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Training Load and Carbohydrate Periodization Practices of Elite Male Australian Football Players: Evidence of Fueling for the Work Required

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The authors aimed to quantify (a) the periodization of physical loading and daily carbohydrate (CHO) intake across an in-season weekly microcycle of Australian Football and (b) the quantity and source of CHO consumed during game play and training. Physical loading (via global positioning system technology) and daily CHO intake (via a combination of 24-hr recall, food diaries, and remote food photographic method) were assessed in 42 professional male players during two weekly microcycles comprising a home and away fixture. The players also reported the source and quantity of CHO consumed during all games ($n = 22$ games) and on the training session completed 4 days before each game ($n = 22$ sessions). The total distance was greater ($p < .05$) on game day (GD; 13 km) versus all training days. The total distance differed between training days, where GD-2 (8 km) was higher than GD-1, GD-3, and GD-4 (3.5, 0, and 7 km, respectively). The daily CHO intake was also different between training days, with reported intakes of 1.8, 1.4, 2.5, and 4.5 g/kg body mass on GD-4, GD-3, GD-2, and GD-1, respectively. The CHO intake was greater ($p < .05$) during games (59 ± 19 g) compared with training (1 ± 1 g), where in the former, 75% of the CHO consumed was from fluids as opposed to gels. Although the data suggest that Australian Football players practice elements of CHO periodization, the low absolute CHO intakes likely represent considerable underreporting in this population. Even when accounting for potential underreporting, the data also suggest Australian Football players underconsume CHO in relation to the physical demands of training and competition.

***Keywords*:** GPS, sports drinks, sports gels

The match activity profile data of Australian Football (AF) are well documented (Coutts et al., 2010; Dawson et al., 2004; Wiseby et al., 2010) and are greater than those observed in other invasive field team sports, such as soccer and rugby league (Varley et al., 2014). Given the high-intensity intermittent nature of AF match play and training, it follows that carbohydrate (CHO) and muscle glycogen are likely the predominant substrate for energy production (Routledge et al., 2019). Accordingly, the current CHO recommendations for invasive team sports advise high CHO availability (>6 g/kg) in the day prior to match play (Burke et al., 2011) and an intake of 30–60 g/hr during match play to maximize physical, technical, and cognitive performance (Burke et al., 2011).

In contrast to ensuring high CHO availability before and during competition, accumulating data over the last decade suggest that deliberately completing carefully selected training sessions with reduced CHO availability may lead to greater adaptive responses of skeletal muscle (Bartlett et al., 2015; Hawley & Morton, 2014; Impey et al., 2018). Indeed, the concept of "fueling for the work required" has recently been suggested as a practical framework for which to apply nutritional periodization strategies to both endurance (Impey et al., 2016, 2018) and team sport athletes (Anderson et al., 2017). Such strategies are intended to promote components of training adaptation (e.g., activation of regulatory cell-signalling pathways), but yet, also ensure adequate CHO (and energy) availability to promote competitive performance, reduce injury risk, and aid recovery (Burke et al., 2011).

We have recently reported that professional rugby league (Bradley et al., 2016), rugby union (Bradley et al., 2015), and soccer players (Anderson et al., 2017) habitually adjust daily CHO intake in accordance with the upcoming workload. To the authors' knowledge, however, the habitual CHO feeding strategies of AF players across weekly microcycles comprising both game play and training sessions have not yet been reported. With this in mind, the aims of the present study were to quantify (a) the periodization of physical loading and daily CHO intake across an in-season weekly microcycle of AF and (b) the quantity and source of CHO consumed during game play versus training.

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Methods

Subjects

Forty-two professional AF players from an AF list (mean ± *SD*: age 24 ± 3 years, height: 188 ± 7.8 cm, and body mass: 85 ± 8.1 kg) volunteered to take part in the study. The study was conducted according to the Declaration of Helsinki and was approved by the Ethics Committee of Liverpool John Moores University.

