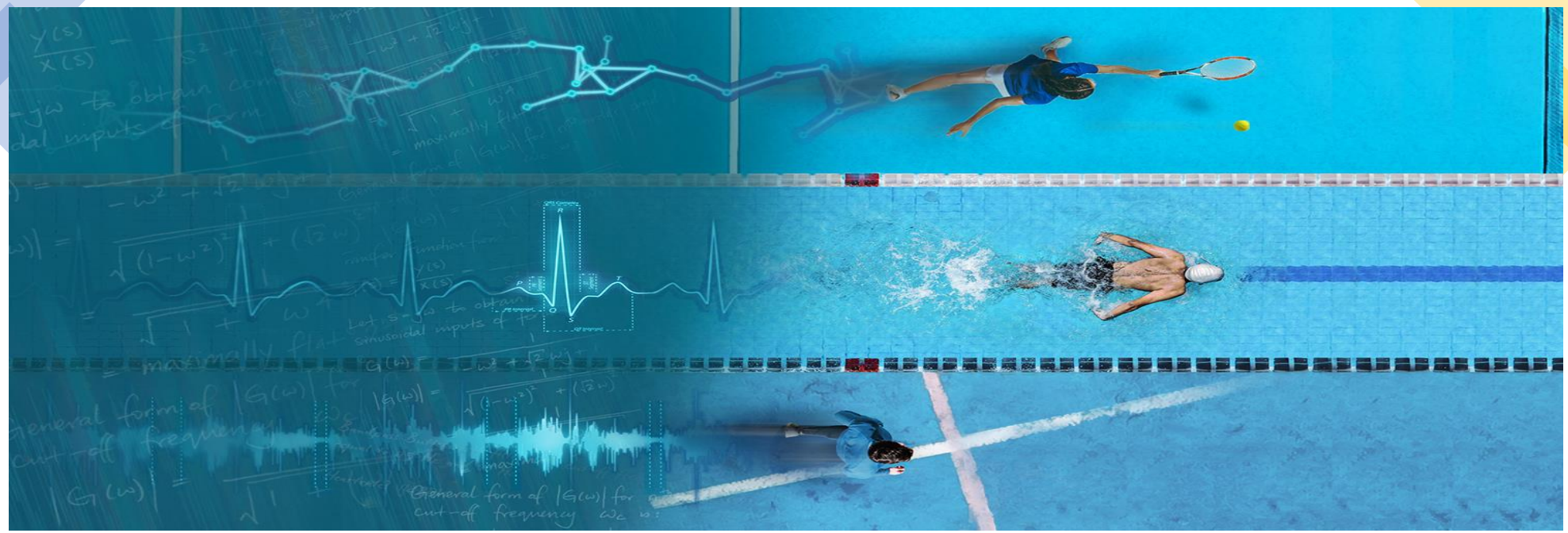

Analysis of glycemic control and variability during exercise: the case of the athlete with type 1 diabetes

Hands-on session

Brixen, September 13th 2023

Use of continuous glucose monitoring in sport and exercise

- Although continuous glucose monitoring (CGM) devices were initially designed to assist in the clinical management of diabetes, there is now interest in their application to athletic populations.

- The capacity of CGM to capture the duration, magnitude, and frequency of interstitial glucose fluctuations every 1–15 min may present a unique opportunity to monitor fueling adequacy around competitive events and training sessions, but it remains largely untested.

Bowler AM, Whitfield J, Marshall L, Coffey VG, Burke LM, Cox GR. The Use of Continuous Glucose Monitors in Sport: Possible Applications and Considerations. Int J Sport Nutr Exerc Metab. 2022;33(2):121-132.

The athlete with type 1 diabetes

- Athletes living with type 1 diabetes (T1D) present unique metabolic responses to various types of exercise.

- The management of this condition is onerous, especially while training and preparing for competition (i.e. glucose monitoring, carbohydrate/macronutrient counting, insulin dosing, and managing stress/sick days).

