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RESEARCH ARTICLE

Acute fuelling and recovery practices of academy soccer players: implications for growth, maturation, and physical performance

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ABSTRACT

Academy soccer players frequently train in the evening (i.e. 1700-2000 h), hence limited time to nutritionally prepare and recover due to schooling, travel and sleep schedules. Accordingly, we assessed timing and quantity of energy intake in the pre-training and post-training period. Over a 3-day in-season training period, male players (n=48; n=8 from under (U) 12, 13, 14, 15/16, 18 and 23 players) from an English Premier League academy self-reported dietary intake and physical activity levels (via the remote food photography method and activity diary, respectively) in the four hours pre- and post-training. Timing of pre-training energy intake ranged from 40 ± 28 mins (U15/U16 players) to 114 ± 71 mins (U18) before training and mean carbohydrate (CHO) intake ranged from 0.8±0.4 g.kg-1 (U23) to 1.5±0.9 g.kg-1 (U12). Timing of post-training energy intake ranged from 39 ± 27 mins (U14) to 70 ± 84 mins (U23) and mean CHO intake ranged from 1.6±0.8 g.kg-1 (U12) to 0.9±0.5 g.kg-1 (U14). In contrast to CHO, all age groups consumed sufficient protein intake in the post-training period (i.e. > 0.3 g.kg-1). We conclude academy soccer players habitually practice sub-optimal fuelling and recovery strategies, the consequence of which could impair growth, maturation and physical performance.

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KEYWORDS
Carbohydrate; training load; GPS; youth soccer

Introduction

The aim of soccer academies is to develop players through improving their tactical, technical, physical, and psychosocial capabilities (Wrigley et al. 2012). Ultimately, the end goal is to produce players to represent the first team at the host club or to be sold for financial gain (Elferink-Gemser et al. 2012). As players transition through the academy pathway (i.e., from under (U) 12 to under 18 age groups), they undergo sustained periods of growth and maturation (Hannon et al. 2020). For example, in a cohort of male academy players from the English Premier League (EPL), we observed increases in body mass (30 kg), fat-free mass (23 kg), and stature (25 cm) between the ages of 12 and 18. Such changes also coincided with increases in resting metabolic rate of approximately 400 kcal.d^{-1} (Hannon et al. 2020). Furthermore, in accordance with increases in absolute daily training load (i.e., increases in duration and total distance) throughout the development pathway (Hannon et al. 2021a), we also observed significant increases in total daily energy expenditure (750 kcal.d^{-1}) between U12 and U18 players (Hannon et al. 2021b). In some individuals, total daily energy expenditure (as evident in U12, U15, and U18 players) was comparable to or exceeded that previously reported from adult EPL players (Anderson et al. 2017). When taken together, such data clearly demonstrate the requirement for academy soccer players to maintain sufficient energy availability to support the energetic requirements of growth and maturation in addition to daily training activities.

Although nutritional strategies for athletic populations have traditionally focused on meeting 'daily' energy requirements, the importance of timing of energy and macronutrient intake is becoming increasingly recognised (Collins et al. 2021). Indeed, the sub-optimal provision of carbohydrate (CHO) before and/or during training and match play can reduce the performance of technical skills such as passing, shooting and dribbling (Russell et al. 2012) as well as physical performance outputs (Rodriguez-Giustiniani et al. 2019). Additionally, the intake of CHO availability around training can also affect the acute regulation of bone turnover (Sale et al. 2015), thus having obvious relevance for the academy soccer player given the requirement to accrue bone mass and maximise skeletal development during the adolescent years (Costa et al. 2022). The importance of sufficient protein intake in recovery from training is also of importance to stimulate muscle protein synthesis and promote the growth of fat-free mass (Boisseau et al. 2007). Nonetheless, despite the critical importance of timing of energy and macronutrient intake, the practicalities of adequate food consumption are complicated by the logistics and often busy lives of academy players. For example, academy players from the EPL (albeit dependent on age) often train in the evening periods (e.g., 17:00-20:00) thereby presenting a limited time-period between the end of the school day (e.g., 15:30) and beginning of training. In this way, the physical opportunity to

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consume sufficient energy intake in the acute period before training is often limited and moreover, the timing of players' previous food intake may have been limited to that consumed at school mealtimes (e.g., 12:00-13:00). Given the time required to transport players to and from training, the acute fuelling and recovery practices of academy players may also occur in their parent's (or guardian's) cars and/or public transport (e.g., bus and trains etc), thus presenting as an additional practical challenge to actively plan and consume meals. When considered this way, it becomes readily apparent that nutritional education programmes for both players and stakeholders (e.g., parents, coaches, support staff, etc.) should align on the technical knowledge and practical execution of strategies to ensure sufficient energy and macronutrient intake in the hours before and after training.

Despite the increasing recognition of the role of nutrition in supporting player development (Collins et al. 2021), a recent audit from our research group identified that English soccer academies are often under-resourced in relation to the quality and extent of service provision that is currently offered to players (Carney et al. 2022). This lack of resource was evidenced by a lack of full-time accredited nutrition staff delivering player and stakeholder education as well as a lack of on-site food provision before and after training. Moreover, it was also identified that players in the foundation and youth development phases (i.e., U9-U11 and U12-U16, respectively) receive significantly less support than players from the professional development phase (i.e., U18-U23). In relation to the latter age group, it is noteworthy that Carter et al. (2022) also reported that players' nutritional knowledge, training venue food provision and access to an accredited nutritionist were cited as 'key enablers' for optimal nutritional practices for academy soccer players. Although a more focused service provision towards the latter phase appears aligned with potential progression to the first team, the apparent lack of provision in the earlier phases is especially concerning given that the transition throughout such phases coincides with peak rates of growth and maturation. As such, there is a definitive requirement to better understand the nuances of the habitual nutritional practices of academy players at varying stages of the academy pathway.

With this in mind, the aim of the present study was to quantify the acute fuelling and recovery practices of male academy soccer players. To this end, players across the academy pathway (i.e., U12 to U23) were assessed for energy and macronutrient intake in the four hours before, during and after training over a three-day assessment period from a typical in-season training microcycle. Additionally, external training load was monitored (via GPS monitoring) and players also completed physical activity diaries (when not training) to assess physical activity patterns across the assessment period. We hypothesised that all age-groups would report sub-optimal fuelling and recovery practices, the prevalence of which would be greater in the younger playing squads.

Methodology

Participants

Forty-eight (n = 43 outfield and n = 5 goalkeepers) male soccer players from a Category One English Premier League soccer academy volunteered to participate in this study. Participants of different chronological and biological ages were non-randomly allocated into groups depending upon their chronological age-group (U12, U13, U14, U15/16, U18, and U23). Participant characteristics are presented in Table 1. Written informed parental/guardian consent and player assent were obtained for participants ≤16 year old, and participants ≥17 year old provided their own consent. Ethical approval was granted by Liverpool John Moores University.

Study design

In a cross-sectional design, self-reported energy and macronutrient intake, pitch-based training load and physical activity data was collected over two (U12-U16) or three (U18-U23) in-season training days. Data were collected in the four hours pre-training, during training and four hours post-training. Data were collected during an in-season period between October and December 2021. During this time, all players continued with their usual education, training, and match schedules. An overview of the on-pitch training schedules of each age group is displayed in Table 2 where data collection days are highlighted in bold.

Table 1. Baseline player characteristics.

