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Abstract

Continuous Glucose Monitoring of Non-Diabetic Professional Cyclists during a Training Camp

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Abstract: Cyclists undergo demanding efforts both in training and competition that may perturb the glucose metabolism. Recent advances in wearable technology have produced a variety of devices which can be used to monitor biometric parameters in athletes like interstitial glucose. The aim of this study was to describe daily glucose fluctuations using a continuous glucose monitoring device in non-diabetic professional cyclists during a training camp. Values showed stability of interstitial glucose concentration and a relatively low occurrence of overnight hypoglycemia. These results suggest that the athletes maintained adequate glucose levels and control across the training camp.

Keywords: cycling, endurance, glucose concentration, real-time glucose tracking

1. Introduction

Professional cycling events, such as multi-day stage races, often require athletes to pedal for several hours covering distances longer than 160 km and elevation gains over 2000 m (Mujika and Padilla, 2001). In order to cope with the demands of this sport, adequate fuel is necessary, mainly carbohydrate (CHO) feeding. Providing and maintaining adequate CHO availability can help to preserve cycling performance.

Continuous glucose monitoring (CGM) devices are gaining popularity in professional cycling to monitor athletes' interstitial glucose levels during training. By evaluating CGM fluctuations during a training camp, it might be possible to gain insights into how athletes respond to training, energy balance/availability, and to different food intake. Despite its potential, the use of CGM in professional cycling is currently not well supported by scientific evidence, therefore these assumptions remain largely speculative (Bowler et al., 2023). Furthermore, the current use of this technology is not allowed in competition (UCI, Technical Regulation. § 4 Onboard technology. Article 1.3.006 BIS).

The aim of the study was to describe the use of a CGM device in professional cyclists during a training camp. By providing this data, the results of the study may help to further develop personalized nutrition and training strategies for professional cyclists, considering their metabolic demands and status.

2. Materials and Methods

26 professional non-diabetic male cyclists (65.7 ± 3.9 kg; 23 ± 3 years; 1.77 ± 0.46

m) wore a CGM sensor (Abbott Libre Sense Glucose Sport Biosensor) for the entire duration of a 11-day-long training camp. Minute-by-minute interstitial fluid glucose concentration data were collected and logged onto the Supersapiens database with the Supersapiens app (www.supersapiens.com). Once the data was gathered, any gap in the CGM traces was filled using linear interpolation, and a 3-minute rolling average was applied. If data gaps were longer than 15 minutes, then data points were not considered in the analysis.

The following glucose-related metrics were evaluated across the entire duration of the training camp:

1. During a 24-hour period (00:00-24:00)
   - The central tendency of the interstitial glucose concentration (average).
   - The dispersion of the interstitial glucose concentration (standard deviation).

2. During the overnight period (23:00-06:00)
   - The central tendency of the interstitial glucose concentration (average).
   - The dispersion of the interstitial glucose concentration (standard deviation).
   - The minimum value of a 3-h rolling average.
   - Minutes spent with interstitial glucose concentration <70 mg/dL.

Heart rate (HR, Bryton heart rate monitor, Bryton Inc, Taipei City, Taiwan) and power output data (PO, Favero Assioma Duo, Favero Electronics srl., Arcade, TV, Italy) were recorded using the same cycle computer (Bryton S800, Bryton Inc, Taipei City, Taiwan), and analyzed using WKO5 Software (WKO5, Peaksware LLC, Lafayette, CO, USA). The following parameters were investigated: average HR; average absolute and relative PO; session rating of perceived exertion (sRPE); time spent at different exercise domains; basal metabolic rate (BMR), exercise energy expenditure (EE); and total daily energy expenditure (TDEE).

Exercise domains were established in three zones: below 70% lactate threshold (LIT); between 70% and 100% lactate threshold (MIT); and above lactate threshold (HIT). Time was expressed as a percentage of total time spent in the mentioned zones.

sRPE (1) and TDEE (2) were calculated using the following formulas:

(1) $sRPE\ (A.U.) =$
$total\ exercise\ duration\ in\ minutes\ *\ RPE$

(2) $TDEE\ (MJ/day)\ =\ BMR\ *\ PAL_N\ +\ EE$

PAL_N (non-exercise physical activity level) was set to 1.80 (Van Hooren et al., 2022). Daily, the medical staff prescribed CHO intake (g/day) to the riders according to the training schedule. Data were reported as mean ± standard deviation (SD).

