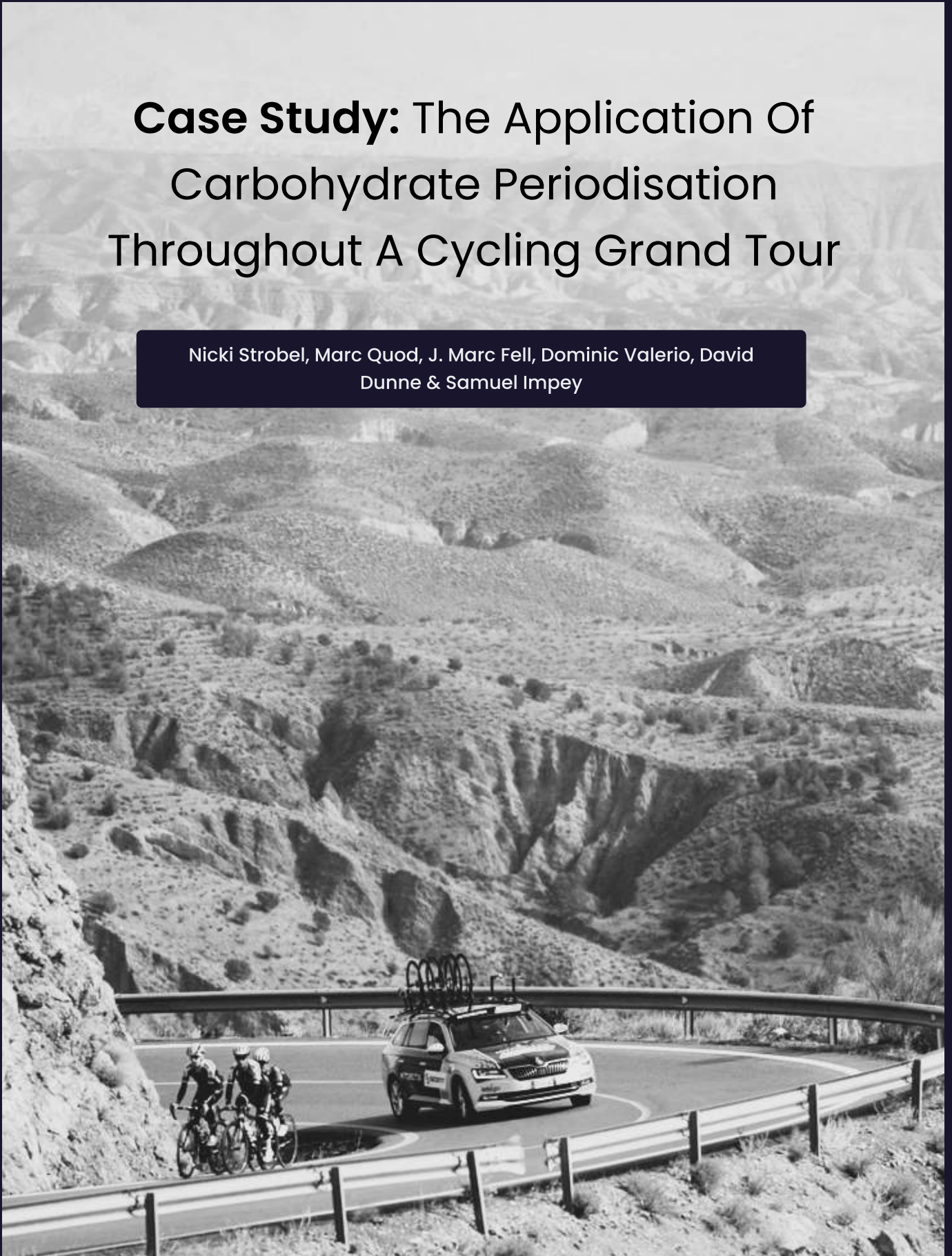


Case Study: The Application Of Carbohydrate Periodisation Throughout A Cycling Grand Tour

Nicki Strobel, Marc Quod, J. Marc Fell, Dominic Valerio, David Dunne & Samuel Impey



Abstract

The aim of this case study was to describe the meal-by-meal and day-by-day periodisation of carbohydrate (CHO) intake of a professional World Tour cyclist during the Vuelta a España. Weighed food records, on-bike exercise energy expenditure and morning body mass were collected across 20 stages of the 2021 Vuelta a España. Using a distributed nutrition support system, we provided feedback after each stage about carbohydrate consumption and provided bespoke CHO recommendations for recovery. Mean absolute daily CHO intake (range) and relative CHO intake (range) were 812 ± 215 g (340 - 1118 g) and 12.2 ± 3.2 g·kg⁻¹ (5.1 - 17.7 g·kg⁻¹) respectively. The highest CHO intake (absolute; range) occurred during dinner (197 ± 76 ; 3.0 ± 1.1 g·kg⁻¹) with lower amounts at breakfast (124 ± 24 g; 1.9 ± 0.4 g·kg⁻¹). Mean on-bike CHO intake was 69 ± 18 g·h⁻¹ (range 41 - 106 g·h⁻¹), with whole foods contributing the majority (37%) of on bike CHO. Here we demonstrate novel periodisation of CHO in take in accordance with the physical workload of each stage. These results highlight the need for greater resolution in CHO recommendations given the unique energy demands of each stage.

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Introduction

Professional road cycling is recognised as one of the most energetically demanding competitive sports. Indeed, within road cycling it is the three-week Grand Tours that are considered as the most demanding and challenging events in the racing calendar. A Grand Tour is composed of 21 stages of almost consecutive daily racing that varies in exercise intensity, duration and terrain (depending on the stage classification, i.e., flat, hilly/semi-mountainous, mountain and time trial) with only two or three rest days interspersed (Sanders & Heijboer, 2018; Van Erp et al., 2020).

