Case Study: The application of daily carbohydrate periodisation throughout a cycling Grand Tour

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Carbohydrates | Periodisation | cycling

Headline

Professional road cycling is recognised as one of the most energetically demanding competitive sports. A Grand Tour is composed of 21 stages of almost consecutive daily racing that varies in exercise intensity, duration and terrain (1,2). Within a Grand Tour there are large variations in on-bike exercise energy expenditure (EEE), from ∼1000 kcal during a time trial to>4500 kcal in mountain stages. To balance adequate fuelling for performance while maintaining or improving a rider's power to weight ratio across 3-weeks of racing requires matching CHO intake to the demands of different stage types.

Aim

The aim of this case report was to describe in detail the quantification of daily on-bike EEE and the delivery of a daily periodised CHO feeding strategy for a male professional cyclist during the 2021 Vuelta a España.

Methods

Athlete and overview of sporting history

The male athlete was 26 years old with six years' experience as a professional cyclist, the last three years at UCI World Tour level. The athlete's role within the team at the 2021 Vuelta a España (his 6^{th} Grand Tour) was as a "domestique", supporting the team's general classification leader during hilly and mountain stages. The athlete provided informed written consent for the publication of these data.

Vuelta a España 2021

Between August 19 – September 20, the race covered 3,417 km, across 21 racing stages and two rest days. The race included two individual time trials (Total 40.9 km), six "flat" stages (Total 1074.0 km), four "hillly" stages (Total = 688.8 km) and nine "mountain" stages (Total 1614.9 km) as classified by the official Vuelta a España website (Table 1). No data were collected on stage 21 (34 km time trial).

Body mass

The athlete measured body mass each morning using calibrated SECA 875 Class III scales (SECA, Hamburg, Germany) in voided and fasted state with minimal clothing.

On bike exercise energy expenditure

Daily on-bike EEE was recorded using a power meter (R9100P, Shimano, Sakai City, Japan) and Garmin 810 bike computer (Garmin, Olathe, Kansas, USA). The data was stored and accessed via Training Peaks (Training Peaks, Colorado, USA). A gross efficiency of 21.7% was used to calculate on-bike kcal from power data.

Carbohydrate periodisation structure

The rider completed a weighed food diary for all foods at breakfast, snacks pre-race, and recorded the number of race foods (rice cakes, small sandwiches etc.) and sports products (gels, bars, CHO drinks) consumed during each stage. This was done using the remote food photographic method (RFPM) (4) and reporting any additions/changes immediately post stage. The recovery meal was weighed and pre-packed by the chef and the rider weighed any unconsumed food and/or weighed and reported additional foods eaten. This information was shared via a mobile app (Whatsapp, California, USA) with the nutrition team. The nutrition team then calculated the CHO intake during the stage and provided within stage fuelling feedback and subsequent recommendations for the amounts of CHO containing foods the rider should consume during the rest of the day. The rider recorded food weights at dinner and any additional snacks and shared the information to complete the day's food record (Figure 1). All meals and recovery food were prepared by the team chef according to pre-planned menus. Alterations to menus due to ingredient availability were documented and added to the food database. Race foods were prepared according to specific recipes providing known quantities of CHO per unit of food. All food was weighed on digital calibrated scales (Terraillon 14253 Kitchen Scales, Paris, France) with a precision of 1 g increments up to 5 kg.

Analysis of nutrient intake and energy expenditure

Food labels were used to create a database of the macronutrient content of all foods. Where foods were cooked in water (i.e., pasta, rice, polenta etc.) a dry weight to cooked weight conversion was used to calculate the CHO content in the cooked food.

Results

Daily carbohydrate intake

The riders' daily CHO intake from Stage 1 to Stage 20 within the Grand Tour is presented in Figure 2. Mean absolute daily

CHO intake and relative CHO intake to body mass was 812 ± 215 g (range: 340 - 1118 g) and 12.2 ± 3.2 g·kg^{1} (range: 5.1 - 17.7 g·kg^{1}), respectively. The largest mean absolute and relative CHO intake occurred on mountain stages, followed by hilly stages, flat stages, and then the individual time trial (ITT) (Figure 2). Additionally, the mean rest day absolute and relative CHO intake was considerably lower than all racing days.

Carbohydrate distribution across meals

The rider consumed similar amounts of CHO at dinner (197 ± 76 g) and during post-stage recovery (189 ± 43 g), and less at breakfast (124 ± 24 g) (Figure 3). There was less variation in absolute and relative CHO intakes at breakfast (71 - 152 g; 1.1 - 2.3 g·kg^{1}) compared to both post stage (70 - 267 g; 1.1 - 4.0 g·kg^{1}) and dinner (80 - 326 g; 1.2 - 4.9 g·kg^{1}).

Carbohydrate intake and type during exercise

The mean intake of CHO, and the form of delivery during each stage is presented in Table 2. Total CHO intake during exercise ranged from 185 - 508 g which equated to an hourly CHO intake range of 41 - 106 g·h-1 (Figure 4a and 4b). The greatest contribution of CHO on-bike came from whole foods (37 ± 10%) then bars (21 ± 10%), gels (14 ± 6%) and high concentration CHO drinks (15 ± 17%).