	U12	U13	U14	U15/16	U18	U23
n	8	8	8	8	8	8
Age * (years)	11.9 ± 0.1^{bcdef} (11.7–12.1)	13.1 ± 0.2^{adef} (12.9–13.6)	13.9 ± 0.1^{adef} (13.8–14.2)	15.8 ± 0.3^{abcef} (15.4–16.2)	17.2 ± 0.3^{abcdf} (16.8–17.8)	18.6 ± 1.5^{abcde} (16.4–21.1)
Maturity offset * (years)	−1.65 ± 0.3^{cd} (−2.1—1.0)	−0.7 ± 0.6^{d} (−1.6 - −0.1)	0.2 ± 0.7^{a} (−0.9–1.3)	2.3 ± 0.6^{ab} (1.1–3.2)	-	-
PAS (%) *	85 ± 1.1^{bcd} (83.6–86.4)	88 ± 2.5^{acd} (84.9–90.1)	92.1 ± 3.4^{abd} (86.7–96.3)	99.3 ± 0.6^{abc} (98.4–100.5)	-	-
Stature * (cm)	154.4 ± 4.3 (148.1–160.0)	161.9 ± 9.1 (146.1–173.0)	168.9 ± 8.6^{a} (154.6–176.9)	184.5 ± 5.3^{abc} (176.6–192.4)	184.5 ± 5.3^{abc} (173.0–192.5)	186.1 ± 7.2^{abc} (178.9–195.4)
Body Mass * (kg)	44.6 ± 7 (37.0–57.7)	49 ± 7.6 (38.2–60.6)	58.1 ± 10^{a} (43.1–75.5)	70.3 ± 6.7^{ab} (58.0–78.9)	70.3 ± 6.7^{abc} (61.5–91.4)	76.6 ± 7.1^{abc} (72.2–87.7)

* Denotes significant difference between squads (main effect, $P < 0.05$). [a]denotes significant difference from U12, [b]denotes significant difference from U13, [c]denotes significant difference from U14, [d]denotes significant difference from U15/16, [e]denotes significant difference from U18, and [f]denotes significant difference from U23 (all $P < 0.05$). Data are presented as means ± SD with range displayed in parentheses.

PAS = percentage of adult stature.

Table 2. An overview of pitch-based training, gym, and match schedules for each squad. Data collection was completed on days in bold.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
U12	Gym 15:45 – 16:15 Pitch-based training 17:00 – 19:00	**Pitch-based training** **17:30 – 19:30**	OFF	**Pitch-based training** **17:30 – 19:30**	OFF	Gym 9:45 – 10:15 Pitch-based training 10:30 – 12:30	Match 11:00 (kick-off)
U13	OFF	**Pitch-based training** **17:30 – 19:30**	Gym 15:00 – 15:40 Pitch-based training 17:00 – 19:00	**Pitch-based training** **17:30 – 19:30**	OFF	Gym 9:45 – 10:15 Pitch-based training 10:30 – 12:30	Match 11:00 (kick-off)
U14	OFF	**Pitch-based training** **17:30 – 19:30**	Gym 15:45 – 16:25 Training 17:00 – 19:00	**Pitch-based training** **17:30 – 19:30**	OFF	Gym 9:45 – 10:15 Pitch-based training 10:30 – 12:30	Match 11:00 (kick-off)
U15/16	**Pitch-based training** **17:30 – 19:30** **Gym** **19:30 – 20:00**	Pitch-based training 10:30 – 12:00 Gym 14:15 – 15:00	OFF	**Pitch-based training** **17:30 – 19:30**	OFF	Match 12:00 (kick-off)	OFF
U18	**Pitch-based training** **10:30 – 12:00**	**Pitch-based training** **10:30 – 12:00** **Gym** **14:15 – 15:00**	OFF	**Pitch-based training** **10:30 – 12:00** **Gym** **14:15 – 15:00**	Pitch-based training 10:30 – 12:00	Match 12:00 (kick-off)	OFF
U23	**Pitch-based training** **10:30 – 12:00** **Gym** **15:00 – 16:00**	**Pitch-based training** **10:30 – 12:00** **Gym** **15:00 – 16:00**	OFF	**Pitch-based training** **10:30 – 12:00**	Match 19:00 (kick-off)	Training/Recovery 10:30 – 12:00	OFF

Baseline measures

Players were assessed at baseline for stature, body mass, and maturity status. Participants wore minimal training kit (t-shirt and shorts) for assessments of stature, sitting height and body mass. Participants' body mass (SECA, model-875, Hamburg, Germany), stature and sitting height (SECA, Hamburg, Germany) were measured to the nearest 0.1 kg, 0.1 cm and 0.1 cm respectively. For participants in the Youth Development Phase (YDP; U12-U15/16), somatic maturity was determined by calculating maturity offset (Mirwald et al. 2002) and predicted adult stature (PAS) and the current percentage of adult stature achieved (%PAS) (Sherar et al. 2005) was also collected.

Quantification of training load

Pitch-based training load was measured using global positioning system (GPS) technology (Vector, Catapult, Melbourne, Australia). Each player was provided a GPS unit (81 mm × 43 mm × 16 mm) and custom-made manufacturer provided vest (Catapult, Melbourne, Australia) to wear on the upper back between both scapulae during each pitch-based training session. Each unit was alarmed to turn on 30-min prior to the start of each session to sample total distance (m), high-speed running (>5.5 $m.s^{-1}$) (m), meters per minute ($m.min^{-1}$), accelerations (>3 $m.s^{-1}$), and decelerations (<3 $m.s^{-1}$) at 10 Hz providing a valid and reliable assessment of soccer-specific movement (Coutts and Duffield 2010; Varley et al. 2012). To ascertain when academy soccer players are capable of achieving the training and match intensities of adult EPL players, absolute speed thresholds commonly used within the adult game were deliberately selected (Malone et al. 2015; Anderson et al. 2016).

Quantification of energy and macronutrient intake

Self-reported energy and macronutrient intake was quantified during the four hours prior to training, during training and the four hours post-training using the remote food photographic method (RFPM). This method has previously been validated in adolescent team sport athletes (Costello et al. 2017) and used by our group to evaluate self-reported energy and macronutrient intakes in male professional adult (Anderson et al. 2017) and academy (Hannon et al. 2021b) soccer players.

Prior to data collection, all participants and parents/guardians were invited to an educational workshop where the study methodology was explained in detail. Players and parents/guardians of players were initially instructed on the rationale for collecting energy and macronutrient intake data how these analyses can be used to positively impact health and performance. Participants were shown a video detailing 'step by step' how to use the RFPM and instructed on additional details to include (i.e., branding, weights and cooking methods). Participants were shown common problems (i.e., difficulty to identify food items or a loss of phone signal) when collecting this data and how to rectify them (i.e., provide ingredients and individual weights or record the time of consumption which could be sent as soon as possible once signal had returned). This workshop was also pre-recorded and sent to each parent/guardian along with a written step-by-step guide as a point of reference throughout data collection. Prior to the start of data collection, the principal investigator also provided one-to-one player education on the RFPM.