The physiological demands and typical exercise intensities inherent to Grand Tour racing have been characterised through the introduction of heart rate monitors and power meters, in combination with the assessment of energy expenditure (via doubly labelled water) (Lucia et al., 2003; Padilla et al., 2001; Padilla et al., 2008; Plasqui et al., 2019; Sanders & Heijboer, 2018; Saris et al., 1989; Van Erp et al., 2020; Vogt et al., 2007a; Vogt et al., 2007b). Indeed, it is now recognised that Grand Tour stages (except for time trials) incorporate daily racing durations of 4 – 6 hours, encompassing daily distances ranging from approximately 110 – 225 km, with on-bike exercise energy expenditure (EEE) ranging from 3000 – 5000 kJ (Plasqui et al., 2019; Muros et al., 2019; Van Erp et al., 2020). Such workloads during the race typically result in total daily energy expenditures equating to 7400 to 8365 kcal (31 to 35 MJ) (Plasqui et al., 2019). In addition, the specific physiological requirements of different mass start stage types within a Grand Tour have also recently been highlighted by Sanders and Heijboer (2019) who reported that mountain stages were found to be the most demanding for both intensity and overall load followed by semi-mountainous and flat stages (Sanders & Heijboer, 2019). Although the main proportion of time spent during mass start stages is at low intensity (zone 1), mountain stages were found to involve longer duration maximal mean power outputs (> 10 min) in comparison to flat and semi-mountainous stages that were found to involve higher short-duration maximal mean power outputs (5 – 30 s for flat, 30 s – 2 min for hilly) (Sanders & Heijboer, 2019). Furthermore, Van Erp et al. (2020) also recently documented that the race winning moments that occur on mountain stages during a Grand Tour typically comprise of 30-minute high-intensity efforts above threshold (i.e., average power outputs >400 W equating to 6.0 W·kg⁻¹ for a 70 kg rider) (Van Erp et al., 2020).

Given the large daily energy requirements to compete in Grand Tours, current nutritional strategies would suggest that high intakes of daily energy and carbohydrates (CHO) are required throughout the event to support race intensities and critical race moments, that are highly CHO dependent (Burke et al., 2011; Hawley & Leckey, 2015). However, a detailed understanding of professional riders' daily CHO intake throughout a Grand Tour is lacking in the current literature. Previous observations have reported daily CHO intakes of 12.6 ± 1.1 g·kg⁻¹ when dietary assessment was conducted on 3 separate 24-h periods (1 flat stage (day 2, 178 km) and 2 mountain stages (day 14, 174 km; day 16, 148 km) during the Vuelta a España (García-Rovés et al., 1998). In more recent observations, Muros et al. (2019) also reported a similar average daily CHO intake of 12.5 ± 1.8 g·kg⁻¹ during the 2015 Vuelta a España when quantified from dietary assessment conducted each day throughout the entirety of the race. Such intakes have therefore been found to be slightly higher than the current sport nutrition recommendations of 8 – 12 g·kg⁻¹ of CHO per day for long duration moderate to high intensity exercise (Thomas et al., 2016).

Whilst such studies provide interesting insights as to habitual feeding strategies, they are limited in that they do not provide the within and between day variation of CHO intake. This information is especially important given the large variations in reported on-bike EEE (individual time trial: 1089 ± 148 kcal, flat: 3170 ± 758 kcal, mid-mountain: 3677 ± 736 kcal and mountain: 4707 ± 772 kcal; Muros et al., 2019) and physiological requirements resulting from different stage types (Sanders & Heijboer, 2019). In this regard, the ability to align CHO intake to the demands of different stage types allows practitioners to better formulate stage specific and individualised nutritional strategies that attempt to achieve the intricate balance between promoting fuelling and recovery whilst also maintaining or improving a rider's power to weight ratio where appropriate. Whilst this concept of carbohydrate periodisation has been communicated for training scenarios according to the "fuel for the work required" concept (Impey et al., 2018), it is yet to be documented in the literature if such a periodised strategy could be implemented in competitive Grand Tour racing scenarios. Thus, the aim of this case report was to document the quantification of daily on-bike EEE and the delivery of a daily periodised CHO feeding strategy for a male professional World Tour road cyclist during the 2021 Vuelta a España. This case study describes this process in detail from Stage 1–20 of the Grand Tour.

Methods

Presentation of athlete and overview of sporting history.

The male athlete was 26 years old at the time of data collection and had been competing at the UCI World Tour level for the previous 6 years. The athlete's role within the team at Vuelta a España 2021 was as a domestique with a focus on supporting the team's general classification leader during hilly and mountain stages. The athlete was competing in his 6th Grand Tour, and his 5th Vuelta a España. The athlete provided informed written consent for the publication of these data.

Overview of the Vuelta a España 2021.

The race totalled 3,417 km and occurred between 19th August and 11th September, comprising 21 racing stages and two rest days. The race had two individual time trials (Total 40.9 km), six "flat" stages (Total 1074.0 km), four "hilly" stages (Total = 688.8 km) and nine "mountain" stages (Total 1614.9 km) as classified by the official Vuelta a España website. An overview of the individual stage characteristics is presented in Table 1.

Body mass measurement.

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

On bike exercise energy expenditure.

Daily on bike energy expenditure 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). The riders gross efficiency of 21.7% was used to calculate on-bike kcal from power data.

Analysis of nutrient intake and energy expenditure.

Food labels were used to calculate the carbohydrate content of foods available at meals. As all food was prepared by the team's performance chef, a comprehensive database of foods with brand specific CHO content was developed to identify total CHO intake. Where foods were cooked in water (i.e., pasta, rice, polenta etc...) the cooked weight was tested and a dry weight to cooked weight conversion was used to calculate the CHO content in the cooked food weighed by the rider at meals. Race foods were produced by the soigneurs using specific recipes to deliver predetermined amounts of CHO per unit of food. Sports foods and drinks labels were used to record CHO content of each product.

Carbohydrate periodisation structure.

The rider completed a weighed food diary for all foods at breakfast, all foods/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 by photographing all the foods taken at the start of each stage by the remote food photographic method (RFPM) (Martin et al., 2009) and reporting any additions/changes immediately post stage. The recovery meal eaten after each stage was weighed and pre-packed by the chef at the race and the rider would weigh any food that was not consumed or weigh and report any additional foods eaten during the recovery period. This information was shared via a mobile app (Whatsapp, California, USA) in as close to real time as possible with the nutrition team.



Using the physiological data recorded during the stage, the nutrition team would then provide feedback on the CHO intake during the stage and provide subsequent recommendations for the amounts of CHO containing foods the rider should consume at dinner that evening. Recommendations were based on the total CHO intake up to and including the post-stage recovery meal, with consideration for the physical workload of the following stage. The rider would then record food weights at dinner and share the information to complete the day's food record (Figure 1). All meals (breakfast and dinner) and recovery meals were prepared by the team chef, with menus pre planned before the race. Any alterations to menus because of ingredient availability was documented by the chef during the stage and alternative ingredients and brands were added to the food database. Breakfast and dinner operated as buffet self-service, with individual foods in individual heaters/containers enabling riders to capture individual food weights. Race foods were prepared by soigneurs 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, respectively.