On-bike energy expenditure and body mass

On-bike EEE for each stage is presented in Table 1, including mean values between different stage types. Body mass for stages 1 – 20 is displayed in Table 1. From Stage 1 to 20 the rider had a 1 kg increase in body mass (66.8 to 67.8 kg), varying between 65.0 – 69.0kg throughout the race.

Discussion

This is the first report to detail the distribution of CHO intake on a meal-by-meal and stage-by stage basis during a Grand Tour. The present data provides a unique insight into the amounts, and the day-to-day variation of CHO required to fuel a professional cyclist and highlights the application of a periodised approach to CHO intake to match the highly variable event demands.

Previous research has reported similar mean daily CHO intake during Grand Tours (∼12.6 g·kg^{1})(3,5,6), however our data indicates that the daily CHO intake can range from 5.1 – 17.7 g·kg^{1} (Figure 2.). Contemporary sport nutrition guidelines recommend 8 to 12 g·kg^{1} to support 4 - 5 h of moderate-to-high intensity exercise (7). While these recommendations are in line with the mean daily CHO intakes reported here, they fail to capture the substantial day-by-day variation in CHO intake employed by athletes during these multi-day events.

CHO consumption was manipulated in this case study by reducing CHO intake on stages where on-bike EEE was lower, such as flat stages (3022 ± 381 kcal) and rest days (563 ± 4 kcal) and increasing intake on more physically demanding stages such as hilly (4040 ± 788 kcal) and mountain (4602 ± 985 kcal) stages (Figure 2). The highest daily CHO intake was reported on Stage 18 (Figure 2a, b) which corresponded with the second most physically demanding (5592 kcal) stage of the race. On this day the athlete consumed 17.7 g·kg^{1} of CHO, ∼150% greater than the current recommendations. This amount of CHO consumption was achieved with 1.9 g·kg^{1} CHO (123 g) at breakfast, 6.8 g·kg^{1} CHO (462 g, 87 g·h^{1}) on the bike, 4.0 g·kg^{1} CHO (267 g) in the immediate post stage recovery period and 4.9 g·kg^{1} CHO (323 g) at dinner. Although the CHO intake was greater than the total daily recommendations, it matched the maximal recommendations for CHO consumption per hour during competition (∼90 g·h^{1}) (8, 9, 10) and recovery (8.9 g·kg^{1} CHO over a 5 - 6-hour period) (7, 11).

In addition to total consumption, this novel data outlines the composition of in-race CHO intake (Table 2). Our data show most of the on-bike CHO intake came from whole foods, followed by Bars, then Gels, and Drinks. During strategic sections of the race, CHO delivery was increased via concentrated multi-source CHO drinks ∼90g CHO per 500ml (Table 2). This strategy delivered additional CHO during parts of the race where energy expenditure was high and the athlete's opportunity/ability to consume solid foods were limited. Excluding in-race CHO consumption, the majority of CHO intake was observed during the post-race recovery period and dinner (Figure 3). This contrasts with Muros et al. (2019)(3) who found riders consumed most of their daily CHO at breakfast (199 ± 43 g) and different to García-Rovés et al. (1998)(5) who found similar intakes of CHO to be at breakfast (298 ± 53 g; 4.5 ± 0.7 g·kg^{1}) and dinner (311 ± 29 g; 4.7 ± 0.6 g·kg^{1}) with lower intakes at post-stage recovery (134 ± 29 g; 2.0 ± 0.5 g·kg^{1}). These observations potentially relate to individual rider and cultural preferences surrounding meal provision with additional research required to determine which feeding pattern is optimal for Grand Tour performance.

Similar to on-bike CHO consumption, the strategic periodised approach to matching CHO intake and EEE resulted in large variations in meal size across stages. CHO intake varied considerably at breakfast (71 - 152 g; 1.1 - 2.3 g·kg^{1}), post-stage (70 - 267 g; 1.1 - 4.0 g·kg^{1}) and dinner (80 - 326 g; 1.2 - 4.9 g·kg^{1}) and this variation was dependent on the physical demands of the current stage in combination with the anticipated demands of the next stage.

A novel function of this intervention was the ability to deliver bespoke nutrition recommendations in a time sensitive and dynamic racing environment. This was achieved by leveraging digital technologies to enhance communication efficiency and removing the dependency on a single practitioner. Having onsite support remains an essential component to capture any nuance and details that can be missed with only digital communication; but the addition of a distributed support system enables the team to support multiple athletes in different locations simultaneously. Here the integration of digital systems facilitated the real time delivery of personalised nutrition recommendations and highlights the scope for development in this area (12).

This case report highlights the large variation in CHO intakes between different stages of a Grand Tour, that range well beyond current best practice recommendations. Despite the availability of specialised sports nutrition products, this athlete predominantly chose whole foods to provide sufficient CHO with the strategic addition of concentrated dual source CHO drinks at key moments of the race. Furthermore, we demonstrate the application of a distributed nutrition support network utilising collaborative cloud-based technologies to enable actionable feedback loops to support riders.