Participants were instructed to take two images of any food or drink consumed using their smart phone; one at 45 degrees and one at 90 ninety degrees allowing for a better estimation of portion size than one image alone and send both images to the principal investigator. Participants were instructed to provide a detailed description of each eating occasion encompassing all ingredients (where possible), branding, weights, cooking methods and pre-existing nutritional information from food labels. Each participant was provided with a set of scales (ARC Digital Kitchen Scales, Salter, England) to assist with this process. Post-consumption, participants were required to send a final image detailing any food or drink remaining with weights of anything which had not been consumed. All images were sent using the instant messaging applications Whatsapp (Facebook, California, United States of America) for U18 and U23 players and Threema (Threema GmbH, Pfäffikon, Switzerland) for players in the U12-U15/16 age groups. In those instances where food was consumed on-site, the principal investigator was also present at the host club training ground to assist with data collection on behalf of the participant (i.e., self-record images and weights at mealtimes) and make written records of energy and macronutrient intakes, specifically for food and drink provided by the club. A database of any food and drink provided by the host club was created by the principal investigator to reduce participant burden as the amount of information required for certain foods and drinks (i.e., homemade energy balls) were on file. All players from the professional development phase (PDP; U18 – U23) were provided with access to pre-training snacks (e.g., fruit smoothie, cereal, fruit) and a hot post-training buffet lunch (e.g., chicken, fish, beef, vegetarian main, pasta/rice/potatoes, vegetables, cooked sauces, salad, fresh fruit, fruit juices and yoghurts). YDP players (U12 – U16) were provided with pre-training snacks and cold post-training food options (e.g., cereal bar, fruit and chicken wrap, pasta pot, flapjack, fruit juice and milkshake). During training, players from the PDP were also given the opportunity to consume CHO (e.g., sports drinks) and/or plain water ad libitum.

At the end of each two or three day data collection phase, each player completed a dietary recall to highlight any missed data and cross reference data collected by the principal investigator (Capling et al. 2017). During this process, the principal investigator clarified all timings, quantities, branding and weights provided by the participant and prompted the participant to recall any missed items. Energy and macronutrient intake was analysed by a Sport and Exercise Nutrition register (SENr) accredited nutritionist using dietary analysis software Nutritics (Nutritics, v5, Dublin, Ireland). Energy, CHO and protein intake was quantified as kilocalories and grams, respectively, in both absolute and relative (to each player's body mass) terms. To ensure reliability of energy and macronutrient intake data, a second SENr nutritionist also analysed a sample of food diaries chosen at random ($n = 10$, equating to 30 days of entries in total). Inter-rater reliability was determined via an independent t-test. No significant differences were observed between researchers for energy ($P = 0.95$, 95% CI −202 to 49),

Table 3. Time spent completing very light, light, moderate, heavy, and heavy physical activities as well as travel time to training in the four hours before training.

	U12	U13	U14	U15/16	U18	U23
Very Light (e.g., sleep and travel to training)	165 ± 46	160 ± 50	156 ± 36	118 ± 60	145 ± 77	130 ± 64
Light * (e.g., completing homework)	35 ± 34	61 ± 53	67 ± 33	98 ± 56[ae]	34 ± 32	64 ± 72
Moderate (e.g., brisk walk)	27 ± 36	10 ± 21	45 ± 8	15 ± 20	26 ± 28	22 ± 20
Heavy (e.g., jogging)	10 ± 17	12 ± 23	0	10 ± 12	26 ± 55	27 ± 42
Very Heavy (e.g., boxing gym training)	8 ± 15	0	0	3 ± 12	19 ± 33	18 ± 26

*Denotes significant difference between squads (main effect, $P < 0.05$). All data was collated using physical activity diaries converted using METs. [a]Denotes significant difference from U12, [b]denotes significant difference from U13, [c]denotes significant difference from U14, [d]denotes significant difference from U15/16, [e]denotes significant difference from U18, and f denotes significant difference from U23 (all $P < 0.05$). Data are presented as means ± SD.

CHO ($P = 0.09$, 95%CI −40 to 1), protein ($P = 0.09$, 95%CI −14 to 1) and fat ($P = 0.11$, 95%CI −13 to 1).

Quantification of physical activity

Self-reported physical activity was quantified in the four hours before training and the four hours after training using a self-reported activity diary on a smartphone application designed by the principal investigator (Glide, California, United States). Each participant was sent a link to download the application prior to the start of the study. At 15-minute intervals during each four-hour period, participants were instructed to provide a short description of their physical activity (e.g., 'walking the dog', 'travelling' or 'watching TV') and rating of perceived exertion (RPE) and submit these via the smartphone app. Each entry was then automatically logged on an online Google sheet (Google, California, United States) and exported to Microsoft Excel (Microsoft, Washington, United States) by the principal investigator. Each activity entry was then converted into metabolic equivalent task (MET) to provide an estimation of energy expenditure and then assigned one of the following intensity thresholds based upon the energy expenditure value; 'very light', 'light', 'moderate', 'heavy', 'very heavy' (Butte et al. 2018).

Statistical analysis

All data were initially assessed for normality using the Shapiro Wilk test. Baseline characteristics between groups was assessed via a one-way between groups analysis of variance (ANOVA). To determine differences in absolute and relative energy and macronutrient intake between age-groups, data were also assessed using a one-way between-groups ANOVA. Where significant main effects were present, LSD post-hoc analysis was conducted to locate specific differences (level of significance set at $P < 0.05$). Ninety-five % confidence intervals for the difference are also presented. All statistical analyses were completed using SPSS (version 26; SPSS, Chicago, IL) where $P < 0.05$ is indicative of statistical significance. All data are presented as mean ± SD.

Results

Baseline characteristics

Player characteristics including age, maturity offset, percent of PAS, stature and body mass are presented in Table 1. All of the aforementioned parameters were significantly different between squads (all main effects, $P < 0.05$) with specific pairwise comparisons displayed in Table 1.

Self-reported physical activity levels, energy, and macronutrient intake in the four hours before training

Pre-training physical activity levels

Physical activity levels in the four hours before training are displayed in Table 3. No differences were observed between squads for the time engaged in *very light* ($P = 0.35$), *moderate* ($P = 0.31$), *heavy* ($P = 0.49$) or *very heavy* ($P = 0.15$) activity. In contrast, there was a significant difference in time spent engaged in *light* ($P = 0.02$) activities. Players in the U15/16 squad reported more time spent in *light activity* when compared with the U18 ($P = 0.02$; 95%CI, 24 to 104) and U12 players ($P < 0.01$; 95%CI, 20 to 106). There was also a significant difference in travel time to training between squads ($P < 0.05$). U18 players spent less time (16 ± 4 min) travelling to training than all YDP players (U12: 38 ± 19 min, 95%CI, −37 to −7, $P < 0.01$; U13: 33 ± 19 min, 95%CI, −35 to 0, $P = 0.04$; U14: 32 ± 19 min, 95%CI, −33 to −2, $P = 0.03$; U15/16: 34 ± 11 min, 95%CI, −34 to −2, $P = 0.03$) players. U23 players also spent less time (21 ± 4 min) travelling to training than U12 players (95%CI, −33 to −1, $P = 0.04$).

Timing of pre-training energy, CHO, and protein intake

The timing of energy, CHO, and protein intake within each squad is displayed visually in Figures 1–3 (pre-training data are displayed *left* of the grey shaded area which represents the timing and duration of training). With the exception of the U18 and U23 players, all squads trained in the evening period. Energy intake was consumed in closer proximity to the start of training in the U15/16 squad (16:50; −40 ± 28 min) compared to the U12 (15:59; −91 ± 77 min), U13 (15:51; −99 ± 63 min), U14 (15:46; −104 ± 56 min), U18 (08:36; −114 ± 71 min) and U23 (08:51; −99 ± 52 min) squads (all $P < 0.01$). There was a significant difference ($P = 0.01$) between squads in the frequency of eating occasions before training. U18 players had more eating occasions (1.9 ± 0.9) than U12 players (1.5 ± 0.5; 95%CI 0.1 to 1.0, $P < 0.05$). U15/16 players displayed fewer eating occasions (1.0 ± 0.3) than U23 (1.7 ± 0.9; 95%CI −1.2 to −0.7, $P = 0.03$), U18 (95%CI −1.4 to −0.4, $P < 0.01$) and U14 (1.9 ± 0.4; 95%CI −1.4 to −0.4, $P < 0.01$) players.