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. While all food weights were recorded, the focus of the nutrition support for the rider presented here was on achieving sufficient CHO intake to facilitate appropriate fuelling before, during and in recovery from each stage, to periodise the CHO intake in line with the individual stage demands. The intake of protein and fat was recorded but is not reported here given the focus on accurately documenting CHO intake across each phase of the racing day and 3 weeks of stage racing. The athlete was experienced and familiar with the process through prior use at training camps and previous stage races. Data for dinner on stage 20 was not recorded and foods throughout stage 21 were not recorded by the rider and thus data for these points is not reported.

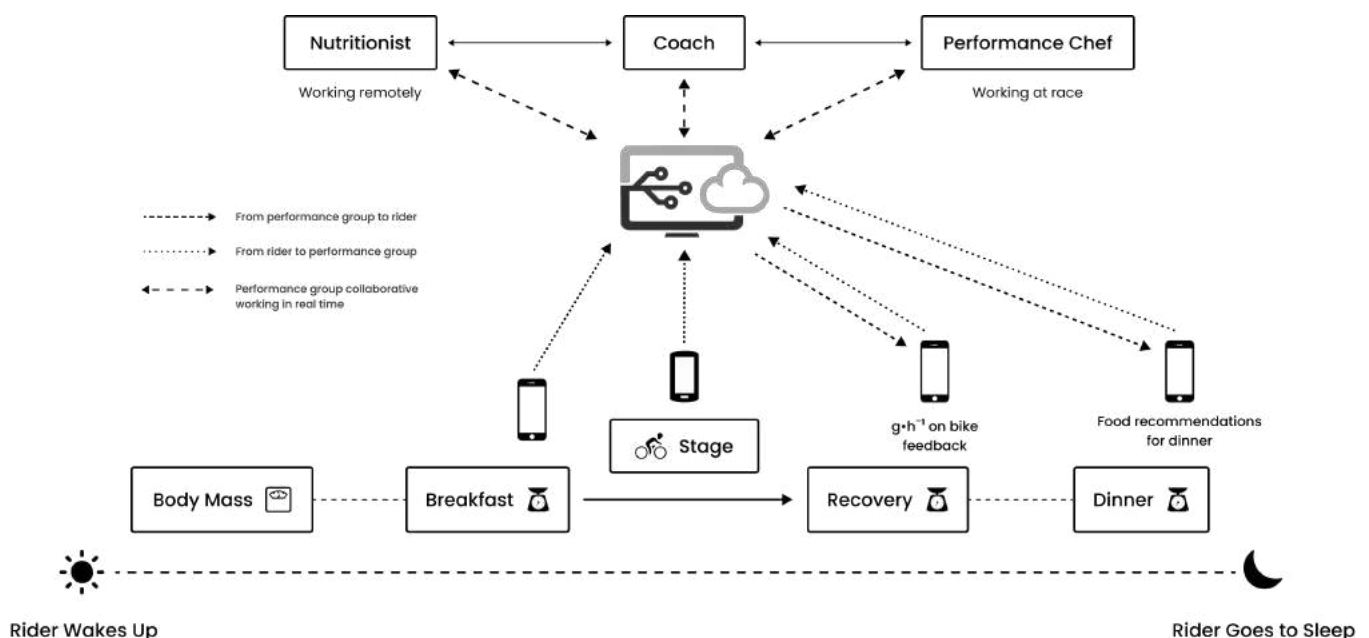


Figure 1. Schematic demonstrating the time course of feedback coming from the rider to the support team. Recommendations for the rider would be generated by either remote or on-site using cloud based collaborative software and delivered to the rider before dinner.

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. Specifically, the mean absolute and relative CHO intake was greatest on mountain stages followed by hilly stages, flat stages and then the individual time trial (ITT) day (Figure 2). Additionally, the mean rest day absolute and relative CHO intake was considerably lower than all racing days (see Figure 2).

Assessment of carbohydrate distribution across meals

The rider consumed the greatest amounts of CHO at dinner (197 ± 76 g), then post-stage recovery (189 ± 43 g) and the least 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 during exercise

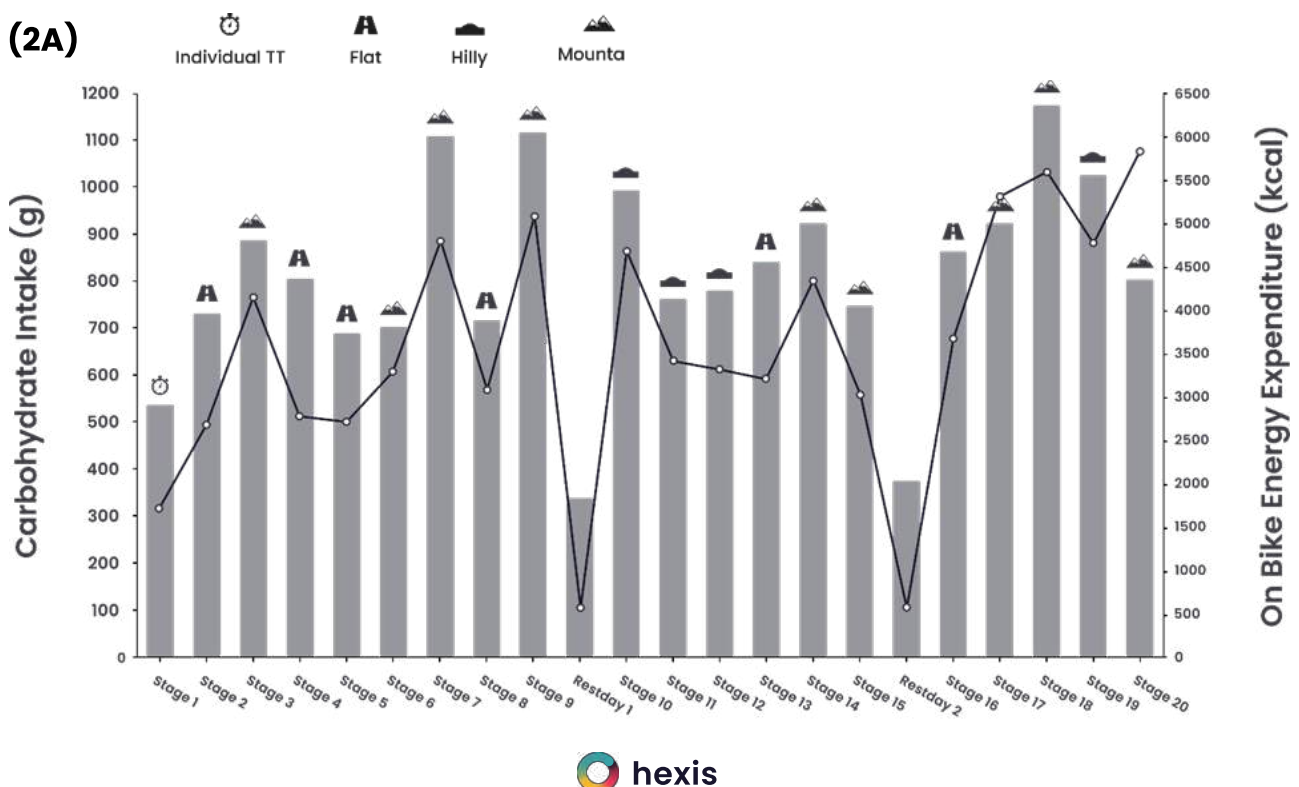
The mean intake of CHO, and the form of delivery during each stage is presented in Table 2. Total CHO intake ranged from 185 - 508 g which equated to an hourly CHO intake range of 41 - 106 g·h⁻¹ (see Figure 4a and 4b). The greatest contribution of CHO on-bike came from whole foods ($37 \pm 10\%$) then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