Study Design

The data collection was conducted across the entire 2017 Australian Football League Premiership season. In a repeated-measures design, the players reported their habitual daily CHO intake during two weekly microcycles comprising a back-to-back home and away fixture during the midseason period of June 2017. For each fixture, the players reported their daily CHO intake for the 4 days prior to each game. In addition, the players also reported CHO consumed during each game of the season ($n = 22$ games), as well as the highest loading training session of each training week across the season ($n = 22$ sessions), the latter occurring 2 days before each game. For game day (GD), the 22 selected players were studied, whereas during training sessions, the full 42-man squad was studied. The players studied had not been exposed to any formal educational training by the club's staff on CHO periodization strategies or messaging (e.g., fueling for the work required), though players had previously received training on the importance of "CHO loading" for game play. In addition, the types of foods and fluids available to the players while present under the club's care (e.g., training ground) did not change from day to day during the study period.

Reported Daily Energy and Macronutrient Intake

Daily energy intake was assessed from a 4-day food diary (using household measures to estimate portion sizes). Food diaries also contained educational pictures of portion sizes to assist players with self-reporting daily energy intakes. On the day prior to data collection, food diaries were explained to the players by the lead researcher, and an initial dietary habits questionnaire (24-hr food recall) was also completed. These questionnaires were used to establish habitual eating patterns and, subsequently, allowed for a follow-up analysis of food diaries, as they helped to retrieve any potential information that players may have missed in their food diary input. In addition to food diaries, each player also completed the remote food photographic method, in which they sent time-stamped photographs each day (via Whatsapp messaging service) to the lead researcher (Martin et al., 2009). The food diaries were cross-checked using a 24-hr recall with the lead researcher after 1 day of entries. In this way, the lead researcher used the information obtained from the three approaches to dietary assessment (i.e., food diaries, 24-hr recall, and the remote food photographic method) to collectively estimate self-reported daily energy intake, an approach used previously with team sport athletes (Anderson et al., 2016). Energy intake and macronutrient composition were assessed from dietary analysis software (Nutritics Ltd, Dublin, Ireland). To assist with entering portion sizes into the dietary analysis software, the players' photographs of single source foods (e.g., rice, bread, fruit, chicken, etc.) and composite meals (e.g., spaghetti bolognese, lasagne, etc.) were cross-referenced against visual databases (www.carbsandcals.com, London, UK).

Reported Carbohydrate Intake During Training and Games

The CHO consumed during training and games was also reported by the players within 30 min after the physical weekly training session ($n = 22$ sessions) on GD minus 2 (GD-2) and within 30 min after each game ($n = 22$ games). The CHO intake during training and games was quantified according to dietary recall, after prior education on reporting quantities and source. The players had unrestricted access to water, sports drinks, and CHO gels during both training and match play, where each player was initially provided with their own individually labeled sports drink and water bottles (both 500 ml). If the players ran out of either bottle, another was then prepared by the lead researcher. Prior to the data collection period (preseason), the players were instructed on the correct method of recalling CHO intake during training and games. During six preseason training sessions with the lead researcher present, the players had unrestricted access to water, sports drinks (36 g CHO, 33 g sucrose, and 3 g glucose; Gatorade, Chatswood, NSW, Australia), and energy gels (29.8 g CHO and 2.9 g sugars; Shotz, Sydney, NSW, Australia). Following each session, the lead researcher would demonstrate the correct method to report CHO intake with the players present. This was repeated six times across the preseason prior to the start of data collection (Round 1 of the 2017 Australian Football League season season). For the data collection period following each game and training session, the players would use a record sheet that was observed by the lead researcher. Furthermore, during matches, the lead researcher was present on the team bench and had visible access to cross-reference player recall data. The lead researcher was also present for all training sessions and had full access to the players to visibly cross-reference player recall.