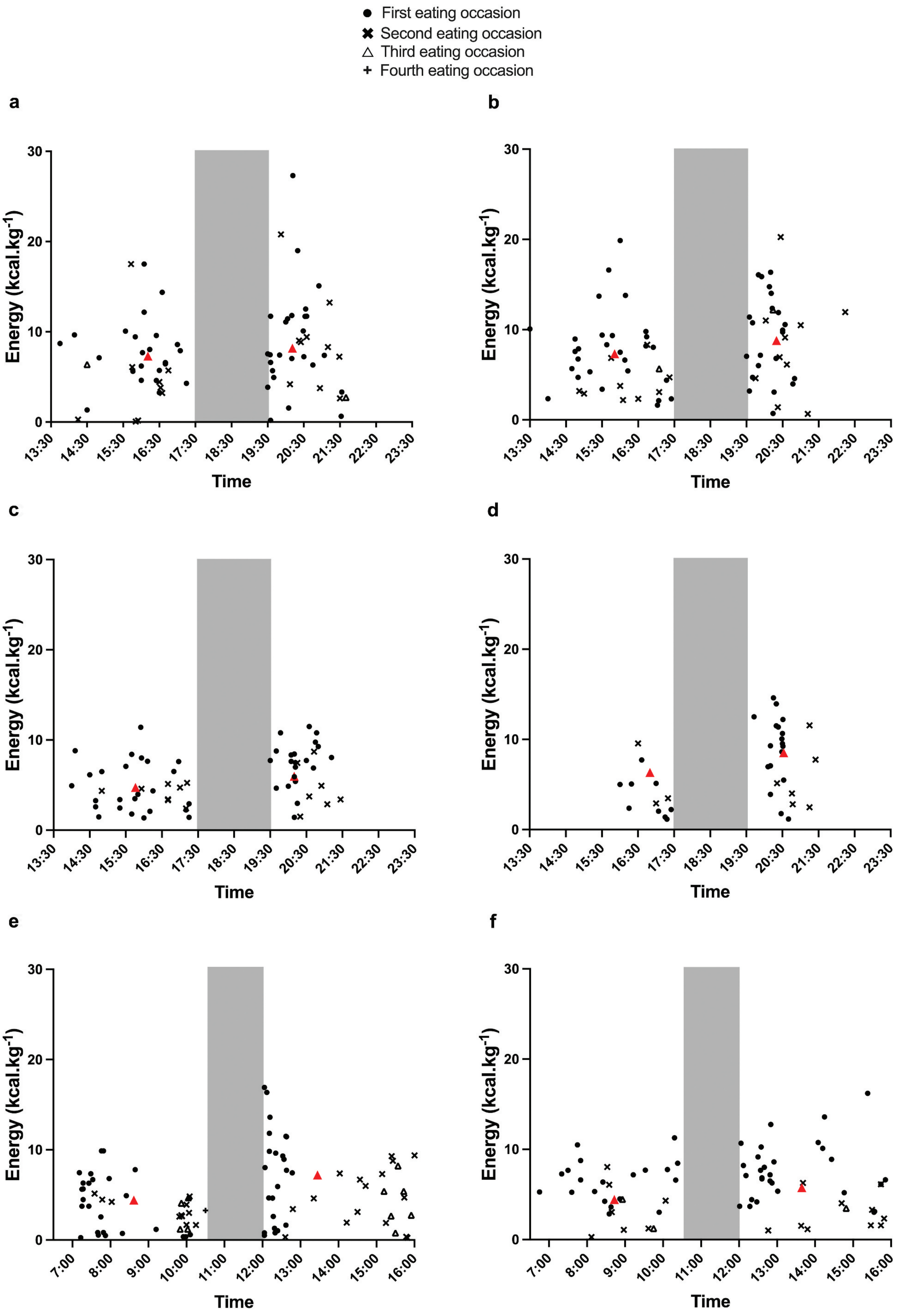

Figure 1. The distribution of relative energy intake pre- and post-training across three in season training days in (a) U12, (b) U13, (c) U14, (d) U15/16, (e) U18 and (f) U23 players. On pitch training is represented by the grey shading. Mean energy intake and mean eating time pre- and post- training is displayed in red.

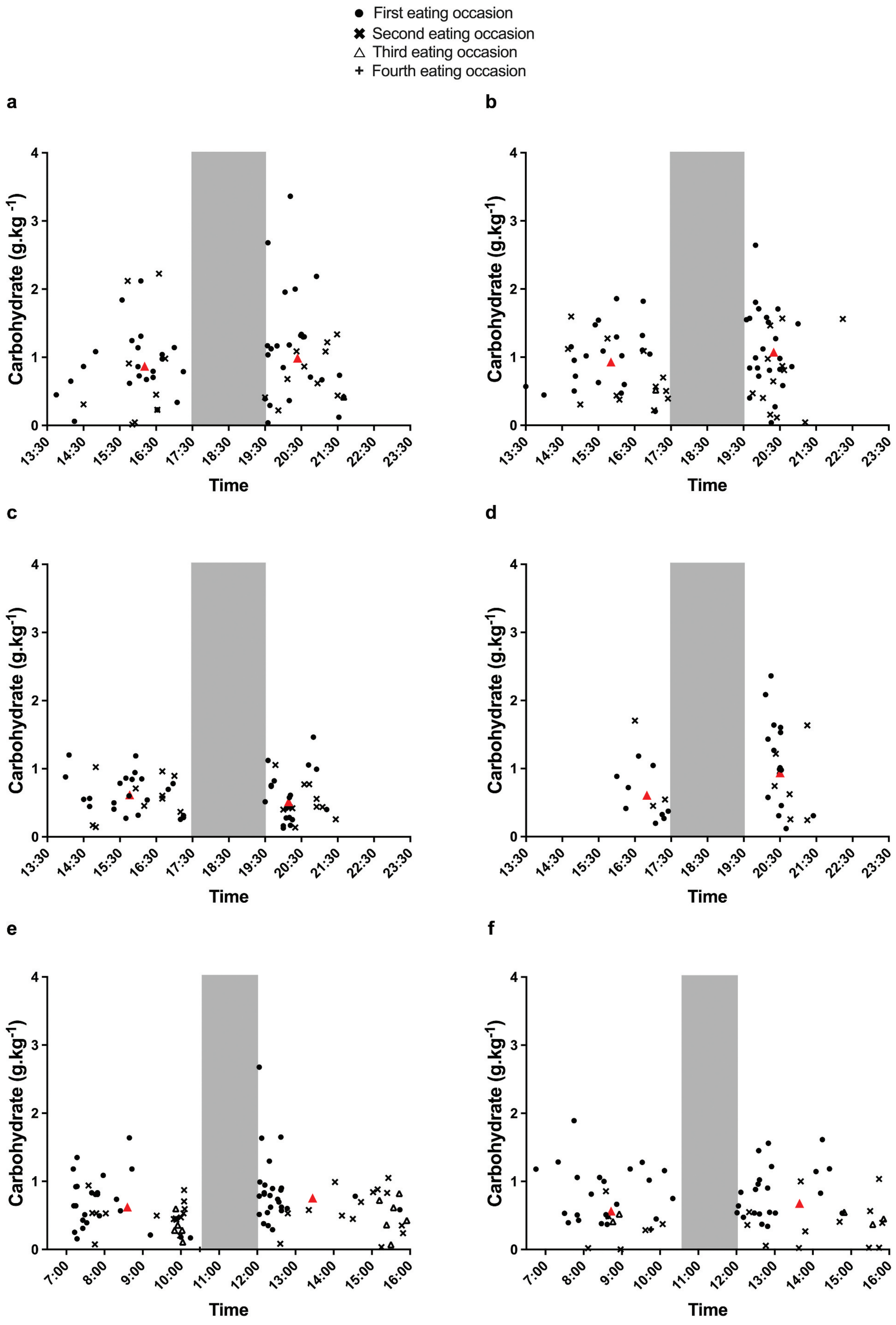

Figure 2. The distribution of relative carbohydrate intake pre- and post-training across three in season training days in (A) U12, (B) U13, (C) U14, (D) U15/16, (E) U18 and (F) U23 players. On pitch training is represented by the grey shading. Mean energy intake and mean eating time pre- and post- training is displayed in red.