Assessment of on-bike energy expenditure

The individual stages on-bike EEE is presented in Table 1. Mean on-bike EEE per stage was 3569 ± 1451 kcal (range: 560 - 5830 kcal), mean on-bike EEE between different stage types is also reported in Table 1.

Assessment of daily body mass

Morning fasted voided body mass for stages 1 - 20 is displayed in Table 1. From Stage 1 to Stage 20 the rider had a 1 kg increase in body mass (66.8 to 67.8 kg). Body mass fluctuated in the range of 65.0 - 69.0kg throughout the race.



(2B)

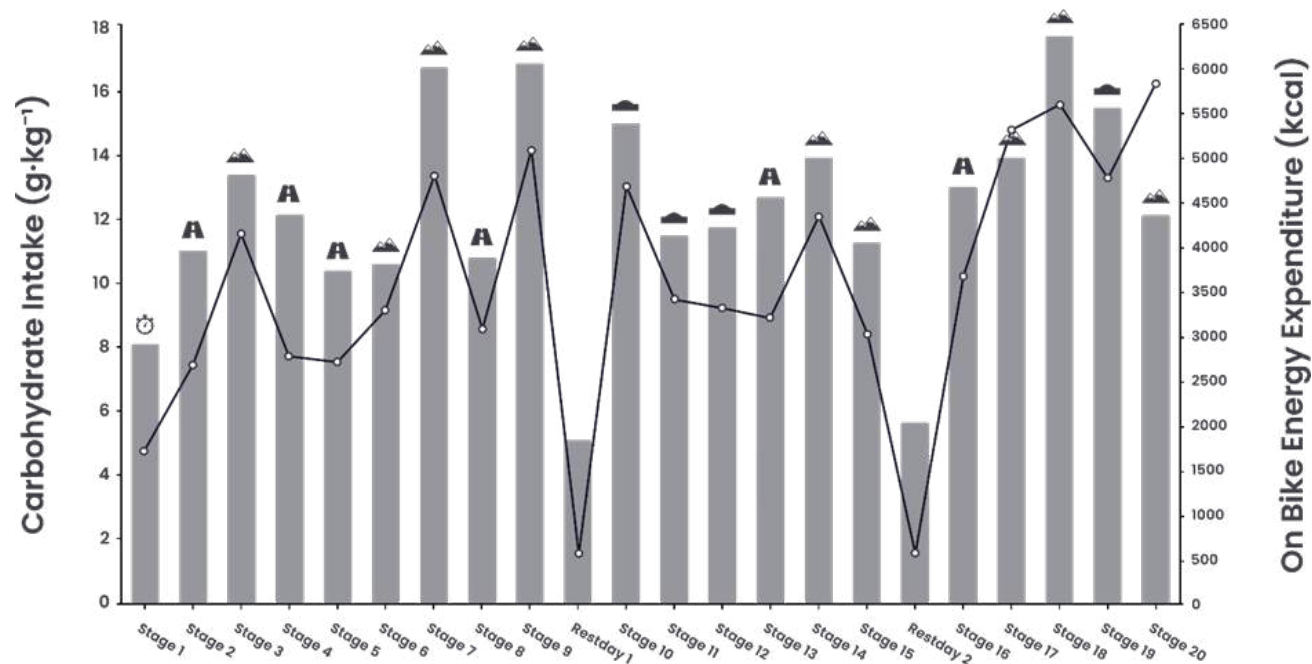
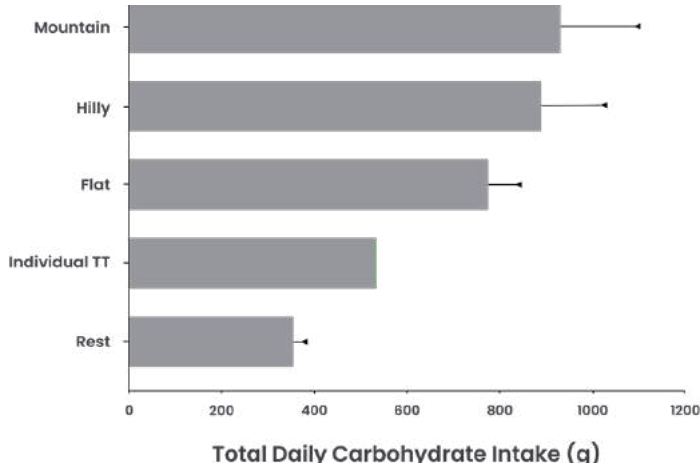
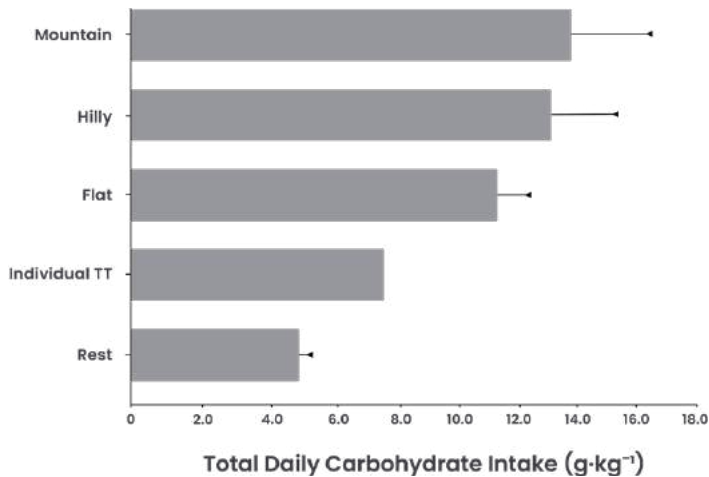


Figure 2. Total daily carbohydrate intake during individual stages (a) absolute and (b) relative intake. Mean and standard deviation of total daily carbohydrate intake by stage types (c) absolute and (d) relative intake. Symbols denote stage type. Stage 20's dinner was not recorded thus total intake is representative of available data for this stage.