Quantification of Training and Game Load

In-season external training load and match activity profiles were quantified using a portable global positioning system microtechnology device (Optimeye S5; Catapult Innovations, Melbourne, VIC, Australia). At the conclusion of each training session and competitive match, data were downloaded and analyzed using the manufacturer specific software (Catapult Openfield software, version 11.1.2; Catapult Innovations). The data were filtered using the manufacturer's "Intelligent Motion Filter" to remove erroneous global positioning system information. Satellite data sampled at 10 Hz provided measures of total distance covered and distance covered relative to specific velocity bands corresponding to (Zone 1, 0–1.5 m/s; Zone 2, 1.5–3 m/s; Zone 3, 3–4.16 m/s; Zone 4, 4.16–5.5 m/s; Zone 5, 5.5–7 m/s; and Zone 6, >7 m/s). For the purposes of this study, the relative velocity bands 4–6 were assigned a qualitative descriptor, Zone 4, "Running"; Zone 5, "High-Speed Running"; and Zone 6, "Sprinting."

Statistical Analysis

Statistical analysis was conducted using the Statistical Package for Social Sciences software program (SPSS, version 17; IBM, Armonk, NY). External load and macronutrient content were analyzed using a two-way repeated-measure General Linear Model, where the within-subject factors were day (GD-4, GD-3, GD-2, and GD-1) and fixture week (Home and Away). All data in the text, figures, and tables are presented as mean ± *SD*, with p values <.05 indicating statistical significance.

Results

Assessment of External Training Load

The external load metrics for the home and away microcycle are presented in Table 1. The external load was higher (all *p*s < .01) on GD compared with GD-4, GD-3, GD-2, and GD-1 for total distance, running, high-speed running, and sprinting. Specifically, GD-2 displayed higher loading (*p* < .01) than GD-4, GD-3, and GD-1 for total distance and running on GD-3 and GD-1, although there was no difference between GD-4 (*p* = .06). High-speed running and sprinting were also greater on GD-2 (*p* < .01) than GD-4, GD-3, and GD-1. There were no differences in the external loads between the home and away games.

Self-Reported Daily Energy and Macronutrient Intakes

The self-reported daily energy and macronutrient intake are presented in Table 2. Daily energy and absolute and relative CHO intake were not significantly different between the home and away fixture schedules (*p* = .19, *p* = .48, and *p* = .23, respectively). Daily absolute and relative CHO intake were significantly different between days (all *p*s < .001), such that significant differences were evident between all pairwise comparisons (all *p*s < .001). The players reported the lowest daily energy and CHO intake on GD-3 (i.e., the day when no training was performed), whereas the highest intakes were reported on GD-1 (i.e., the day before the game). Although the reported absolute and relative protein (both *p*s < .001) and fat intakes (both *p*s < .001) were also significantly different between days, they did not follow the same pairwise comparisons as the reported energy and CHO intakes (see Table 2 for location of specific differences). The players also reported consuming more protein and less fat during home fixture schedules compared with away fixture schedules (*p* = .002 and *p* = .005, respectively).

Reported Pregame CHO Intake

Reported absolute (*p* = .8) and relative CHO intake (*p* = .7) consumed in the prematch meal was not significantly different between the home and away game (see Figure 1a and 1b).

Reported CHO Intake During Training and Games

Carbohydrates consumed during game play (59 ± 19 g) was higher (*p* < .05) than that consumed during training sessions (1 ± 1 g; Figure 1c). Accordingly, CHO intake during exercise when expressed as gram per hour (34 ± 11 g/hr vs. 1 ± 1 g/hr; Figure 1d) and gram per minute (0.6 ± 0.2 g/min vs. 0.01 ± 0.1 g/min; Figure 1e) was also higher (*p* < .05) during game play compared with training. In the context of game play, 53% of the athletes achieved CHO intakes in the recommended range of 30–60 g/hr, with 30% consuming <30 g/hr and 17% consuming >60 g/hr. During game play, a greater amount of CHO was consumed from fluids versus gels (*p* < .05) when expressed as total CHO (38 ± 18 g vs. 22 ± 20 g) in gram per hour (21 ± 24 g/hr vs. 13 ± 14 g/hr) and gram per minute (0.4 ± 0.2 g/min vs. 0.2 ± 0.2 g/min).