Table 1. Overview of the physiological demands and stage characteristics during the period of data collection. On-bike exercise energy expenditure is inclusive of any race-day reconnaissance, warm-ups, racing and cool-down were appropriate.

Stage	Stage type	Body Mass (kg)	Distance (km)	Elevation (m)	On-bike EEE (kcal)
1	Individual TT	66.8	7.1	93	1701
2	Flat	66.3	166.7	1019	2681
3	Mountain	66.8	202.8	2771	4150
4	Flat	65.0	163.9	1532	2780
5	Flat	67.3	184.4	671	2715
6	Mountain	66.8	158.3	1002	3293
7	Mountain	66.9	152	3567	4800
8	Flat	66.4	173.7	897	3083
9	Mountain	66.8	188	4349	5086
Rest day		68.4		561	566
10	Hilly	66.6	189	2181	4672
11	Hilly	66.9	133.6	2517	3411
12	Hilly	66.4	175	2096	3307
13	Flat	66.9	203.7	1639	3202
14	Mountain	68.0	165.7	3301	4343
15	Mountain	66.9	197.5	3694	3014
Rest day		69.0		284	560
16	Flat	67.5	180	2041	3671
17	Mountain	68.3	185.8	2730	5306
18	Mountain	68.4	162.6	4412	5592
19	Hilly	68.2	191.2	3296	4769
20	Mountain	67.8	202.2	4207	5830
Total Mean ± SD		67.2 ± 0.9	169 ± 42	2522 ± 1212	3569 ± 1451
Rest day mean ± SD		68.7 ± 0.4	-	423 ± 196	563 ± 4
Individual TT		66.8	7	-	1701
Flat stages mean ± SD		66.6 ± 0.9	179 ± 15	1300 ± 521	3022 ± 381
Hilly stages mean ± SD		67.0 ± 0.8	172 ± 27	2523 ± 547	4040 ± 788
Mountain stages mean ± SD		67.4 ± 0.7	179 ± 20	3337 ± 1076	4602 ± 985

Table 2. Overview of daily in race carbohydrate intake, carbohydrate per hour of racing and forms of carbohydrate consumed.

Stage	Stage type	Carbohydrate Intake (g)						g/h
		Gels Bars	Whole Foods	Drinks	Concen-trated	Drinks	Total	
1	Individual TT	-	-	-	-	-	-	-
2	Flat	66	75	96	30	0	267	63
3	Mountain	88	75	86	60	0	309	52
4	Flat	22	50	58	60	0	190	48
5	Flat	44	75	118	30	0	267	57
6	Mountain	22	75	72	30	0	199	50
7	Mountain	88	150	96	0	80	414	92
8	Flat	22	75	120	30	0	247	58
9	Mountain	66	75	120	30	160	451	82
Rest day		-	-	-	-	-	-	-
10	Hilly	44	50	120	30	160	404	82
11	Hilly	44	0	120	0	80	244	65
12	Hilly	66	50	120	60	0	296	70
13	Flat	44	100	142	0	0	286	54
14	Mountain	22	50	152	0	160	384	81
15	Mountain	22	37	96	30	0	185	41
Rest day		-	-	-	-	-	-	-
16	Flat	44	50	154	90	0	338	79
17	Mountain	22	50	152	0	80	304	55
18	Mountain	22	100	120	60	160	462	87
19	Hilly	44	75	118	90	80	407	86
20	Mountain	88	50	120	90	160	508	106
Mean ± SD		46 ± 24	66 ± 31	115 ± 26	38 ± 31	59 ± 70	324 ± 97	69 ± 18
Flat stages mean ± SD		40 ± 17	71 ± 19	115 ± 34	40 ± 31	0 ± 0	266 + 48	60 ± 11
Hilly stages mean ± SD		55 ± 11	44 ± 31	120 ± 1	45 ± 39	80 ± 65	338 ± 81	76 ± 10
Mountain stages mean ± SD		49 ± 33	74 ± 35	113 ± 28	33 ± 32	89 ± 74	357 ± 115	72 ± 23