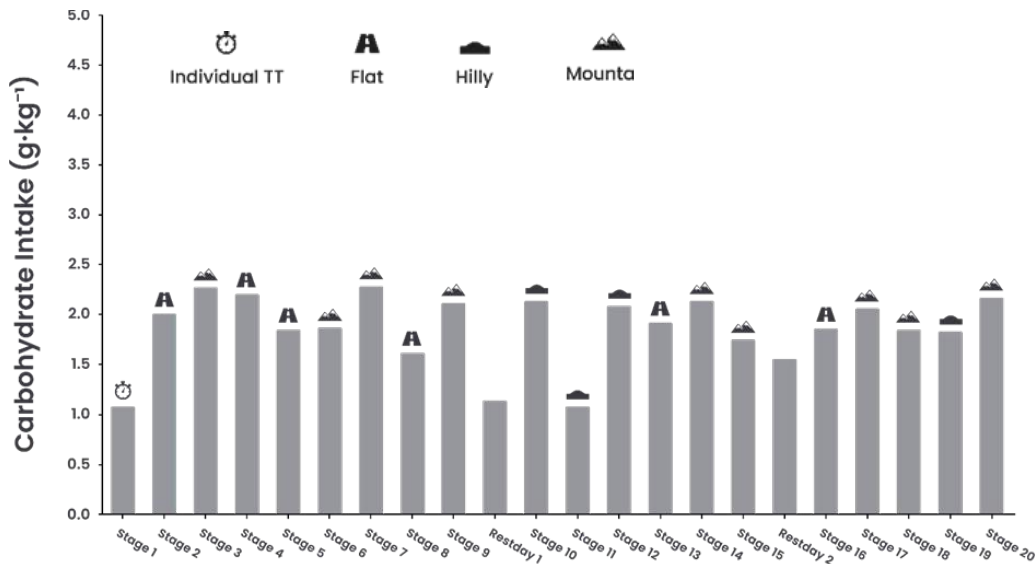
(2C)



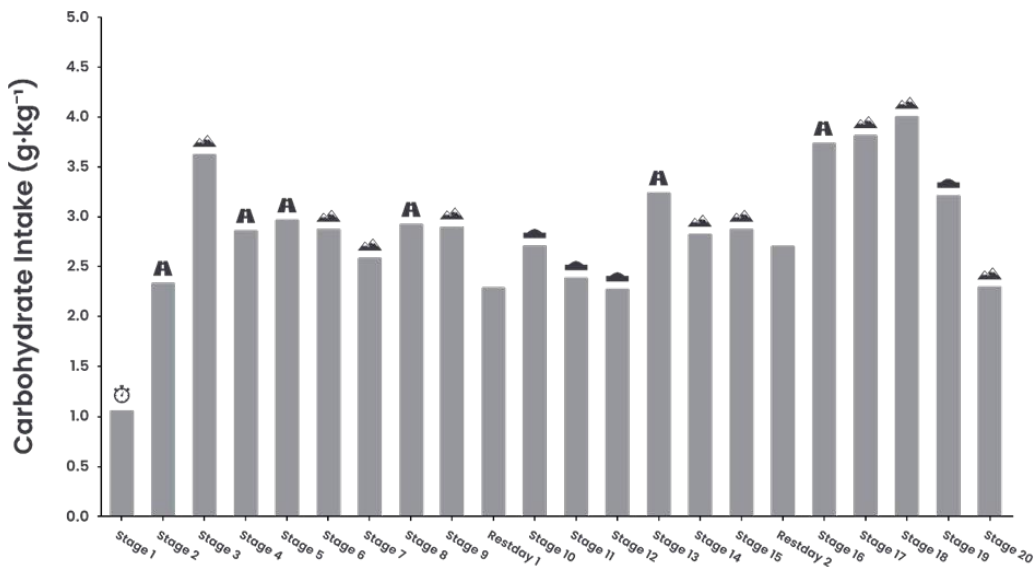
(2D)



(3A)



(3B)

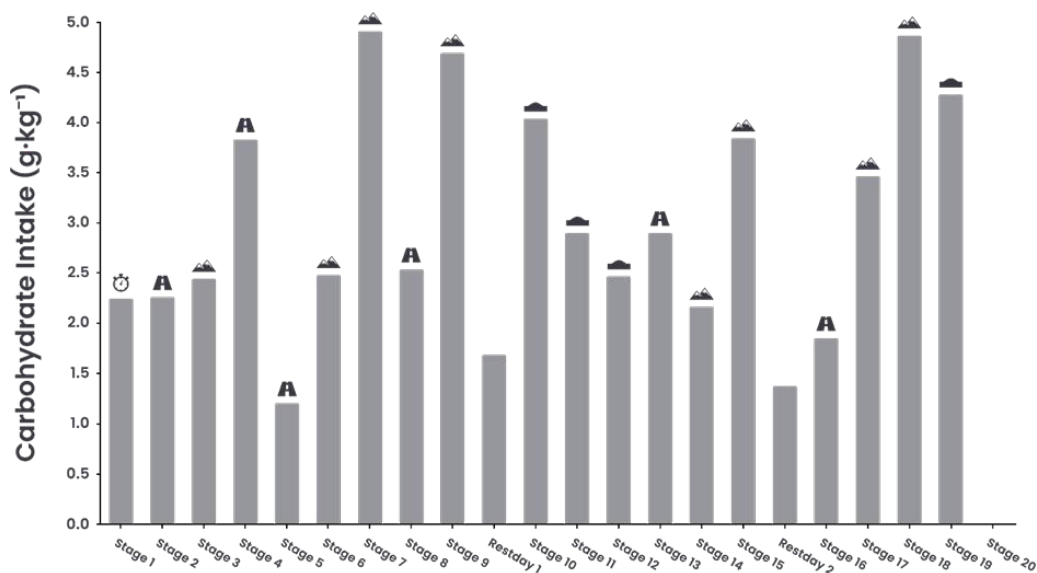


Dicussion

The aim of this case report was to quantify the within and between day variation of CHO intake and outline the delivery of a practical approach to daily CHO periodisation for a male professional UCI World Tour road cyclist during the Vuelta a España. This is the first report to detail the distribution of CHO intake on a meal-by-meal and stage-by stage basis for a professional rider during a Grand Tour. In this regard, 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 further highlights the application of a periodised approach to CHO intake during a Grand Tour in accordance with the daily physical demands associated with each stage.