Discussion

Using a seasonal long analysis, we report for the first time that (a) "in-season" AF training sessions exhibit marked reductions in physical load compared with game play, (b) players' reported daily CHO intake varies during the weekly microcycle, and (c) players consume greater amounts of CHO (predominantly from fluid sources) during game play versus training. Altogether, these data suggest that players adjust their daily CHO intake in accordance with periodization of the weekly loading patterns. However, an evaluation of reported daily CHO intake suggests that players are likely underconsuming CHO, especially when considered in the context of CHO loading for match play.

Table 1 Total Distance, Distance Covered While Running (4.16–5.5 m/s), High-Speed Running (5.5–7 m/s), Sprinting (>7 m/s), and Session Duration During a Weekly Microcycle Comprising a Home and Away AF Fixture

Fixture	GD-4	GD-3	GD-2	GD-1	GD
Total distance (m)					
Home	7,644 ± 578*,** (59%)	0 ± 0*,** (0%)	7,568 ± 437* (59%)	3,588 ± 278*,** (28%)	12,900 ± 1,152 (100%)
Away	6,667 ± 511*,** (50%)	0 ± 0*,** (0%)	8,084 ± 497* (60%)	3,603 ± 260*,** (27%)	13,372 ± 1,378 (100%)
Running (m)					
Home	1,389 ± 348* (52%)	0 ± 0*,** (0%)	1,050 ± 195* (40%)	540 ± 136*,** (20%)	2,650 ± 592 (100%)
Away	862 ± 182* (33%)	0 ± 0*,** (0%)	1,436 ± 282* (55%)	534 ± 132*,** (21%)	2,626 ± 567 (100%)
High-speed running (m)					
Home	624 ± 190*,** (64%)	0 ± 0*,** (0%)	907 ± 216* (93%)	228 ± 82*,** (23%)	977 ± 341 (100%)
Away	427 ± 106*,** (44%)	0 ± 0*,** (0%)	714 ± 161* (74%)	251 ± 155*,** (26%)	962 ± 333 (100%)
Sprinting (m)					
Home	70 ± 49*,** (48%)	0 ± 0*,** (0%)	123 ± 54* (84%)	25 ± 33*,** (17%)	146 ± 121 (100%)
Away	103 ± 44*,** (69%)	0 ± 0*,** (0%)	97 ± 60* (65%)	24 ± 30*,** (16%)	149 ± 116 (100%)
Session duration (min)					
Home	78 ± 3 (75%)	0 ± 0 (0%)	83 ± 0 (79%)	40 ± 2 (38%)	104 ± 9 (100%)
Away	78 ± 5 (71%)	0 ± 0 (0%)	81 ± 0 (74%)	41 ± 3 (37%)	110 ± 14 (100%)

Note. Data in parentheses represent data expressed as a percentage of the game play load. AF = Australian Football; GD = game day.
*Significance from GD, *p* < .05. **Significance from GD-2, *p* < .05.

Table 2 Total Energy, Absolute and Relative CHO, Protein, and Fat Intakes During a Weekly Microcycle Comprising a Home and Away AF Fixture