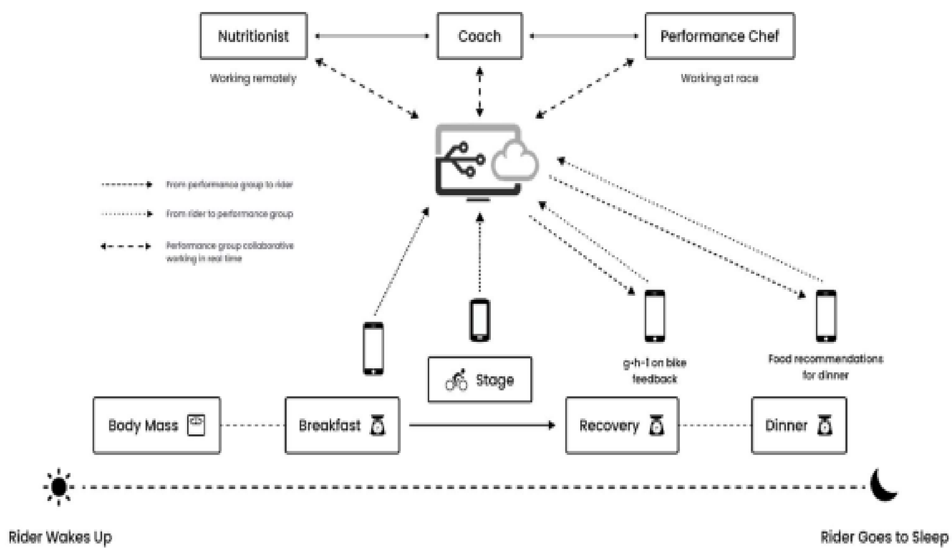
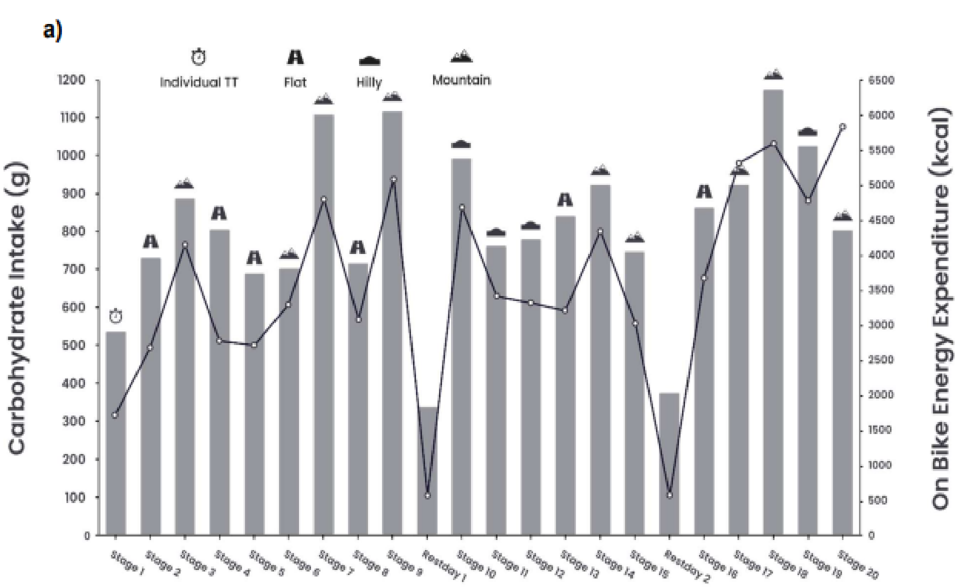


Fig. 1. **Schematic demonstrating the time course of feedback coming from the rider to the support team. The nutrition strategy was delivered via a distributed nutrition support network consisting of the performance nutritionist (remote) and performance chef (at race), with additional support from the doctor (at race) and riders coach (remote) as required.**



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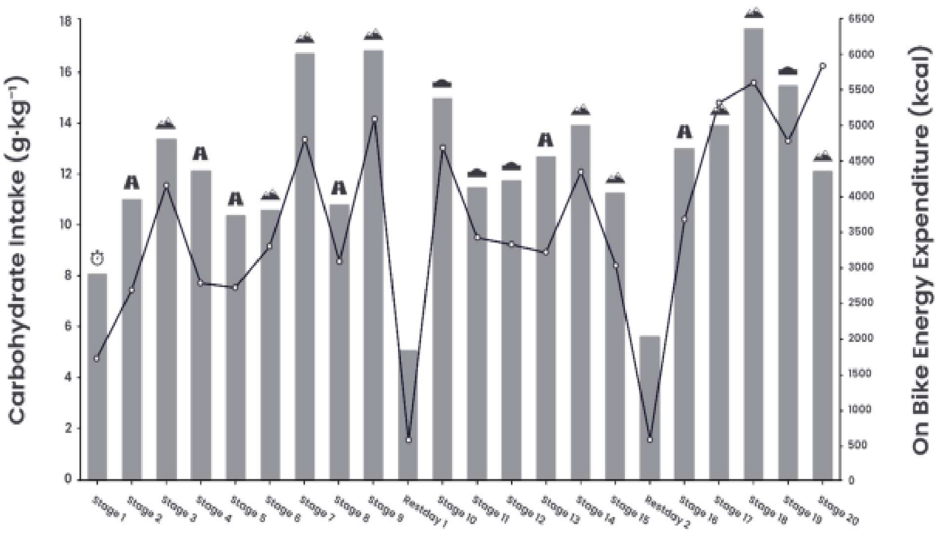
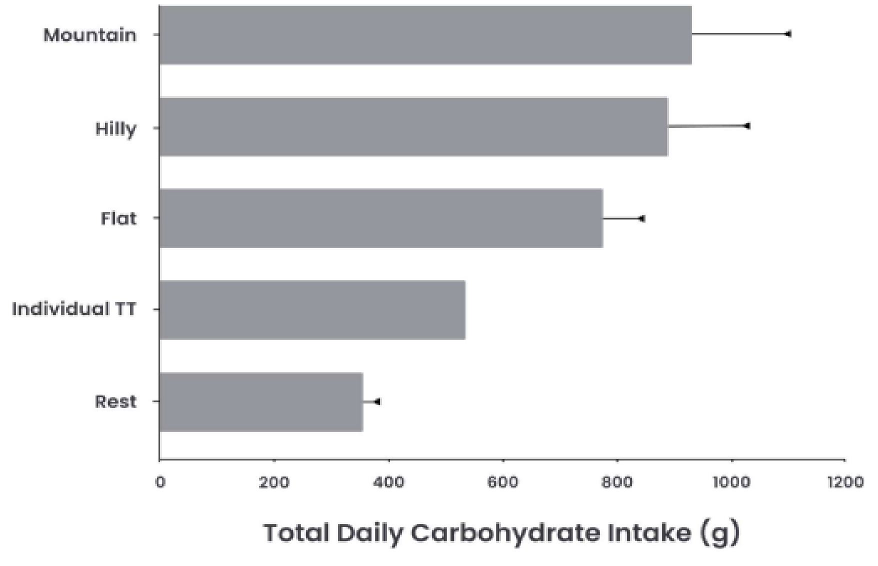