Here we report a similar mean daily CHO intake to that previously reported in Grand Tours (~12.6 g·kg⁻¹) (García-Rovés et al., 1998; Muros et al., 2019; Saris et al., 1989), however we provide novel data on the range of daily CHO intake across stages, 5.1 – 17.7 g·kg⁻¹ (Figure 2.). The present data in combination with the previous studies suggest that the reported mean daily CHO intakes during Grand Tours represent the upper boundaries of contemporary sport nutrition guidelines of 8 to 12 g·kg⁻¹ to support 4 – 5 h of moderate-to-high intensity exercise (Thomas et al., 2016). However, one of the major shortcomings of reporting only the mean daily CHO intake is that it fails to identify the potential significant day-by-day variation in CHO intake in accordance with the different physical and physiological demands associated with different stage types (Sanders & Heijboer, 2019; Van Erp et al., 2020).

(3C)



(3D)

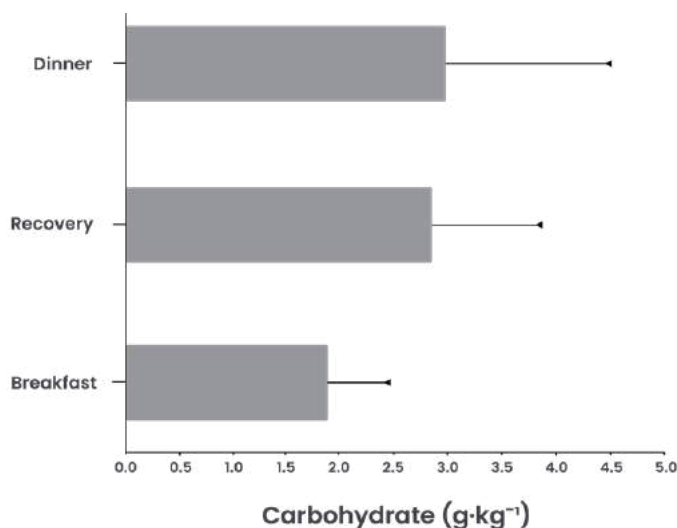


Figure 3. Relative carbohydrate intakes at (A) breakfast, (B) recovery and (C) dinner across each stage. Mean and standard deviation of (D) relative carbohydrate intakes at each meal. Symbols denote stage type. Stage 20's dinner was not recorded thus total intake is representative of available data for this stage.

While a general focus for Grand Tour nutrition is to provide high daily intakes of CHO, here we present a periodised approach designed to promote the individual performance of the rider by providing sufficient CHO intake to promote performance but also balancing CHO and energy intake to maintain an optimal body mass throughout the duration of the race. The latter was especially important for this rider given that their individual role within the team was to support the General Classification rider during hilly and mountain stages. Thus, a key performance determinant for this rider was ensuring a high relative power ($\text{W}\cdot\text{kg}^{-1}$) to promote climbing performance when required (Mujika & Padilla, 2001; Olds et al., 1995; Van Erp et al., 2020).

The periodised approach was implemented to achieve this 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) but increased on more physically demanding and higher energetic stages such as hilly (4040 ± 788 kcal) and mountain (4602 ± 985 kcal) stages. In this regard, the lowest daily CHO intakes typically occurred on rest days followed by flat stages, with higher intakes for hilly and mountain 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. Stage 18 was underpinned by 1.9 $\text{g}\cdot\text{kg}^{-1}$ CHO (123 g) at breakfast, 87 $\text{g}\cdot\text{h}^{-1}$ of CHO when on the bike (462 g), 4.0 $\text{g}\cdot\text{kg}^{-1}$ CHO (267 g) in the immediate post stage recovery and 4.9 $\text{g}\cdot\text{kg}^{-1}$ CHO (323 g) at dinner.

In this way, the rider fuelled to the upper recommendations of ~ 90 g·h⁻¹ of CHO when on the bike in attempts to promote performance (Cermak & van Loon, 2013; Fell et al., 2021; Stellingwerff & Cox, 2014) whilst then aiming to optimise recovery in preparation for the following stage by consuming ~ 1.5 g·kg⁻¹ CHO per hour for two – three hours immediately following the stage with a considerable amount of CHO then consumed at dinner. Collectively this strategy provided 8.9 g·kg⁻¹ CHO over a 5 – 6-hour period post stage which can be considered conducive to maximal glycogen storage (Burke et al., 1997; Thomas et al., 2016), which was especially relevant given that Stage 19 was anticipated to be another physically demanding hilly stage (on-bike EEE: 4769 kcal). Although such extremely high CHO intakes are considered greater than the contemporary sport nutrition recommendations, such high daily CHO intakes support the on-bike EEE required during specific, but not all stages. Such intakes are also in line with a recently published report by BBC Sport (Fordyce, 2018) that described a CHO intake of 18.9 g·kg⁻¹ CHO for a professional cyclist during a mountain stage of the 2018 Giro d'Italia that resulted in an on-bike EEE value of 6180 kJ. Moreover, this report further outlined the concept of CHO periodisation approach whereby a CHO intake of 5.8 g·kg⁻¹ CHO was also described for the same rider for a significantly lower energetic hilly stage (3635 kJ). In addition, we present novel data outlining the formulation of in-race CHO intake (Table 2), despite on-bike CHO intake reported here (69 ± 18 g·h⁻¹) being lower than the average of 90.8 ± 15.0 g·h⁻¹ and ~ 94 g·h⁻¹ reported in previous Grand Tours by Muros et al. (2019) and Saris et al. (1989), these data add resolution in describing how these average CHO (g·h⁻¹) values are practically achieved. Our data show whole foods contributed the greatest percentage to total on-bike CHO intake, followed by CHO bars and then CHO gels and drinks. Research has demonstrated little difference in exogenous CHO oxidation rates (albeit in fluid matched conditions) between the bars, gels, and drinks (Pfeiffer et al., 2010a; Pfeiffer et al., 2010b). Interestingly, the contribution of CHO forms was similar across all stage classifications, a key differentiator to increasing CHO delivery where required was the use of concentrated multi-source CHO drinks (~ 90 g CHO per 500ml) during both hilly and mountain stages.