Fixture	GD-4	GD-3	GD-2	GD-1
Energy (kcal)				
Home	2,606 ± 80	2,344 ± 104*,***	2,981 ± 471*,**	3,559 ± 584*,**,***
Away	2,586 ± 105	2,347 ± 99*,***	3,119 ± 443*,**	3,597 ± 573*,**,***
CHO (g)				
Home	190 ± 7	135 ± 21*,***	221 ± 10*,**	389 ± 54*,**,***
Away	164 ± 30	126 ± 16*,***	224 ± 11*,**	428 ± 47*,**,***
CHO (g/kg)				
Home	2.1 ± 0.2	1.5 ± 0.2*,***	2.5 ± 0.3*,**	4.3 ± 0.8*,**,***
Away	1.8 ± 0.3	1.4 ± 0.2*,***	2.5 ± 0.2*,**	4.8 ± 0.8*,**,***
Protein (g)				
Home	232 ± 29	190 ± 47*	252 ± 26*,**	188 ± 43*,***
Away	226 ± 35	175 ± 42*	234 ± 24*,**	190 ± 45*,***
Protein (g/kg)				
Home	2.6 ± 0.3	2.1 ± 0.6*	2.8 ± 0.4*,**	2.1 ± 0.5*,***
Away	2.5 ± 0.5	1.9 ± 0.5*	2.6 ± 0.3*,**	2.1 ± 0.5*,***
Fat (g)				
Home	102 ± 13	116 ± 12*	121 ± 14*,**	139 ± 32*,**
Away	114 ± 19	127 ± 11*	143 ± 17*,**	125 ± 24*,**
Fat (g/kg)				
Home	1.1 ± 0.2	1.3 ± 0.2*	1.3 ± 0.2*,**	1.5 ± 0.4*,**
Away	1.3 ± 0.2	1.4 ± 0.2*	1.6 ± 0.3*,**	1.4 ± 0.3*,**

Note. GD = game day; AF = Australian Football; CHO = carbohydrate.
*Significant difference from GD-4. **Significant difference from GD-3. ***Significant difference from GD-2.

To the authors' knowledge, we are the first group to quantify physical loading of multiple training sessions as opposed to weekly accumulative loads (Ritchie et al., 2016). We report that physical loads of training sessions were significantly less than game play, as quantified according to the total distance in both the home and away fixture weeks. The training session data are in conjunction with previous authors (Bartlett et al., 2017) who highlighted training session distance to be 6,389 ± 3,315 m. Total running, high-speed running, and sprinting metrics were all lower during training compared with games. Nonetheless, the distances covered during running (1,400 m) and high-speed running (550 m) in AF training are greater than the absolute distances observed in soccer (Anderson et al., 2016), where values of 500 and 100 m were reported, respectively. Such differences between codes are perhaps a reflection of the greater duration of training sessions in AF versus the training sessions observed by Anderson et al. (2016) (i.e., approximately 20 min longer), although we acknowledge this hypothesis is limited to the data provided for only two professional clubs. However, the present data clearly illustrate the periodization of training load across a weekly training microcycle.

In accordance with the evidence of training load periodization, our data also highlight practices of nutritional periodization, whereby a greater amount of CHO (5 g/kg) was consumed on the day prior to game play compared with lower relative CHO intakes (i.e., <3 g/kg) on training days. The CHO intake reported here on GD-1 agree with previous data, where AF players reported consuming an average of 4.1 g ± 1.6 g/kg CHO per day, as estimated from a 24-hr dietary recall (Bilsborough et al., 2016). However, the low CHO intakes reported on the remainder of the training days do not seem conducive to supporting the daily energetic requirement of male athletes (ranging from 80 to 90 kg), even when considering rest days. As such, we acknowledge the potential of underreporting as a limitation of the present study. Support for the hypothesis of specifically underreporting CHO is provided by the observation that similar periodization patterns of daily energy and CHO intake were observed (see Table 1), whereas daily fat and protein intake did not follow similar patterns. When considering that daily protein and fat intakes were also within the recommended ranges for elite athletes, our data therefore suggest that players may be specifically underreporting CHO intakes.

In an attempt to account for the magnitude of potential underreporting (e.g., 10–45%) previously observed in athletic populations (Magkos & Yannakoulia, 2003), the range of players' self-reported CHO intakes on GD-1 can be recalculated to 5.3–6.9 g/kg, a range that is somewhat closer to the CHO loading guidelines (i.e., 7–12 g/kg) advised for the 24 hr prior to competition. Nonetheless, even when accounting for such magnitudes of underreporting of daily CHO intake on the remaining training days (i.e., GD-4, GD-3, and GD-2), recalculation of players' CHO intake is still <3.6 g/kg. Such intakes may be considered suboptimal when compared with the CHO guidelines (i.e., 5–7 g/kg) for athletes performing moderate-intensity training for 1–2 hr per day (Thomas et al., 2016). When considered this way, our data therefore suggest that the current cohort of AF players is likely underconsuming CHO in relation to contemporary guidelines, even when accounting for underreporting.