A series of one-way repeated measures analysis of variance (ANOVA) tests were performed to investigate differences for the following CGM-related variables: average glucose overnight; minimum glucose overnight, and time spent below 70 mg/dL of glucose concentration overnight. When the assumption of sphericity was not met, Greenhouse-Geisser correction was applied. Post-hoc analyses using pairwise comparisons were performed using Bonferroni correction, when significant effects were found. Statistical significance was accepted at $p < 0.05$.

3. Results

Full disclosure of the data regarding daily and nocturnal glucose levels, and training load can be found in Tables 1-3. BMR, EE, and TDEE values are shown in Figure 1.

Due to missing and/or erroneous data, sixteen participants were included in the statistical analysis.

Glucose overnight (p = 0.006); and minimum glucose overnight (p = 0.021) were different between time points.

Post-hoc analyses revealed that, compared to day 1, average glucose overnight was lower on days 6, 7, 9, and 10 ($p < 0.05$). Minimum glucose overnight was lower on days 6, 7, and 10 ($p < 0.05$). Figure 2.

No differences were found for time below 70 mg/dL ($p = 0.443$). Figure 3.

4. Discussion

The aim of this study was to describe CGM data in a group of professional cyclists during a 11-day training camp. By evaluating glucose-related metrics using CGM devices, this study sought to gain insights into how athletes respond to training, energy balance/availability, and food intake.

Two important findings of this study are: (i) the stability of the interstitial glucose concentration and (ii) the relatively low occurrence of hypoglycemia across the training camp. The time spent with interstitial glucose concentration <70 mg/dL was minimal, particularly during the overnight period (23:00-06:00), suggesting that the athletes maintained adequate glucose control during the resting period. This is particularly relevant because nocturnal hypoglycemia is a potential risk for athletes who undergo strenuous exercise during the day (Kulaweic et al., 2019, Flockhart, et al., 2021), suggesting that athletes were able to maintain glucose levels within a normal range during the training camp. Daily CHO intake prescriptions done by the medical staff may have contributed to maintaining stable levels of glucose during exercise. This amount might be deemed adequate for the daily EE, which was found to be in line with values reported in the literature (Van Hooren et al., 2022). Finally, athletes' metabolic status was not compromised by training load.

Due to the nature of observational studies, one limitation of the current work is the lack of a more detailed statistical analyses for training related variables that may explain the differences found in several days on CGM-related parameters. Future research should aim to explore a better statistical approach (i.e., analysis of covariance) in order to take into account training and other metabolic parameters. Another aspect that could be considered in future work is intra-individual variability. Further research is required to find potential CGM reference values in professional cyclists.

Summarizing, this study provides CGM data in a group of professional cyclists during a 11-day training camp. The stable glucose control observed across the training camp, the low occurrence of hypoglycemia, and the absence of significant changes in glucose-related metrics during the overnight period and in response to the training load indicate that the athletes maintained adequate glucose availability and control throughout the training camp.

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Conflicts of Interest: AG, B-MG, and MV declare no conflict of interest. AZ and KS are employed by Supersapiens.

References

Bowler, A. L. M., Whitfield, J., Marshall, L., Coffey, V. G., Burke, L. M., & Cox, G. R. (2023). The Use of Continuous Glucose Monitors in Sport: Possible Applications and Considerations. International Journal of Sport Nutrition and Exercise Metabolism, 33(2), 121-132. DOI: 10.1123/ijsnem.2022-0139

Flockhart, M., Nilsson, L. C., Tais, S., Ekblom, B., Apró, W., & Larsen, F. J. (2021). Excessive exercise training causes mitochondrial functional impairment and decreases glucose tolerance in healthy volunteers. Cell metabolism, 33(5), 957-970. DOI: 10.1016/j.cmet.2021.02.017

Kulawiec, D. G., Zhou, T., Knopp, J. L., & Chase, J. G. (2021). Continuous glucose monitoring to measure metabolic impact and recovery in sub-elite endurance athletes. Biomedical Signal Processing and Control, 70, 103059. DOI: 10.1016/j.bspc.2021.103059