Riddell MC, Scott SN, Fournier PA, et al. The competitive athlete with type 1 diabetes. Diabetologia. 2020;63(8):1475-1490.

Analysis and interpretation of CGM data

- In parallel with the advancement in CGM technology, the need for interpreting the large amount of produced data has led to the definition of lots of **metrics** useful to assess glycemic variability and control.

- In general, CGM data interpretation has been suffering from a lack of standardization, even though in the last 10 years, much work has been done to overcome this limitation:
  - adoption of a template report named Ambulatory Glucose Profile (AGP);
  - international consensus on CGM data analysis and standard metrics that should be computed for **clinical care**.

Danne T, Nimri R, Battelino T, et al. International Consensus on Use of Continuous Glucose Monitoring. Diabetes Care. 2017;40(12):1631-1640.

Battelino T, Danne T, Bergenstal RM, et al. Clinical Targets for Continuous Glucose Monitoring Data Interpretation: Recommendations From the International Consensus on Time in Range. Diabetes Care. 2019;42(8):1593-1603.

Software packages and tools for the analysis and interpretation of CGM data

	GlyCulator	EasyGV	CGM-GUIDE	GVAP	Tidepool	CGManalyzer	cgmanalysis	GLU	CGMStats Analyser	iglu	rGV	cgmquantify
Tool version used	3.0	10	—	1.1	—	1.3	2.7.3	0.2.0	0.1.0	3.3.1	0.0.1	0.1.0
Metrics												
eA1c (%)							8.4		8.4	8.4		8.4
TAR-level 1[e] (%)	49	49	—	49[b]	—		50	50[b,i]	50	49	24	
TBR-level 1[e] (%)	10	10	—	10[b]	—		10	10[b,i]	4	10	4	
TAR-level 2 (%)	25	25	—	25[b]	—		25	25[b,i]	25	25	25	
TBR-level 2 (%)	6	6	—	6[b]	—		6	6[b,i]	6	6	6	
TIR (%)	41	41	—		—		0[e]	41[i]	41	41	41	
Expected CGM readings (%)	100[f]				—		100[b]			100		
ADRR (d.n.)		65.7								54.6[b]	65.7	Soon
AUC[d]	10.7 mmol/L						6.2·(10^4)[g] (mmol/L)·min	10.7 mmol/L		10.7[g] mmol/L	1.5·(10^4)[g] (mmol/L)·min 24-h AUC	
AUC-high/low[d]			—	2.4/0.1[g] mmol/L					133.0·(10^2)/ — (mmol/ L)·min			
COGI (%)										36[j]		
CONGA1 (mmol/L)		3.1[c]	—	2.2[b,g]		2.5	2.5[g]		2.5	2.5[g]	2.5[g]	Soon
%CV (%)	48	48[i]			—		48[i]		48	48	48	48
Distance travelled (mmol/L)											215.9[g]	
EF (count)				20								
Excursions over/ under (count)							7/3					
Fasting proxy (mmol/L)								5.8				
GMI (%)	7.9				—		7.9			7.9	7.9	7.9
GRADE (d.n.)	14.85	14.37								14.85	14.85	
GRADE-Hypo (%)		14								14	13[j]	
GRADE-Euglyc (%)		3								3	3[j]	
GRADE-Hyper (%)		83								84	83[j]	
GVP (%)		29.68								1.29[f]	29.68	
HBGI (d.n.)	14.22	14.23					17.46[a]		14.26	14.23	14.23	5.54[a]
Hyper/hypo index (d.n.)										3.66/ 3.13		
IGC (d.n.)		6.78								6.78		
IQR (mmol/L)										6.7[g]		
J-index (d.n.)	81.60	81.44					81.44		81.44	81.44	81.46	81.44
LBGI (d.n.)	2.53	2.54					13.75[a]		2.54	2.54	2.54	3.60[a]
LI (d.n.)		6.3									6.3[g]	
MAD (mmol/L)						4.9[f]		3.5		3.3[g]		
MAG (mmol/L)		2.3								2.2	2.3	
MAGE[k] (mmol/L)	8.7	12.4	—	9.0[g]			8.1[g]		8.6	12.5[g]	Not present	Soon
MAGE+/MAGE−[k] (mmol/L)				9.1/8.9[g]						12.6/12.5[g]	Not present	
Max/min (mmol/L)			—			22.2/2.2	22.2/2.2[g]			22.2/2.2[g]		22.2/2.2[g]
Mean (mmol/L)	10.7	10.7	—	10.7[g]	—	10.7	10.7[g]		10.7	10.7[g]	10.7[g]	10.7[g]
Median (mmol/L)	9.9					9.9	9.9[g]			9.9[g]		9.9[g]
MGE (mmol/L)												11.7[g]
MGN (mmol/L)												10.7*-g
MODD (mmol/L)		4.4	—	−1.0[b]		0.9[b]	4.4[g]			4.4[g]	4.4[g]	Soon