In relation to the quantity of CHO consumed during exercise, we observed marked differences between training (1 ± 1 g/hr) and match play (34 ± 11 g/hr). This apparent difference between CHO intake during each activity is similar to that reported by professional soccer players of the English Premier League, where values

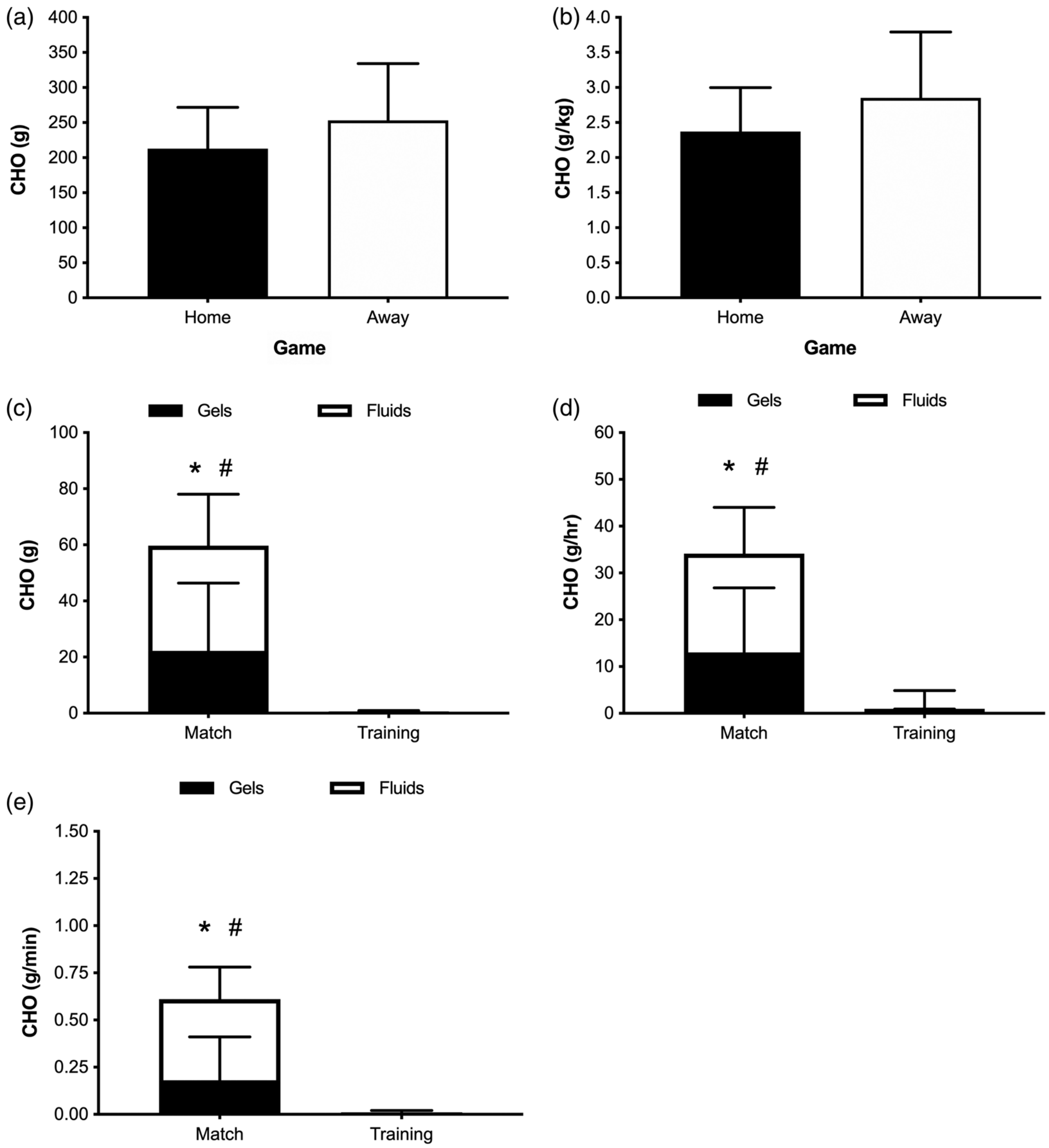

Figure 1 — Reported CHO intake in the prematch meal expressed as (a) absolute and (b) relative intake during a weekly microcycle comprising a home and away AF fixture. CHO consumed from fluids and gels during training and game play when expressed as (c) total CHO, (d) g/hr, and (e) g/min. *Significant difference between games and training, $p < .05$. #Significant differences between gels and fluids, $p < .05$. CHO = carbohydrate; AF = Australian Football.

of 3 ± 4 and 32 ± 22 g/hr were reported in training and match play, respectively (Anderson et al., 2017). In a case study account, we reported that consumption of 54 g/hr of CHO during AF match play reduced muscle glycogen utilization compared with consumption of 0 g/hr (Routledge et al., 2019). Of the athletes studied here, 53% achieved CHO intakes in the recommended range of 30–60 g/hr. This finding contrasts with soccer players, where only 33% of the players consumed >30 g/hr (Anderson et al., 2017). Furthermore, although we reported that 63% of the CHO consumed by soccer players was from gel sources (Anderson et al., 2017), the athletes studied here consumed 75% of the CHO from fluid sources and only 25% from gel sources. Such differences between studies may be related to regular access to fluids and CHO gels during rotations in AF match play, as well as higher ambient temperatures observed during AF game play (as opposed to that typically observed during the annual English Premier League), potentially suggesting that players consciously practice a CHO feeding strategy that simultaneously intends to promote hydration. In contrast, the choice of gels may offer a superior strategy to English Premier League soccer players, as opposed to fluids per se (usually 6–8% CHO solutions), owing to the flexibility for achieving CHO targets regardless of individual differences in body mass, hydration requirements, and differences in interchange number inherent to AF.