Mujika, I., & Padilla, S. (2001). Physiological and performance characteristics of male professional road cyclists. Sports medicine, 31(7), 479-487. DOI: 10.2165/00007256-200131070-00003

Van Hooren, B., Cox, M., Rietjens, G., & Plasqui, G. (2023). Determination of energy expenditure in professional cyclists using power data: Validation against doubly labeled water. Scandinavian Journal of Medicine & Science in Sports, 33(4), 407-419. DOI: 10.1111/sms.14271

Table 1. Daily glucose metrics

	Central (mg/dL)	**Dispersion (mg/dL)**	**CHO (g)**
Day 1	120 ± 8	19.7 ± 4.7	351 ± 117
Day 2	118 ± 8	20.3 ± 3.7	369 ± 115
Day 3	113 ± 8	17.7 ± 3.2	204 ± 12
Day 4	119 ± 8	21.2 ± 4.0	316 ± 18
Day 5	113 ± 7	18.2 ± 2.8	313 ± 19
Day 6	112 ± 10	19.1 ± 4.1	474 ± 29
Day 7	109 ± 12	17.4 ± 4.3	317 ± 20
Day 8	112 ± 10	18.5 ± 3.6	317 ± 21
Day 9	113 ± 12	21.0 ± 4.2	472 ± 30
Day 10	113 ± 10	18.7 ± 3.4	317 ± 19
Day 11	114 ± 11	22.8 ± 4.9	474 ± 29

Data are presented as mean ± standard deviation.

Table 2. Nocturnal glucose metrics

	Minimum (mg/dL)	Central (mg/dL)	Dispersion (mg/dL)	Duration <70 mg/dL (min)
Day 1 to Day 2	95 ± 8	101 ± 7	8.8 ± 3.7	5 ± 21
Day 2 to Day 4	90 ± 7	96 ± 8	9.4 ± 2.9	8 ± 18
Day 3 to Day 4	89 ± 7	93 ± 7	6.5 ± 2.7	0 ± 0
Day 4 to Day 5	90 ± 9	96 ± 9	8.5 ± 3.6	8 ± 26
Day 5 to Day 6	88 ± 8	93 ± 8	7.5 ± 2.9	7 ± 27
Day 6 to Day 7	86 ± 10	90 ± 10	7.0 ± 3.3	21 ± 62
Day 7 to Day 8	86 ± 12	90 ± 12	6.9 ± 3.0	24 ± 85
Day 8 to Day 9	89 ± 11	94 ± 10	7.8 ± 3.1	13 ± 34
Day 9 to Day 10	87 ± 11	91 ± 12	7.2 ± 3.0	35 ± 87
Day 10 to Day 11	86 ± 11	90 ± 12	8.3 ± 3.7	25 ± 59
Day 11 to Day 12	87 ± 10	91 ± 10	7.6 ± 4.2	30 ± 63

Data are presented as mean ± standard deviation.

Table 3. Training load metrics

	Duration	LIT	MIT	HIT	sRPE	Average HR	Average relative PO	Average Absolute PO
	(min)	(%)	(%)	(%)	(A.U.)	(bpm)	(W/kg)	(W)
Day 1	201 ± 66	87 ± 8	8 ± 5	1.68 ± 1.51	991 ± 788	119 ± 12	2.42 ± 0.19	158 ± 15
Day 2	230 ± 19	77 ± 6	16 ± 5	2.96 ± 1.78	1,341 ± 446	129 ± 6	2.74 ± 0.19	179 ± 15
Day 3	49 ± 14	87 ± 21	9 ± 19	2.71 ± 7.81	146 ± 51	130 ± 15	2.80 ± 0.48	183 ± 30
Day 4	326 ± 11	67 ± 7	26 ± 6	2.30 ± 1.21	2,055 ± 511	134 ± 8	3.10 ± 0.20	204 ± 16
Day 5	248 ± 16	76 ± 5	20 ± 4	1.19 ± 1.07	1,218 ± 382	124 ± 8	2.85 ± 0.19	186 ± 14
Day 6	163 ± 27	69 ± 12	21 ± 8	5.59 ± 3.57	876 ± 259	135 ± 8	3.38 ± 0.28	223 ± 21
Day 7	58 ± 21	90 ± 12	8 ± 8	1.91 ± 4.91	177 ± 93	127 ± 16	2.83 ± 0.46	187 ± 28
Day 8	134 ± 3	92 ± 4	6 ± 3	1.32 ± 0.67	261 ± 122	109 ± 6	2.22 ± 0.16	146 ± 16
Day 9	175 ± 14	69 ± 6	25 ± 4	3.13 ± 2.51	839 ± 277	134 ± 8	3.09 ± 0.23	203 ± 18
Day 10	342 ± 15	73 ± 6	20 ± 4	3.77 ± 2.15	2,570 ± 524	129 ± 6	2.93 ± 0.17	194 ± 14
Day 11	290 ± 15	72 ± 7	19 ± 5	6.02 ± 3.08	2,335 ± 558	137 ± 6	3.19 ± 0.20	211 ± 17