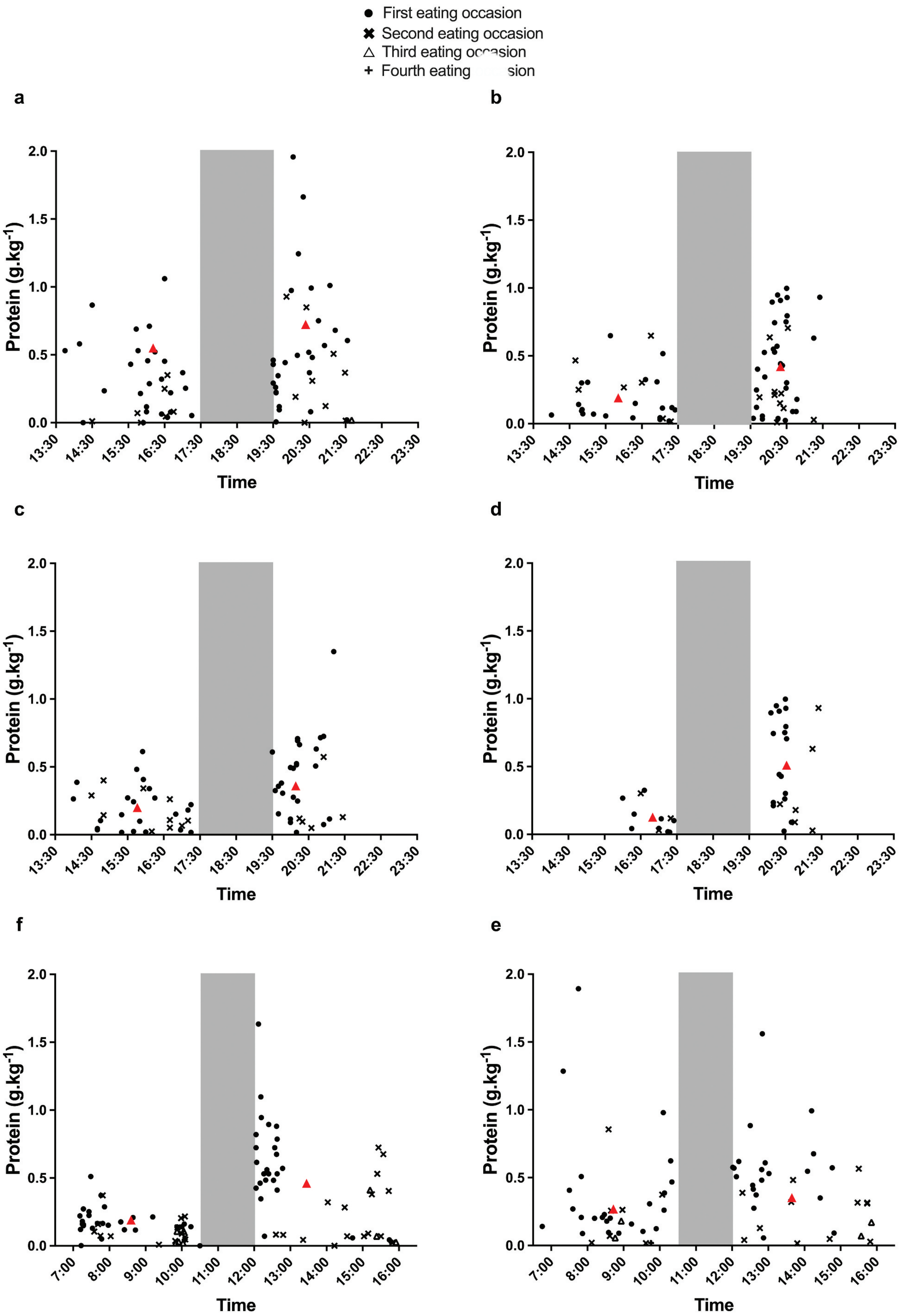

Figure 3. The distribution of relative protein intake pre- and post-training in (a) U12, (b) U13, (c) U14, (d) U15/16, (e) U18 and (f) U23 players. On pitch training is represented by the grey shading. Mean energy intake and mean eating time pre- and post- training is displayed in red.

Quantity of pre-training energy, CHO, and protein intake

The quantity of energy, CHO, and protein intake within each squad is displayed in Figure 4a–c. Relative EI was greater in U12 (11 ± 6 kcal.kg^{-1}) and U13 (11 ± 7 kcal.kg^{-1}) players when compared to U15/16 (7 ± 8 kcal.kg^{-1}, 95% CI: 1 to 7, P = 0.02; 95%CI: 1 to 8, P = 0.02, respectively) and U23 players (7 ± 3 kcal.kg^{-1}, 95%CI: 0 to 7 P = 0.03, 95% CI: 0 to 7, P = 0.04 respectively) (see Figure 4a).

Relative CHO intake in the U12 (1.5 ± 0.9 g.kg^{-1}) and U13 (1.5 ± 1.0 g.kg^{-1}) players were greater than the U14 (0.9 ± 0.5 g.kg^{-1}, 95%CI: 0.2 to 1.0, $P < 0.01$; 95%CI: 0.1 to 1.0, $P = 0.01$, respectively), U15/16 (0.8 ± 0.8 g.kg^{-1}, 95%CI: 0.2 to 1.0, $P = 0.02$; 95%CI: 0.2 to 1.1, $P < 0.01$, respectively) and U23 (0.8 ± 0.4 g.kg^{-1}, 95%CI: 0.2 to 1.0, $P = 0.01$; 95%CI: 0.2 to 1.0, $P < 0.01$, respectively) players (see Figure 4b).

Relative protein intake was greater in U12 (0.5 ± 0.5 g.kg^{-1}) compared to the U15/16 (0.3 ± 0.3 g.kg^{-1}, 95%CI: 0 to 0.4, P = 0.05) and U18 players (0.3 ± 0.1 g.kg^{-1}, 95%CI: 0 to 0.4, P = 0.05). Relative protein intake in the U13 (0.5 ± 0.5 g.kg^{-1}) players was also greater than U15/16 (95%CI: 0.1 to 0.5, P = 0.04) and U18 (95%: 0.1 to 0.5, P = 0.04) players (see Figure 4c).

External training load

Mean external training load metrics for the three-day data collection period are displayed in Figure 5. Total distance (TD) was greater in the U12 (6057 ± 1494 m) than the U23 (4878 ± 1171 m, 95%CI: 58 to 2305, $P = 0.03$) players (see Figure 5a). Additionally, TD in the U15/16 (6162 ± 1165 m) players was greater than the U18 (5099 ± 1160 m, 95%CI: 57 to 2069, $P = 0.03$) and U23 players (95%CI: 320 to 2248, $P < 0.01$).