Carbohydrate Intake (g·kg⁻¹)
On Bike Energy Expenditure (kcal)
Stage 1
Stage 2
Stage 3
Stage 4
Stage 5
Stage 6
Stage 7
Stage 8
Stage 9
Restday 1
Stage 10
Stage 11
Stage 12
Stage 13
Stage 14
Stage 15
Restday 2
Stage 16
Stage 17
Stage 18
Stage 19
Stage 20

c)


Mountain
Hilly
Flat
Individual TT
Rest
0
200
400
600
800
1000
1200
Total Daily Carbohydrate Intake (g)

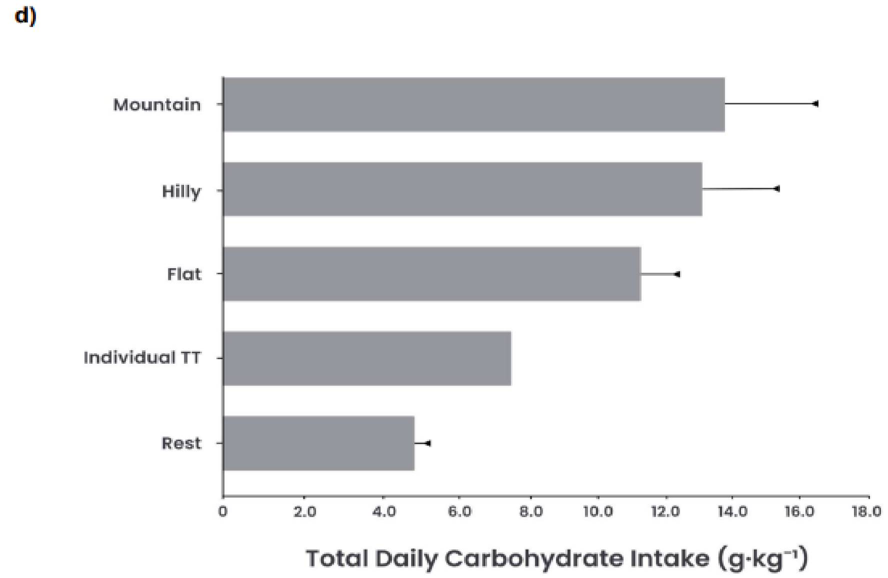
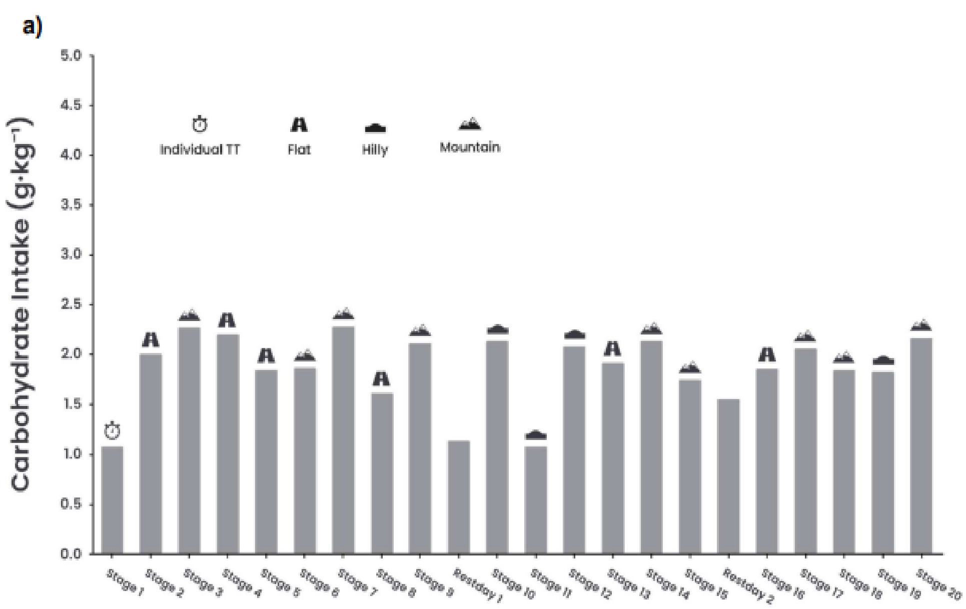


