wizard if meal within 90 minutes of exercise due to little or no basal running as IOB is high.</p> 	<p><b>Control IQ Exercise Target 7.8-8.9mmol/L.</b></p> <p>Can set <b>insulin setting profiles</b> with basal rates, ICR and ISF relaxed e.g. -25% (mixed) &amp; -50% (aerobic).</p> <p>Set Exercise Target and insulin profile 90 minutes before activity.</p> <p>Effective for preventing hypos after activity by extending up to 6 hours after.</p> <p>As shows below: 90 minutes after eating, basal is running normally as recognises carbs on board, therefore more chance of Exercise target, change of insulin settings profile and Control IQ preventing hypo.</p> 	<p><b>Ease Off:</b> No insulin delivered below 7.7mmol/L, insulin sensitivity increased by 50% in the algorithm, target increased by 2.5mmol/L (5.8 to 8.2mmol/L)</p> <p>Set 90 minutes before activity.</p> <p>Effective for preventing hypos after activity by extending up to 6 hours after.</p> <p>As shows below: 90 minutes after eating, basal is running normally as the algorithm recognises carbs on board, therefore more chance of "Ease off" preventing hypo. May still need less carbs (25%) entered into bolus calculator if exercise within 90 mins of eating.</p> 	<p><b>DIY: user set (3.5 – 14.0 mmol/L)</b></p> <p>Can set <b>insulin setting profiles</b> with basal rates, ICR and ISF relaxed e.g. 25% (mixed) &amp; 50% (aerobic).</p> <p>Set Exercise Target and insulin profile 90 minutes before activity.</p> <p>Effective for preventing hypos after activity by extending up to 6 hours after.</p> 

# Must drip feed carbs during exercise as needed (same for DIY)?

Variable	670G & 780G	T-Slim Control IQ	CamAPS FX
Preventing highs with basal increases	If Algorithm predicts above the Temp target level the basal insulin is increased = <b>Hypo risk</b>	If Algorithm predicts above the Exercise target level the basal insulin is increased = <b>Hypo risk</b>	If Algorithm predicts above the "Ease off" target level the extended bolus is increased = <b>Hypo risk</b>
Preventing highs with auto corrections	If 780G Algorithm predicts above the Temp target level and going high fast autocorrection no longer applied = <b>hypo protection</b>	If Algorithm predicts above the Temp target level and going above 10.0mmol/L an auto correction is delivered = <b>Big hypo risk</b>	If Algorithm predicts above the "Ease off" level and going high fast a more aggressive extended bolus is delivered = <b>Big hypo risk</b>
Solution: Small amount carbs just before & during exercise – <b>cap calculations at 60kg as cannot absorb more than 1g/min of glucose</b>	Drip feed glucose every 20 minutes. Start at 0.5g/kg/hr and vary according to CGM trend arrows. E.g. 30kg = 4g per 20 minutes	Drip feed glucose every 20 minutes. Start at 0.5g/kg/hr and vary according to CGM trend arrows. E.g. 50kg = 8g per 20 minutes	Drip feed glucose every 20 minutes. Start at 0.5g/kg/hr and vary according to CGM trend arrows. E.g. 60kg = 10g per 20 minutes

# Moser et al 2020 – how much carbs?

## 20 minutes before

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	Ex 0 and/or high hypo risk	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 <sup>a</sup> , Can start AE	Consider insulin correction <sup>a</sup> , Can start all Ex
			→	Consider insulin correction <sup>a</sup> , Can start AE	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	Can start all Ex
			→	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	
			↘↘	~5 g CHO (0.2 g/kg), Can start all Ex	~10 g CHO (0.3 g/kg), 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	~5 g CHO (0.2 g/kg), Can start all Ex
			→	~5 g CHO (0.2 g/kg), Can start all Ex	~10 g CHO (0.3 g/kg), Can start all Ex
			↘	~10 g CHO (0.3 g/kg), Delay all Ex <sup>b</sup>	~15 g CHO (0.4 g/kg), Delay all Ex <sup>b</sup>
			↓	Individual amount CHO ingestion, Delay all Ex <sup>b</sup>	
<5.0 mmol/l (<90 mg/dl)				Individual amount CHO ingestion, Delay all Ex <sup>b</sup>	

Moser et al (2020)