Data are presented as mean ± standard deviation.

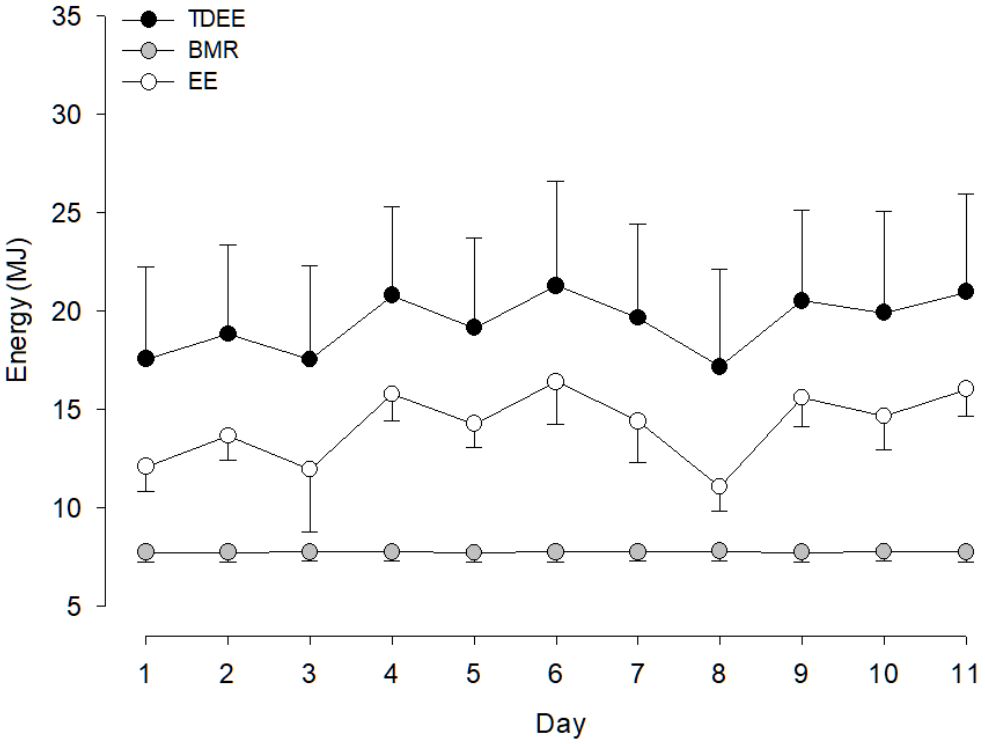

Figure 1. Basal metabolic rate (BMR). Exercise energy expenditure (EE). Total daily energy expenditure (TDEE). Data are presented as mean ± standard deviation.