Average meters per minute per session was significantly greater in the U14 (68 ± 9 m.min^{-1}, 95%CI: 1 to 31, $P = 0.03$), U15/16 (81 ± 12 m.min^{-1}, 95%CI: 16 to 42, $P < 0.01$), U18 (79 ± 15 m.min^{-1}, 95%CI: 13 to 41, $P < 0.01$) and U23 (75 ± 17 m.min^{-1}, 95%CI: 9 to 37, $P < 0.01$) players compared to the U12 (53 ± 27 m.min^{-1}) players (see Figure 5b). Metres per minute was also greater in the U15/16 players compared to the U13 players (69 ± 8 m.min^{-1}, 95%CI: 2 to 28, $P = 0.01$).

High-speed running meter (HSR) was significantly greater in the U23 players (262 ± 164 m) compared to U14 (73 ± 39 m, 95%CI: 84 to 295, $P < 0.01$), U13 (95 ± 76 m, 95%CI: 65 to 269, $P < 0.01$) and U12 players (60 ± 50 m, 95%CI: 87 to 299, $P < 0.01$) (see Figure 5c). HSR meters was greater in the U18 players (251 ± 162 m) compared to the U14 (95%CI: 70 to 287, $P < 0.01$), U13 (95%CI: 51 to 262, $P < 0.01$) and U12 (95%CI: 74 to 291, $P < 0.01$) players. HSR meters in the U15/16 players (195 ± 118 m) was greater than U14 (95%CI: 19 to 225, $P = 0.01$), U13 (95%CI: 1 to 199, $P < 0.05$) and U12 (95%CI: 24 to 229, $P = 0.01$) players.

The frequency of accelerations per session were greater in U23 (48 ± 19) and U18 players (48 ± 20) compared to U15/16 (28 ± 14, 95%CI: 9 to 32, $P < 0.01$; 95%CI: 9 to 33, $P < 0.01$, respectively), U14 (18 ± 9, 95%CI: 17 to 44, $P < 0.01$; 95%CI: 17 to 45, $P < 0.01$, respectively), and U12 (20 ± 11, 95%CI: 15 to 41, $P < 0.01$; 95%CI: 15 to 42, $P < 0.01$, respectively) players (see Figure 5d). Frequency of accelerations in the U13 (40 ± 14) players was also greater than those in the U15/16 (95%CI: 0 to 25, $P = 0.048$), U14 (95%CI: 8 to 37, $P < 0.01$) and U12 players (95%CI: 6 to 34, $P = 0.01$). The frequency of decelerations per session in the U23 (40 ± 21, 95%CI: 1 to 33, $P = 0.03$), U18 (44 ± 24, 95%CI: 4 to 36, $P < 0.01$), and U15/16 (39 ± 18.1, 95%CI: 1 to 31, $P < 0.05$) players were greater than U12 players (28 ± 11) (see Figure 5e).

Self-reported physical activity levels, energy and macronutrient intake in the four hours after training

Post-training physical activity levels

Physical activity levels in the four hours after training are displayed in Table 4. In contrast to reported physical activity levels in the pre-training period, much more variation between squads was evident in post-training activity levels. Specifically, significant main effects were observed between squads for time spent completing *moderate* (P = 0.02) and *heavy* ($P = 0.01$) activities. U23, U18 and U12 players completed more *moderate* activities than U15/16 (95%CI 14 to 57 min, $P < 0.01$; 95%CI 9 to 55 min, $P < 0.01$; 95%CI 10 to 57 min, $P < 0.01$), and U13 (95%CI 14 to 56 min, $P < 0.01$; 95%CI 9 to 53 min, $P < 0.01$; 95%CI 10 to 57 min, $P < 0.01$) players. U23 players also completed more *heavy* activities than U15/16 (95%CI 25 to 102 min, $P < 0.01$), U14 (95%CI 14 to 115 min, $P = 0.01$), U13 (95%CI 25 to 100 min, $P < 0.01$), and U12 players (95%CI 15 to 98 min, $P < 0.01$).

There was a significant difference in travel time post training ($P = 0.04$). U23 players spent less time travelling home (21 ± 10 min) from training than U12 players (38 ± 20 min, 95%CI, −32 to 2, $P = 0.03$). U18 players (17.1 ± 2.5 min) spent less time travelling home from training than U14 (34 ± 23 min, 95%CI, −32 to −1.4, $P = 0.03$), U13 (34 ± 19, 95% CI, −34 to −1, $P = 0.04$), and U12 players (95%CI, −36 to −5, $P = 0.01$).

Timing of post-training energy, CHO, and protein intake

The timing of energy, CHO, and protein intake within each squad is displayed visually in Figures 1–3 (post-training data are displayed *right* of the grey shaded area which represents the timing and duration of training). In contrast to pre-training, there was no difference in the timing of EI between groups in relation to the proximity of finishing training (U12: 20:24, +56 ± 39 min; U13: 20:20, +50 ± 34 min; U14: 20:09, +39 ± 27 min; U15/16: 20:23, +53 ± 25; U18: 13:26, +54 ± 91 min; U23: 13:40, +70 ± 84 min).

The frequency of eating occasions post-training was significantly different between squads ($P < 0.01$). Specifically, U23 and U15/16 players displayed 1.9 ± 0.6 and 1.8 ± 0.2 eating occasions, respectively, greater than 1.5 ± 0.3 in the U13 squad (95% CI 0.5 to 0.9, $P = 0.03$; 95%CI 0.0 to 0.8, $P < 0.05$ respectively). Players in the U18 squad had greater eating frequencies (2.2 ± 0.4) than all players in younger squads; U15/16 (95% CI 0.1 to 0.8, $P = 0.02$), U14 (1.5 ± 0.2, $P < 0.01$, 95%CI 0.4 to 1.2), U13 (1.5 ± 0.3 $P < 0.01$, 95%CI 0.5 to 1.2), and U12 (1.6 ± 0.3, $P = 0.01$, 95%CI 0.3 to 1.1).

Quantity of post-training energy, CHO, and protein intake

The quantity of energy, CHO, and protein intake within each squad is displayed in Figure 4d–f. Relative post-training EI was greater in U18 players (15 ± 5 kcal.kg^{-1}) compared to U14 (9 ± 4 kcal.kg^{-1}, 95%CI: 3 to 9, $P < 0.01$),