The strategic approach of incorporating highly concentrated CHO drinks during hilly and mountain stages was utilised given the reduced opportunities to feed solid foods during parts of the parcours in these stage types. The strategic use of these drinks aligned with the stages predicted to have increased periods of higher exercising intensities and energy requirements for this rider, for example in preparation for and during the critical moments within hilly and mountain stages. By incorporating highly concentrated CHO drinks the rider could access an easy and efficient solution to promoting higher CHO intake during such scenarios. The within-day distribution of CHO intake (excluding in-race CHO intake) revealed that the greatest CHO intakes were typically observed during dinner and the post-stage recovery period compared with breakfast (Figure 3.). This is in contrast to Muros et al. (2019) who found riders to consume most of their daily CHO at breakfast (199 ± 43 g) and different to García-Rovés et al. (1998) 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; thus, it is difficult to extract an “optimal” feeding pattern in relation to Grand Tour performance. Our novel data demonstrate large variations between meal types across stages in relation to the strategic periodised approach recommended by the nutrition team to the rider. For example, 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) depending on the physical demands of the current stage undertaken and the anticipated physical demands of the next stage. For example, CHO intake at dinner during less demanding stages such as stage 2, 6, 12 and 13 (on-bike EEE $\sim 2600 - 3300$ kcal) ranged from $2.3 - 2.9$ g·kg⁻¹, in comparison stages 17 – 20 (on-bike EEE $\sim 4750 - 5850$ kcal) CHO intake ranged from $3.5 - 4.9$ g·kg⁻¹ at dinner. The higher CHO intakes recommended and subsequently ingested by the rider during stages with greater energy expenditure highlight the magnitude of periodisation of the fuelling requirements during a Grand Tour.



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.

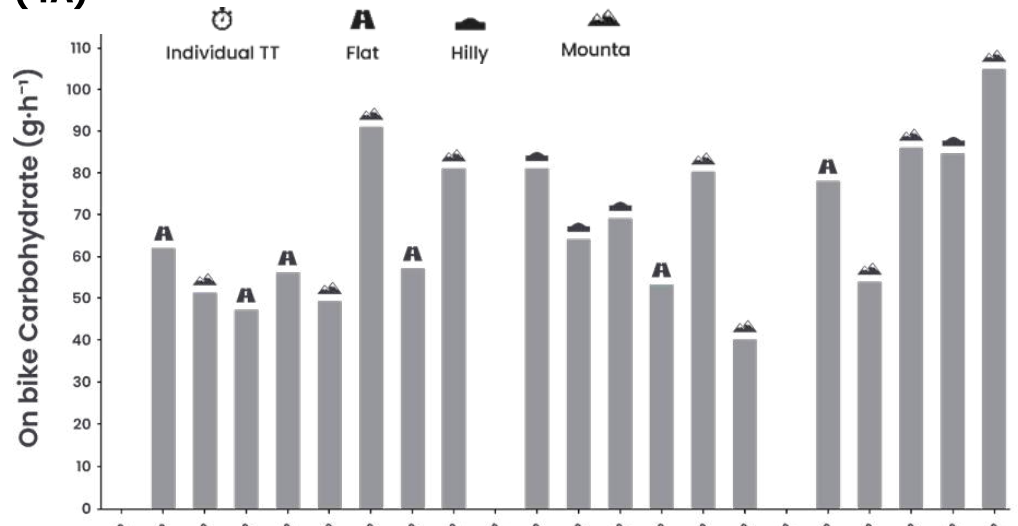
Stage	Stage type	Body Mass (kg)	Distance (km)	Elevation (m)	On-bike EEE (kJ)
1	Individual TT	66.8	7.1	93	1701
2	Flat	66.3	166.7	1019	2681
3	Mountain	66.8	202.8	2771	4150
4	Flat	65.0	163.9	1532	2780
5	Flat	67.3	184.4	671	2715
6	Mountain	66.8	158.3	1002	3293
7	Mountain	66.9	152	3567	4800
8	Flat	66.4	173.7	897	3083
9	Mountain	66.8	188	4349	5086
Rest day		68.4	20.1	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	24.7	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 \pm SD		67.2 \pm 0.9	169 \pm 42	2522 \pm 1212	3569 \pm 1451
Rest day mean \pm SD		68.7 \pm 0.4	22.4	423 \pm 196	563 \pm 4
Individual TT		66.8	7.1	93	1701
Flat stages mean \pm SD		66.6 \pm 0.9	179 \pm 15	1300 \pm 521	3022 \pm 381
Hilly stages mean \pm SD		67.0 \pm 0.8	172 \pm 27	2523 \pm 547	4040 \pm 788
Mountain stages mean \pm SD		67.4 \pm 0.7	179 \pm 20	3337 \pm 1076	4602 \pm 985

Challenges and Limitations

A primary challenge of this intervention was the ability to deliver bespoke nutrition recommendations in a time sensitive and dynamic racing environment. This was achieved through the structure of the nutrition team supporting the rider, as well as leveraging digital technologies to enhance the efficiency of the analysis and feedback loops. Delivering feedback about in-race fuelling in the immediate hours after each stage provides significantly greater contextual information to the rider (Lave and Wenger, 1980) and allows any changes and improvements to be made in accordance with the demands of upcoming stages. To provide feedback in a timely manner, the use of collaborative cloud-based systems removes the dependency of a single practitioner to collate the information and generate feedback.

The use of collaborative digital platforms allows the cognitive load to be shared between practitioners, with the identification of the foods available at dinner, and the calculation of bespoke recommendations based on the preferences of the individual rider. Maintaining a verbal (chef on site) and digital (distributed support) dialogue between the nutrition team and rider also provides the opportunity for the rider to ask questions about protocols and seek validation about recommendations. Having onsite support remains an essential part of nutrition provision to capture any nuance or details that can be missed with only digital communication; but using a distributed support system enables practitioners 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 (Jonvic et al. 2022).