It is difficult to ascertain if the low absolute CHO intake reported here and the apparent CHO periodization practices were a deliberate choice of the player or alternatively, an unconscious decision. All players had access to the same array of CHO foods and fluids during games and training, and they were not following any coach-led nutritional program, with the exception of receiving prior dietary education on increasing CHO portion sizes on the day before a game. Nonetheless, the CHO periodization practices reported here appear in accordance with the principle of "fuel for the work required" that suggests that athletes should adjust their daily CHO intake in accordance with the workload (Impey et al., 2018). When considered with our previous observations of professional rugby league (Morehen et al., 2016), rugby union (Bradley et al., 2015), and soccer players (Anderson et al., 2017), the present data contribute to the emerging evidence that team sport athletes habitually adjust both the total daily CHO intake and CHO intake during exercise in accordance with the upcoming workload. Nonetheless, even when accounting for potential underreporting of CHO, the low CHO intakes reported here (considered indicative of underfueling) suggest that the current cohort of AF players would benefit from specific education on the CHO requirements of training and GDs. This is especially relevant when considering the training loads completed on GD-4 and GD-2, where total distances >7 km were completed.

In summary, we simultaneously quantified for the first time the daily physical loading and habitual daily CHO intakes during two weekly in-season microcycles of elite-level AF players. When such data are considered in conjunction with the seasonal quantification of CHO intake during training and matches, our data demonstrate that AF players appear to practice elements of CHO periodization. Furthermore, although we acknowledge that the low absolute CHO intakes likely represent considerable underreporting in this population, the data also suggest that the current cohort of AF players underconsume CHO in relation to the physical demands of training and competition.

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