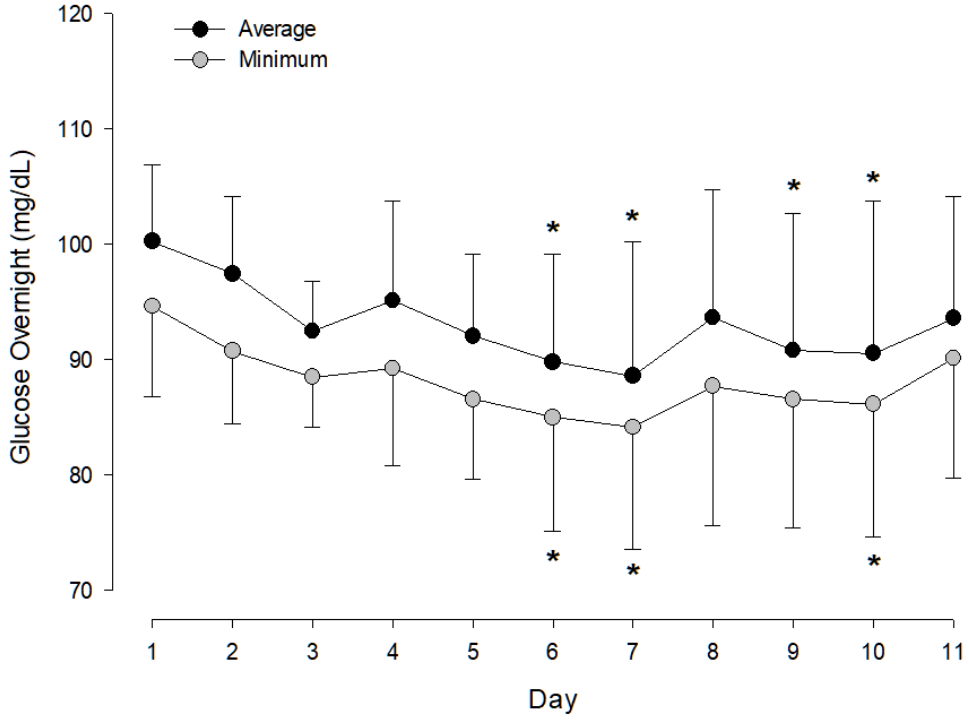

Figure 2. Glucose overnight. Data are presented as mean ± standard deviation. * denotes differences from day 1.

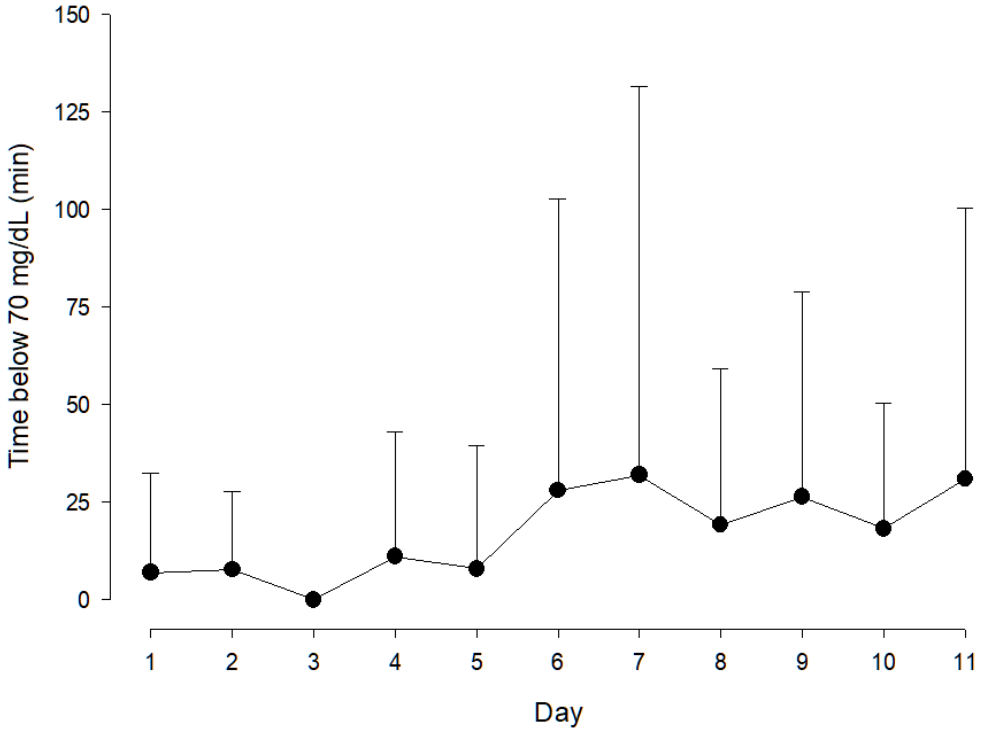

Figure 3. Time spent below 70 mg/dL overnight. Data are presented as mean ± standard deviation.