Fig. 2. **Total daily carbohydrate (CHO) intake (bars, left axis) and daily on-bike exercise energy expenditure (line, right axis) during individual stages (a) absolute and (b) relative intake of CHO. Mean and standard deviation of total daily carbohydrate intake by stage types (c) absolute and (d) relative intake. Symbols denote stage type. Stage 20's dinner was not recorded thus total intake is representative of available data for this stage.**



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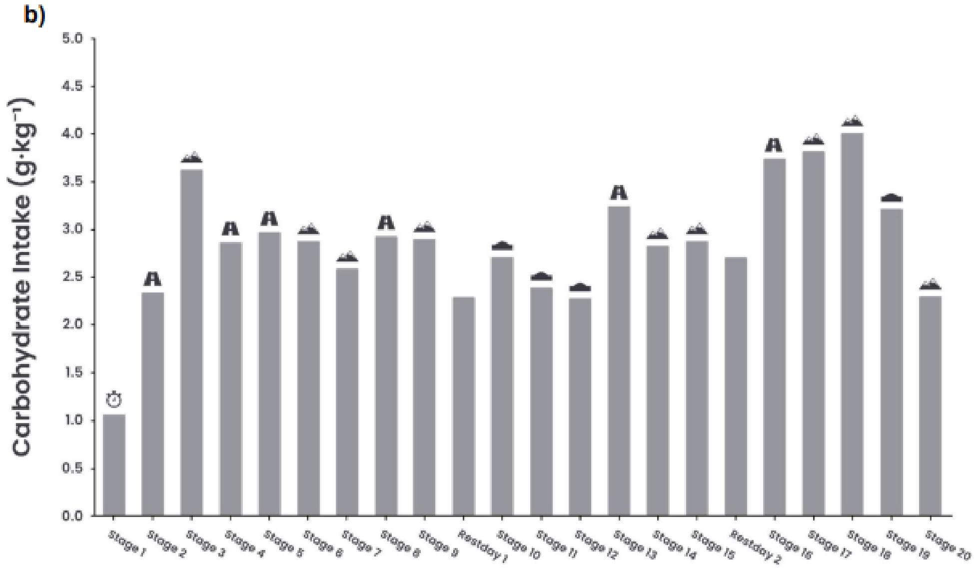
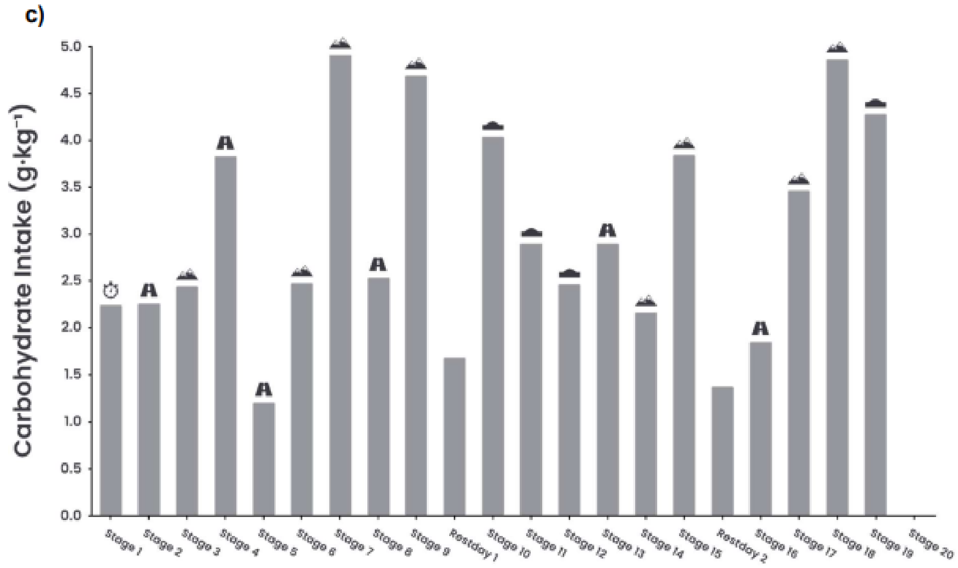

Carbohydrate Intake (g·kg⁻¹)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Stage 1
Stage 2
Stage 3
Stage 4
Stage 5
Stage 6
Stage 7
Stage 8
Stage 9
Restday 1
Stage 10
Stage 11
Stage 12
Stage 13
Stage 14
Stage 15
Restday 2
Stage 16
Stage 17
Stage 18
Stage 19
Stage 20

c)


Carbohydrate Intake (g·kg⁻¹)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Stage 1
Stage 2
Stage 3
Stage 4
Stage 5
Stage 6
Stage 7
Stage 8
Stage 9
Restday 1
Stage 10
Stage 11
Stage 12
Stage 13
Stage 14
Stage 15
Restday 2
Stage 16
Stage 17
Stage 18
Stage 19
Stage 20