## Every 15-20 minutes during

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	Ex 0 and/or high hypo risk	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 <sup>a</sup> , Can start AE	Consider insulin correction <sup>a</sup> , Can start all Ex
			→	Consider insulin correction <sup>a</sup> , Can start AE	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	Can start all Ex
			→	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	
			↘↘	~5 g CHO (0.2 g/kg), Can start all Ex	~10 g CHO (0.3 g/kg), 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	~5 g CHO (0.2 g/kg), Can start all Ex
			→	~5 g CHO (0.2 g/kg), Can start all Ex	~10 g CHO (0.3 g/kg), Can start all Ex
			↘	~10 g CHO (0.3 g/kg), Delay all Ex <sup>b</sup>	~15 g CHO (0.4 g/kg), Delay all Ex <sup>b</sup>
			↓	Individual amount CHO ingestion, Delay all Ex <sup>b</sup>	
<5.0 mmol/l (<90 mg/dl)				Individual amount CHO ingestion, Delay all Ex <sup>b</sup>	

Moser et al (2020)

# The Carbs algorithm based on Moser

Sensor glucose Levels	Trend arrow & action to take	Grams carb g/kg/20min (60min) - Aerobic	Grams carb g/kg/20min (60min) - Mixed	Grams carb g/kg/20min (60min) - Anaerobic
<4.0mmol/L	<b>Treat hypo, re-check &amp; follow below guidance</b>	0.5/kg	0.5/kg	0.5/kg
4.0-4.9 mmol/L		0.5 (1.5)	0.45 (1.35)	0.4 (1.2)
		0.4 (1.2)	0.35 (1.05)	0.3 (0.9)
		0.3 (0.9)	0.25 (0.75)	0.2 (0.6)
		0.2 (0.6)	0.15 (0.45)	0.1 (0.3)
		0.1 (0.3)	0.05 (0.15)	0 (0)
E2: 5.0-6.9 mmol/L E1: 5.0-7.9 mmol/L E0: 5.0-8.9 mmol/L		0.5 (1.5)	0.45 (1.35)	0.4 (1.2)
		0.4 (1.2)	0.35 (1.05)	0.3 (0.9)
		0.3 (0.9)	0.25 (0.75)	0.2 (0.6)
		0.2 (0.6)	0.1 (0.3)	0 (0)
E2: 7.0-10.0mmol/L E1: 8.0-11.0mmol/L E0: 8.0-12.0mmol/L		0.3 (0.9)	0.25 (0.75)	0.2 (0.6)
		0 (0)	0 (0)	0 (0)
		0 (0)	0 (0)	0 (0)
13.9 mmol/L	All Arrows	0 (0)	0.0 (0)	0.0 (0)
>13.9 mmol/L & ketones <0.5mmol/L		<b>Ok to exercise: No carbohydrate needed for 20 minutes</b>		
		<b>Ok to exercise: No carbohydrate needed for 20 minutes, may need 50% of correction dose</b>		
ketones >0.5mmol/L	All Arrows	<b>No exercise: Requires corrective dose of insulin to get ketones less than 0.6mmol/l before starting exercise</b>		

Capped at 60kg due to glucose absorption limit of 1g/min for glucose and 1.5g/kg for mixed fast acting carb sources –  
 Jeukendrup (2014) *Sports Med* **44**, 25–33

# 670G & 780G Calculator Algorithm

Calculator Algorithm for 670G & 680G for exercise of at least 30 minutes duration

		Before exercise		During exercise	After exercise		
		Meal insulin: carbohydrate reduction into Bolus Wizard	Target	Carbohydrate 20 mins before, every 20 mins during			
Exercise type	Plan execution	Within 90mins of exercise, reduction of carbohydrate to enter into Bolus Wizard	More than 90 minutes before exercise	Target to activate 90 minutes before exercise	See carbs chart for glucose level and trend arrows	If eating after exercise: Reduction of carbohydrate to enter into Bolus Wizard	If not eating after exercise Set Target
Aerobic	Went low first time	-75% carbs	No change	Temp Target 90 minutes before exercise		-75% carbs & Normal Target	Temp target for 6 hours
	Starting plan	-50% carbs	No change	Temp Target 90 minutes before exercise		-50% carbs & Normal Target	Normal Target
	Went high first time	-25% carbs	No change	Temp Target 90 minutes before exercise		-25% carbs & Normal Target	Normal Target
Mixed	Went low first time	-50% carbs	No change	Temp Target 90 minutes before exercise		-75% carbs & Normal Target	Temp target for 6 hours
	Starting plan	-25% carbs	No change	Temp Target 90 minutes before exercise		-50% carbs & Normal Target	Normal Target
	Went high first time	No change	No change	Temp Target 90 minutes before exercise		-25% carbs & Normal Target	Normal Target
Anaerobic	Went low first time	-25% carbs	No change	Temp Target 90 minutes before exercise		50% carbs & Normal Target	Temp target for 6 hours
	Starting plan	No change	No change	Normal Target		-25% carbs & Normal Target	Normal Target
	Went high first time	No change and small bolus 15 mins pre-exercise	No change	Normal Target		No change & Normal Target	Normal Target