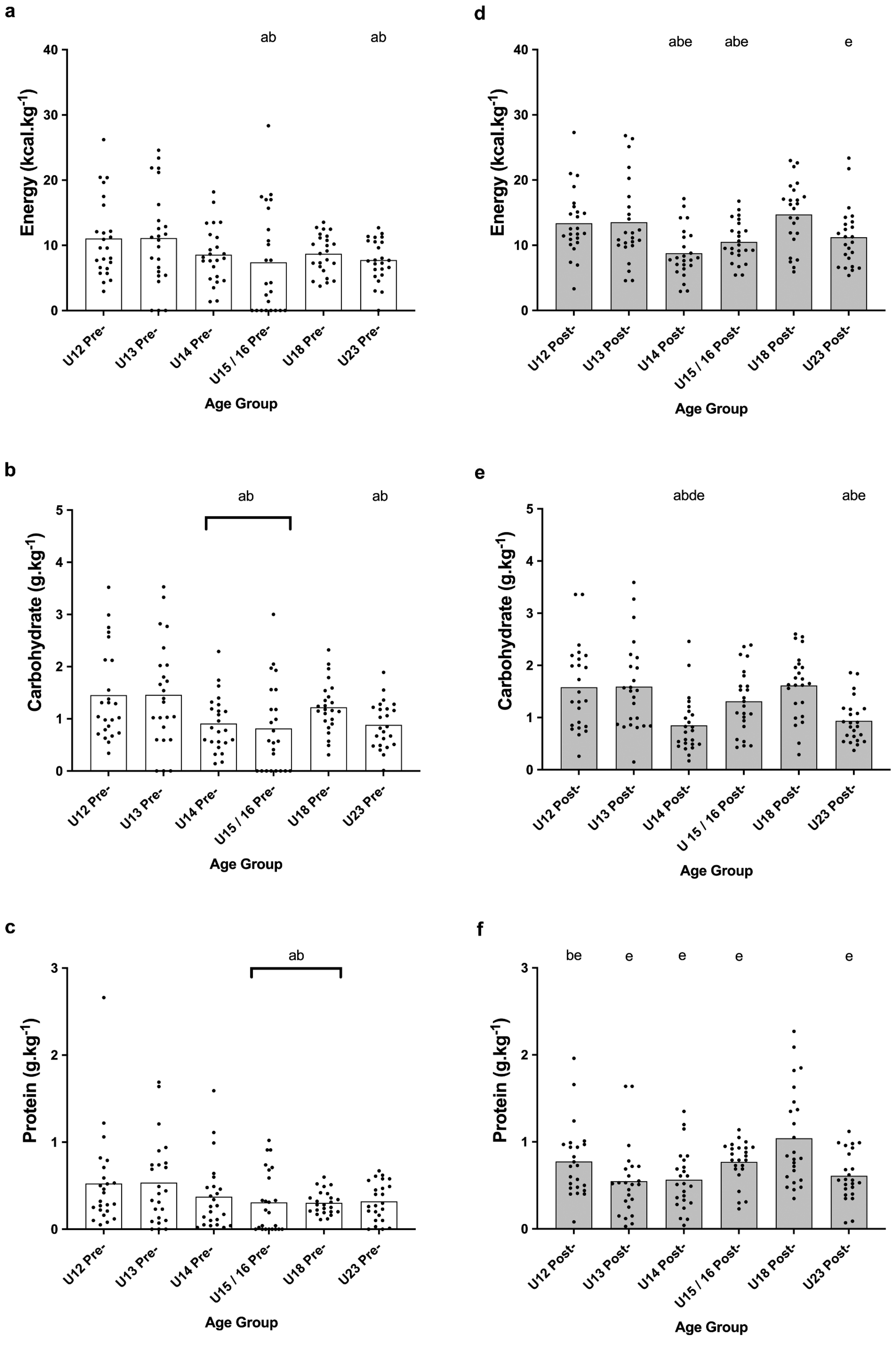

Figure 4. Total energy, carbohydrate and protein intake in the four hours before (a – c) and after (d – f) training. Mean values are represented by solid bars, black circles represent each player's mean intake. ^{a} denotes significant difference from U12, ^{b} denotes significant difference from U13, ^{c} denotes significant difference from U14, ^{d} denotes significant difference from U15/16, ^{e} denotes significant difference from U18, and ^{f} denotes significant difference from U23 (all $P < 0.05$).

U15/16 (11 ± 3 kcal.kg^{-1}, 95%CI: 1 to 7, $P < 0.01$), and U23 (11 ± 5 kcal.kg^{-1}, 95%CI: 1 to 7, $P = 0.01$) players (see Figure 4d). Relative EI was also greater in both the U12 (12 ± 6 kcal.kg^{-1}) and U13 players (13 ± 7 kcal.kg^{-1}) compared to the U14 (95%CI: 0 to 6, $P = 0.04$, 95%CI: 1 to 7, $P < 0.01$) and U15/16 squads respectively (95%CI: 0 to 6, $P = 0.04$, 95%CI 2 to 8, $P < 0.01$).

Post-training relative CHO intake was greater (all $P < 0.01$) in the U12 (1.6 ± 0.8 g.kg^{-1}), U13 (1.6 ± 0.8 g.kg^{-1}), U15/16 (1.3 ± 0.6 g.kg^{-1}) and U18 (1.6 ± 0.6 g.kg^{-1}) age groups compared to U14 (0.9 ± 0.5 g.kg^{-1}, 95%CI: 0.4 to 1.0; 95%CI: 0.4 to 1.0; 95%CI: 0.3 to 1.1, 95%CI 0.1 to 1.0; 95% CI 0.4 to 1.0) respectively. Post training CHO was also greater in U12 (95%CI 0.3 to 1.0, $P < 0.01$), U13 (95%CI 0.3 to 1.0, $P < 0.001$), and U18 (95%CI 0.3 to 1.1) squads compared to U23 players (all $P < 0.01$) (see Figure 4e).

Post-training protein intake was greater (all $P < 0.01$) in U18 players (1.0 ± 0.6 g.kg^{-1}) compared to all squads (U12, 0.8 ± 0.4 g.kg^{-1}, 95%CI: 0.1 to 0.5; U13, 0.5 ± 0.4 g.kg^{-1}, 95%CI: 0.3 to 0.7; U14, 0.6 ± 0.3 g.kg^{-1}, 95%CI: 0.3 to 0.7; U15/16, 0.8 ± 0.2 g.kg^{-1}, 95%CI: 0.1 to 0.5 and U23, 0.6 ± 0.3 g.kg^{-1}, 95%CI: 0.2 to 0.7). Relative protein intake in the U12 age group was greater compared to the U13 squad (95%CI 0.0 to 0.4, $P < 0.05$) (see Figure 4c).

Discussion

In considering, the limited time available to nutritionally prepare and recover from academy soccer training sessions (e.g., constraints associated with schooling, travelling and sleep schedules, etc.), the aim of the present study was to quantify the acute fuelling and recovery practices of male academy soccer players. To this end, we assessed dietary intake and self-reported physical activity levels in the four hours before, during and after training over three days of an in-season training microcycle. Although players readily achieve sufficient protein intake, our data demonstrate that academy players (from across the academy pathway of U12-U23) under-consume CHO both before and after training. Given the well-documented role of energy and CHO availability in promoting both physical performance (i.e., training intensity) and development (i.e., growth and maturation), the present data suggest that nutritional education programmes for academy players and key stakeholders (e.g., parents, coaches, etc.) should target behaviour change strategies that specifically promote sufficient quantity and timing of CHO intake before, during and after training.

Although we acknowledge that our data are compiled from one Category One EPL academy only, it is noteworthy that the training and game schedule studied here is representative of the typical academy schedules within England (see Table 2) and is similar to that studied previously by our group when monitoring players from other Category One academies (Enright et al. 2015; Naughton et al. 2016; Brownlee et al. 2018; Hannon et al. 2021a,b). As such, players from the youth development phase (i.e., U12-U16) trained in the evening periods between 17:30 and 19:30 whereas players from the professional development phase (i.e., U18-U23) trained in the morning period between 10:30 and 12:00. In considering the timing of training within both phases in combination with their daily lives (i.e., afternoon schooling and morning routines, respectively), it is unsurprising that we observed little differences in the intensity of self-reported pre-training activity between age-groups (see Table 4). Indeed, the majority of time was spent engaging in activities classified as very light (e.g., sleeping, watching television, travelling), light (e.g., doing homework) or moderate (e.g., walking).