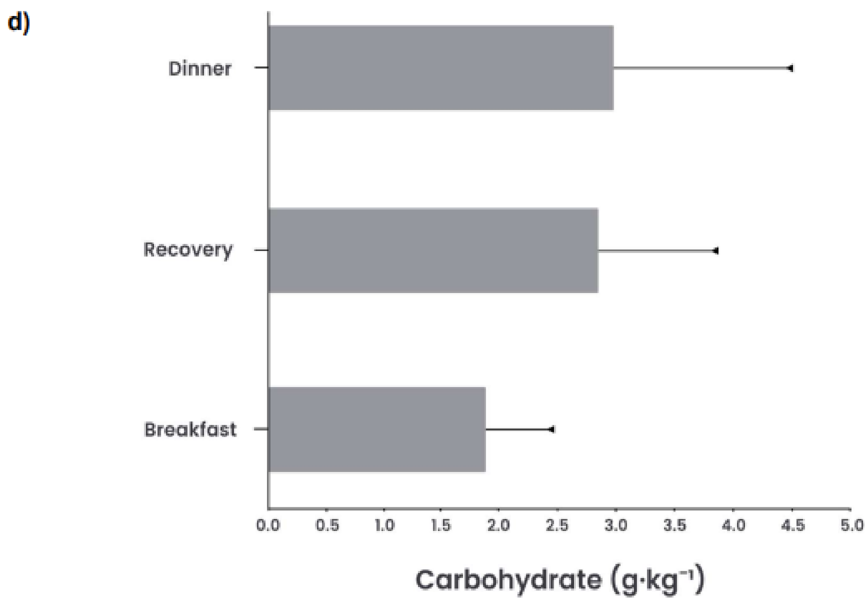
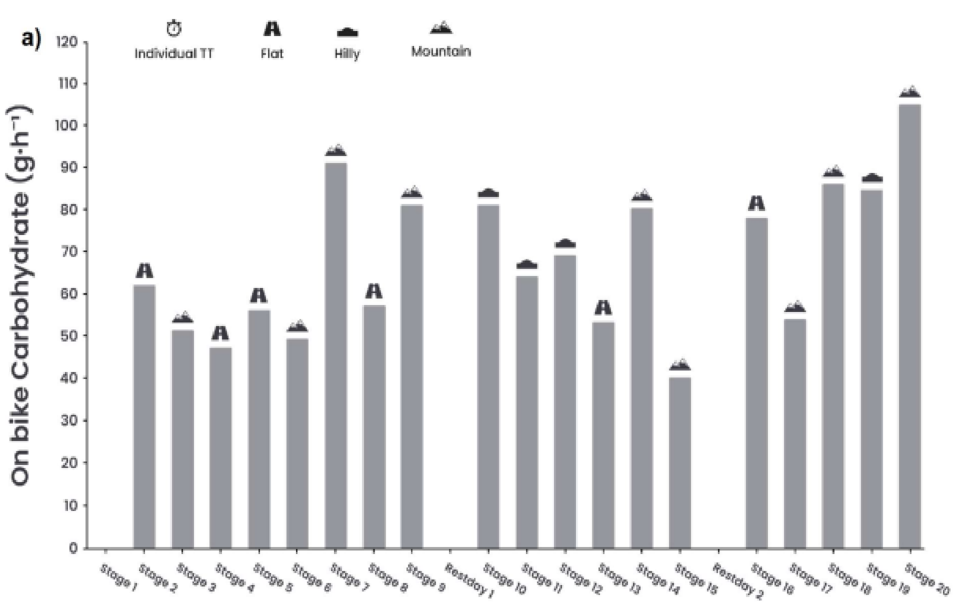


Fig. 3. **Relative carbohydrate intakes at (a) breakfast, (b) recovery and (c) dinner across each stage. Mean and standard deviation of (d) relative carbohydrate intakes at each meal. Symbols denote stage type. Stage 20's dinner was not recorded thus total intake is representative of available data for this stage.**