(continued)

	GlyCulator	EasyGV	CGM-GUIDE	GVAP	Tidepool	CGManalyzer	cgmanalysis	GLU	CGMStats Analyser	iglu	rGV	cgmquantify
MSE (d.n.)						Array						
M-value (d.n.)	294.8[a]	47.5								47.5	65.5[f]	
Number of days CGM worn	4						4			4		
Number of episodes per day											0.5	
Number of missing values		0				0						
PGS (d.n.)		26.99										
PIR (%)												Not present
POR (%)												33
Post-event AUC								No event				
Post-event time to peak (min)								No event				
Q1/Q3 (mmol/L)						7.2/13.9	7.2/13.9[g]			7.2/13.9[g]		7.2/13.9[g]
Range (mmol/L)										20.0[g]		
ROC [mmol/(L·min)]										Array		
SD (mmol/L)	5.1	5.1	—	5.1[g]	—	5.1	5.1[g]		5.1	5.1[g]	5.1[g]	5.1[g]
SD of ROC [mmol/(L·min)]										0.05[g]		
sGVP (%)								0.022				
Total computed metrics	19	26	11	12	11	10	23	11	15	39	28	19
Total computed standard metrics	13	9	6	5	6	1	14	6	10	14	11	6
Total error and warning/total metrics	1/19	1/26	—	2/12	—	1/10	4/23	0/11	0/15	1/39	0/28	3/19

12 software packages/tools published until December 2021

Piersanti A, Giurato F, Göbl C, Burattini L, Tura A, Morettini M. Software Packages and Tools for the Analysis of Continuous Glucose Monitoring Data. Diabetes Technol Ther. 2023;25(1):69-85.

AIM of the hands-on session

- To analyze CGM data pertaining to athletes with T1D acquired in an exercise day;
- To compute significant CGM metrics in the whole day and/or in the pre-exercise/exercise/post-exercise phase;
- To interpret the results and identify the athlete with the "most favorable glycemic condition".

Tool for the analysis and interpretation of CGM data for the hands-on session

iglu: Interpreting data from Continuous Glucose Monitors (CGMs)

https://irinagain.github.io/iglu/

Broll S, Urbanek J, Buchanan D, et al. Interpreting blood GLUcose data with R package iglu. PLoS One. 2021;16(4):e0248560.

Athletes' CGM data for the hands-on session

- 5 young athletes;
- CGM recordings including pre-exercise, exercise and post-exercise (<24-h recording).
- 75-min exercise session.

Hints on the identification of the most favorable glycemic condition

- Hypoglycemia during and after exercise;
- Compliance with proposed glycemic targets in terms of:
  - time in range,
  - time below target range,
  - time above target range,
  - coefficient of variation.

Useful information can be found at the following reference:

Riddell MC, Scott SN, Fournier PA, et al. The competitive athlete with type 1 diabetes. Diabetologia. 2020;63(8):1475-1490.