# T-Slim Control IQ Algorithm

Calculator Algorithm for Control IQ for exercise of at least 30 minutes duration

		Before exercise		During exercise	After exercise	
		Insulin Profile	Target	Carbohydrate 20 mins before, every 20 mins during		
Exercise type	Plan execution	Select insulin profile 90 minutes before activity	Target to activate 90 minutes before exercise	See carbs chart for glucose level and trend arrows	If eating after exercise: Select insulin profile for 90 minutes after activity	If not eating after exercise Set Target
Aerobic	Went low first time	-50% insulin profile 90 minutes before exercise	Exercise Target 90 minutes before exercise		-50% insulin profile 90 minutes after exercise & Normal Target	Exercise Target for 6 hours
	Starting plan	-25% insulin profile 90 minutes before exercise	Exercise Target 90 minutes before exercise		-25% insulin profile 90 minutes after exercise & Normal Target	Normal Target
	Went high first time	Normal insulin profile	Exercise Target 90 minutes before exercise		Normal profile & Normal Target	Sleep Target for 6 hours
Mixed	Went low first time	-25% insulin profile 90 minutes before exercise	Exercise Target 90 minutes before exercise		-50% insulin profile 90 minutes after exercise & Normal Target	Exercise Target for 6 hours
	Starting plan	Normal Insulin profile	Exercise Target 90 minutes before exercise		-25% insulin profile 90 minutes after exercise & Normal Target	Normal Target
	Went high first time	Normal Insulin profile	Normal Target		Normal profile & Normal Target	Sleep Target for 6 hours
Anaerobic	Went low first time	-25% insulin profile 90 minutes before exercise	Exercise Target 90 minutes before exercise		-25% insulin profile 90 minutes after exercise & Normal Target	Exercise Target for 6 hours
	Starting plan	Normal Insulin profile 90 minutes before exercise	Normal Target		Normal profile & Normal Target	Normal Target
	Went high first time	Normal insulin profile & small bolus 15 mins pre-exercise	Normal Target		Normal Profile & Sleep Target for 6 hours	Sleep Target for 6 hours

# CAMAPS FX Calculator Algorithm

Calculator Algorithm for CAMAPS FX for exercise of at least 30 minutes duration

		Before exercise		Target	During exercise	After exercise	
		Meal insulin: carbohydrate reduction into Bolus Wizard			Carbohydrate 20 mins before, every 20 mins during		
Exercise type	Plan execution	Within 90mins of exercise, reduction of carbohydrate to enter into Bolus Calculator	More than 90 minutes before exercise	Target to activate 90 minutes before exercise	See carbs chart for glucose level and trend arrows	If eating after exercise: Reduction of carbohydrate to enter into Bolus Wizard	If not eating after exercise Set Target
Aerobic	Went low first time	-50% carbs	No change	Ease Off 90 minutes before exercise		-50% carbs & Normal Target	Ease off for 6 hours
	Starting plan	-25% carbs	No change	Ease Off 90 minutes before exercise		-25% carbs & Normal Target	Normal Target
	Went high first time	No change	No change	Ease Off 90 minutes before exercise		No change & Normal Target	Boost for 3 hours
Mixed	Went low first time	-25% carbs	No change	Ease Off 90 minutes before exercise		-50% carbs & Normal Target	Ease off for 6 hours
	Starting plan	No change	No change	Ease Off 90 minutes before exercise		-25% carbs & Normal Target	Normal Target
	Went high first time	No change	No change	Normal Target		No change & Normal Target	Boost for 3 hours
Anaerobic	Went low first time	-25% carbs	No change	Ease Off 90 minutes before exercise		25% carbs & Normal Target	Ease off for 6 hours
	Starting plan	No change	No change	Normal Target		No change & Normal Target	Normal Target
	Went high first time	No change and small bolus 15 mins pre-exercise	No change	Normal Target		No change & Boost for 3 hours	Boost for 3 hours