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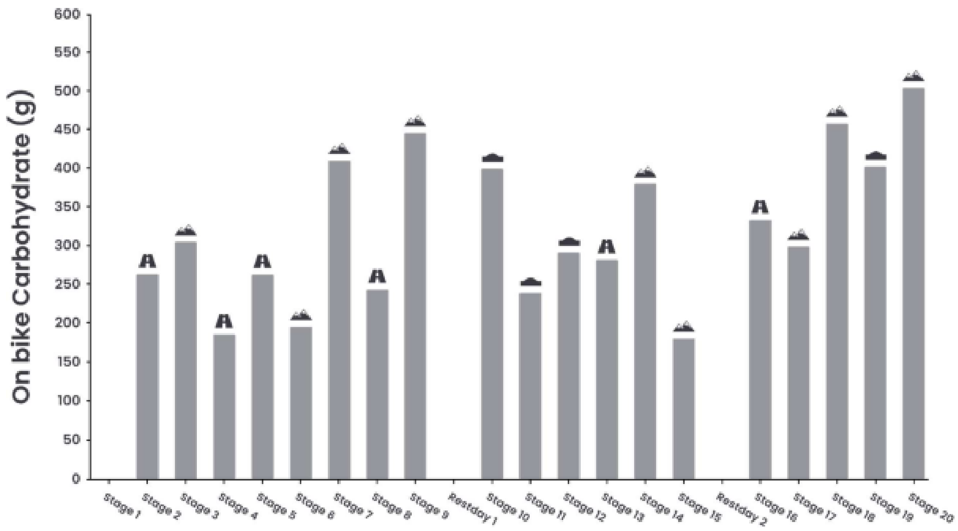
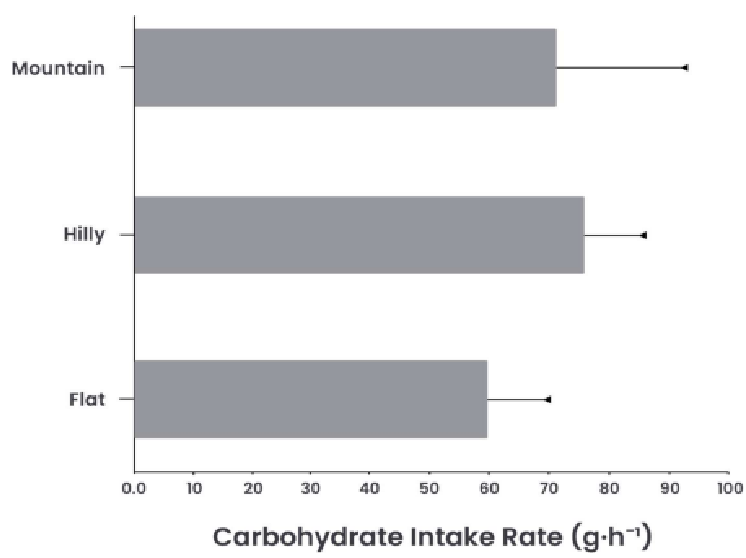

On bike Carbohydrate (g)
600
550
500
450
400
350
300
250
200
150
100
50
0
Stage 1
Stage 2
Stage 3
Stage 4
Stage 5
Stage 6
Stage 7
Stage 8
Stage 9
Restday 1
Stage 10
Stage 11
Stage 12
Stage 13
Stage 14
Stage 15
Restday 2
Stage 16
Stage 17
Stage 18
Stage 19
Stage 20

c)


Mountain
Hilly
Flat
0.0
10
20
30
40
50
60
70
80
90
100
Carbohydrate Intake Rate (g·h⁻¹)

d)

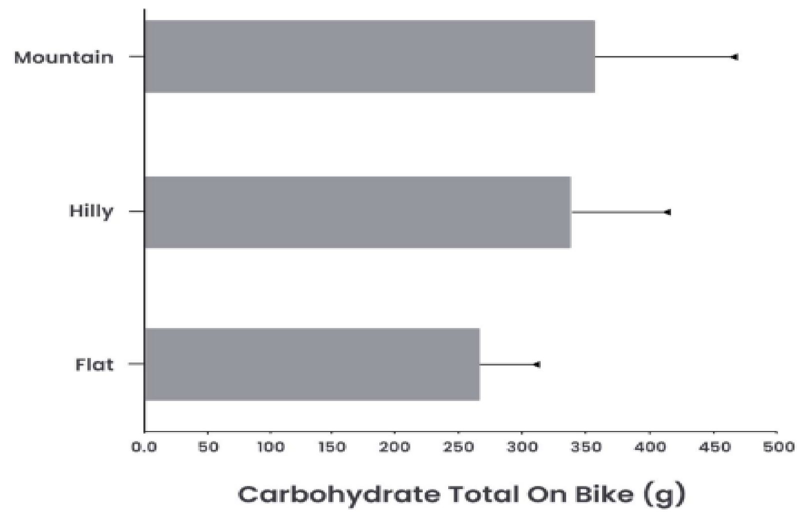


Fig. 4. On-bike carbohydrate intake across each stage (a) grams of CHO per hour of racing and (b) absolute carbohydrate intake. Mean and standard deviation of on-bike carbohydrate intake by stage types (c) grams of CHO per hour of racing and (d) absolute carbohydrate intake.

Practical Applications

- Generic recommendations of CHO in g·kg ^{1} per day do not reflect the dynamic requirements of Grand Tour racing
- Integration of athlete data allows day-to-day periodisation of nutrition
- Collaborative digital platforms can facilitate a distributed nutrition support system

Limitations

The analysis of an athlete's diet can be susceptible to errors in data collection through conscious or unconscious mechanisms (13) and recording itself can change eating behaviours (14). We attempted to mitigate these factors through extensive familiarisation with this protocol at multiple training camps and races. Given the duration of the intervention we choose to use mobile technology to improve compliance by reducing the burden of recording dietary intakes (15).

Acknowledgements

The authors wish to thank the supporting race staff at GreenEdge cycling who helped facilitate the intervention.

Conflicts of Interest

JMF, NS, MQ and DV have no competing interests to declare. DD and SI are shareholders in Applied Behaviour Systems Ltd.

Data Availability

The data set corresponding to this case study is available from the corresponding author on reasonable request.

Twitter: Niki Stroble (@nicki_strobel), Marc Fell (@marcfell1), David Dunne (@david_m_dunne), Sam Impey (@samimpey_)

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