(4A)



(4B)

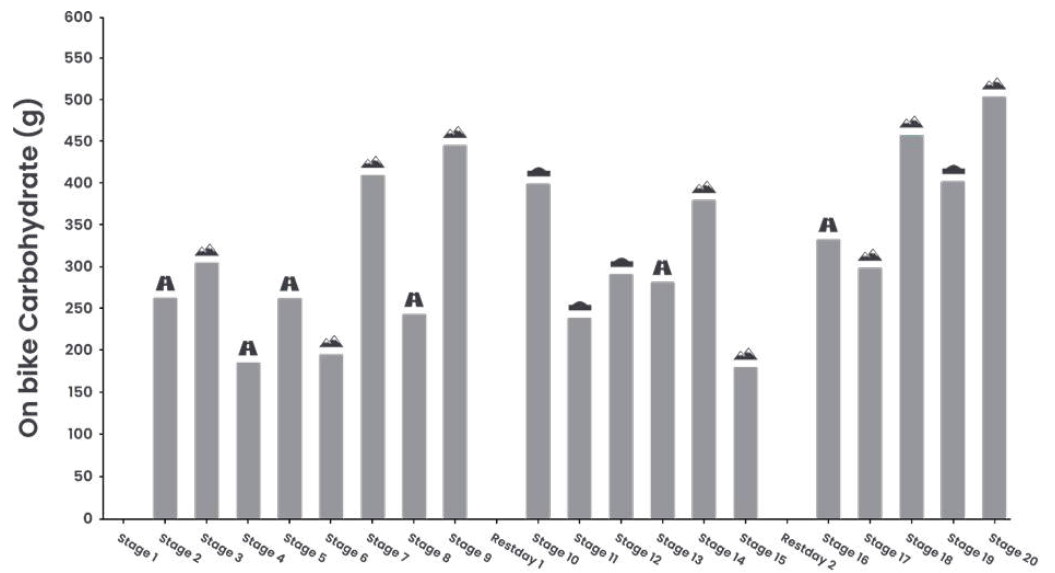
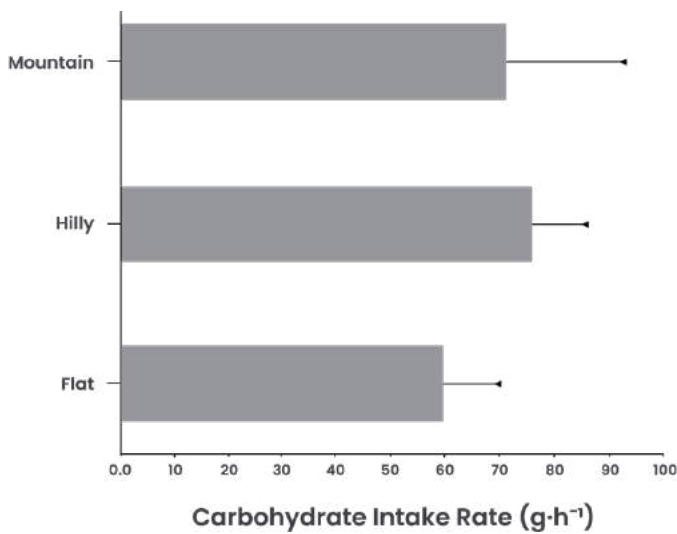
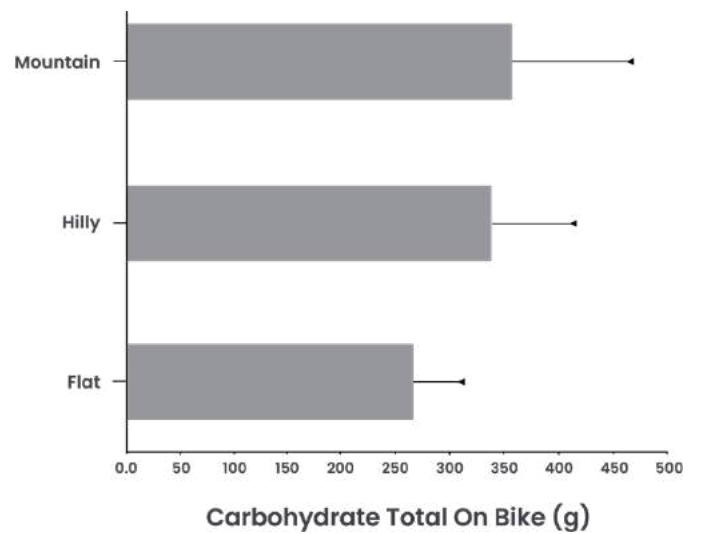


Figure 4. On-bike carbohydrate intake across each stage (A) grams of CHO per hour of racing and (B) absolute carbohydrate intake. Mean and standard deviation of on-bike carbohydrate intake by stage types (C) grams of CHO per hour of racing and (D) absolute carbohydrate intake.

(4C)



(4D)



Stage	Stage type	Carbohydrate Intake (g)					Total	g/h
		Gels	Bars	Whole Foods	Drinks	Concentrated Drinks		
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

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

The analysis of an athlete's diet can be susceptible to errors in data collection through conscious or unconscious exclusion of foods, motivation and fatigue from long durations of recording (Capling et al., 2017) and recording itself changing eating behaviours (Magkos and Yannakoulia, 2003). We attempted to mitigate these factors through prior use of this protocol with the rider at multiple training camps and races, to ensure familiarity with the requirements and accuracy of food weighing. Further this intervention was offered as an "opt in" support mechanism to riders, under which they were free to engage with the support at a frequency and intensity that suited their individual needs, thus the motivation to provide accurate consistent data was internally driven by the athlete. The effect of fatigue can be seen here where the rider chose not to weigh food at all points during the final stage, and we cannot rule out unconscious errors from the rider.

Given the duration of the intervention we choose to use mobile technology to improve compliance by reducing the burden of recording dietary intakes (Capling et al., 2017). A significant issue surrounding diet analysis in athletes is often the number of days over which the diet is assessed to capture habitual practices owing to the day-to-day variation of intake and total energy expenditure in athletes (Hill and Davies, 2001). By capturing 20 of the 21 days of the race we are able to highlight the significant changes between days (e.g., mountain vs rest) and minimise the risk of not capturing the dietary practices in sufficient detail. Caution should be taken when interpreting the individual meal compositions presented here given that they represent the individual preferences of one rider and thus may not be generalisable to cycling per se.

Conclusions

Here we demonstrate the meal-by-meal and day-by-day periodisation of CHO in accordance with the physical demands of each specific stage during a cycling Grand Tour. This case report highlights the potential large variation in CHO intakes between different stages of the race, and thus the need to carefully consider the physiological requirements of each day, and the time available for recovery to fuel the next stage. The identification of in-race fuelling predominantly coming from whole foods also represents a novel finding, with the strategic addition of concentrated dual source CHO drinks to boost on-bike fuelling in stages with the highest on-bike EEE. Furthermore, we demonstrate the application of a distributed nutrition support network utilising collaborative cloud-based technologies to enable actionable feedback loops to support riders. Future research and case studies should look to identify any potential differences in CHO and energy periodisation between different team members with different roles within the race group.

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Disclosure Statement

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

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