Although we observed marked individual variation in both the timing (see Figures 1–3) and quantity (see Figure 4) of pre-training energy and macronutrient intake, it is noteworthy that the habitual-fuelling patterns reported here are likely sub-optimal in relation to preparing for the energetic demands of the upcoming training session. Indeed, this was especially evident for CHO where both the mean reported intakes of 1 g.kg^{-1} and sub-optimal intakes in individual players (see Figures 2 and 4b) is less than the recommended intake of 1–3 g.kg^{-1} in the 3–4 hours before soccer-specific activity (Collins et al. 2021). When such data are considered with our previous reports of sub-optimal ‘total daily’ CHO intakes in male academy players (Naughton et al. 2016; Hannon et al. 2021b), it is likely that players (as evident within in all age groups) commenced training with sub-optimal muscle and liver glycogen stores, the result of which may impair physical performance and development (Souglis et al. 2013).

Unfortunately, the present study did not ascertain the potential reasons underpinning the apparent prevalence of under-fuelling, though considering such reasons through the lens of behaviour change models such as the COM-B framework (capability, opportunity, motivation, and behaviour) and behaviour change wheel may afford some insight (Michie et al. 2011). In this regard, Carter et al. (2022) used this framework to qualitatively explore the perspectives of the barriers and enablers to nutritional adherence in male academy soccer players. These researchers reported that players (of the PDP phase) and stakeholders (e.g., parents or host families) may lack the psychological capability (i.e., awareness of nutritional guidelines) and/or physical capability (ability to plan and prepare appropriate meals and snacks) to promote the behaviours that could facilitate optimal nutritional practices. In considering such insight in combination with the present data, such lack of capability may also be exacerbated by the lack of both social opportunity (i.e., scheduling of training in close proximity to finishing school) and physical opportunity (i.e., the requirement to consume sufficient energy intake whilst travelling to training) to actually engage with the necessary nutritional practices. In contrast to our hypothesis, however, it is noteworthy that U18 and U23 players also reported sub-optimal pre-training CHO intakes, despite the fact that players from the professional development phase spent less time travelling to training and typically receive more educational support (i.e., capability) and on-site food provision (i.e., opportunity) than younger players (Carney et al. 2022). In such instances, the role of a player’s automatic motivation (i.e., emotions and impulses towards consuming specific foods before and after training) and their reflective motivation (i.e., beliefs about consequences of consuming specific foods) may therefore need to be assessed in order to bring about the necessary change (Bentley et al. 2019). For example, in a cohort of female soccer players (encompassing both youth and adult players), we recently observed that

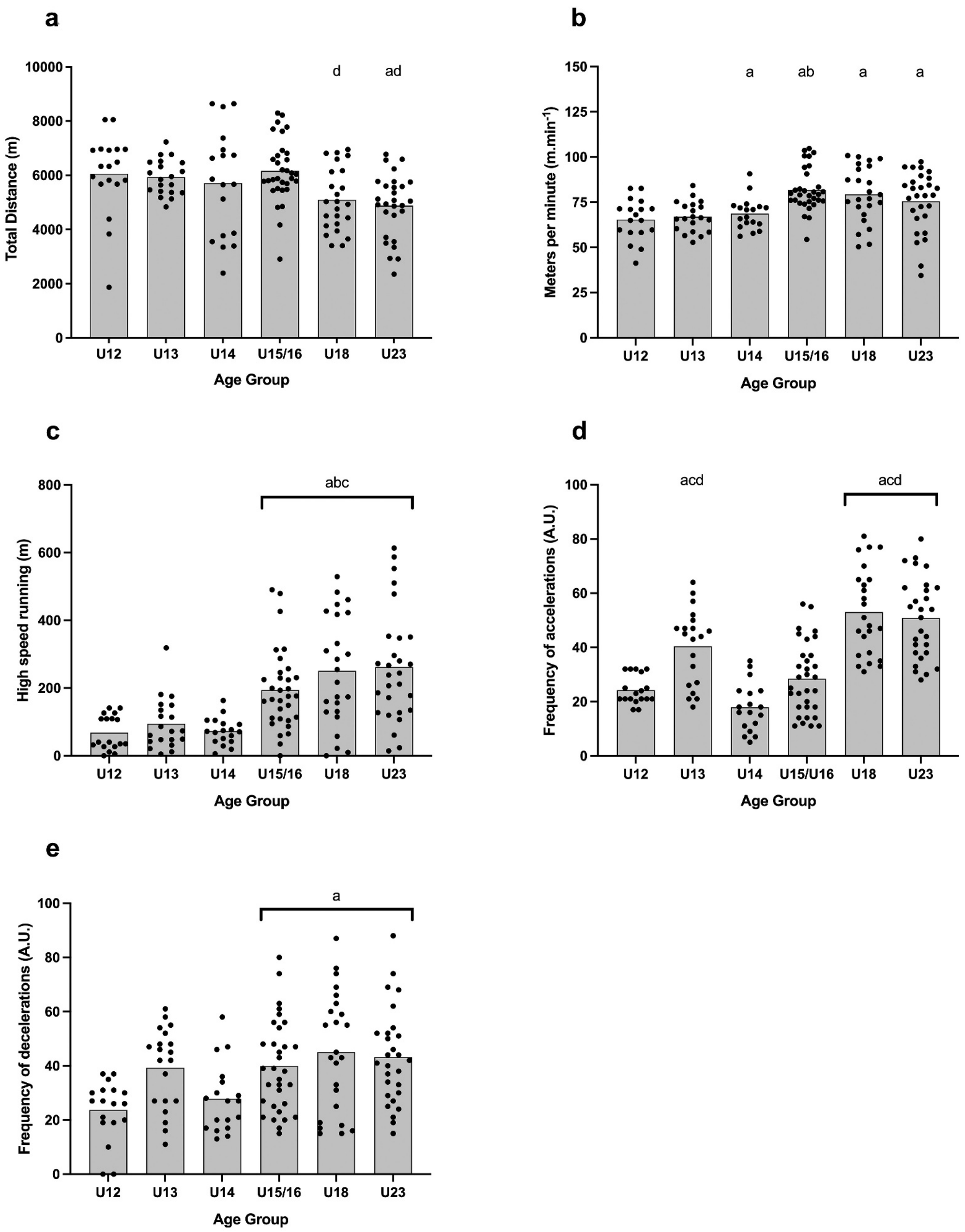

Figure 5. Overview of training duration and external load characteristics. (a) Total distance (b) average meters per minute (c) high speed running distance (d) accelerations and (e) decelerations across U12, U13, U14 (mean data compiled from n = 3 training sessions) and U15/16, U18 and U23 (data compiled from n = 4 training sessions) in-season training sessions. [a] denotes significant difference from U12, [b] denotes significant difference from U13, [c] denotes significant difference from U14, [d] denotes significant difference from U15/16, [e] denotes significant difference from U18, and [f] denotes significant difference from U23 (all $P < 0.05$).

Table 4. Time spent completing very light, light, moderate, heavy, and very heavy physical activities in the four hours after training.

	U12	U13	U14	U15/16	U18	U23
Very Light (e.g., sleep and travel from training)	170 ± 37	179 ± 48	139 ± 40	177 ± 41	130 ± 76	95 ± 80
Light (e.g., completing homework)	30 ± 29	58 ± 51	48 ± 22	58 ± 30	37 ± 36	23 ± 49
Moderate * (e.g., brisk walk)	35 ± 34[bd]	2 ± 8	24 ± 32	1 ± 4	33 ± 31[bd]	34 ± 40[bd]
Heavy * (e.g., jogging)	8 ± 20	2 ± 8	0	1 ± 4	24 ± 37	60 ± 98[abcd]
Very Heavy (e.g., boxing gym training)	9 ± 16	0	0	0	26 ± 76	20 ± 25

*Denotes significant difference between squads (main effect, $P < 0.05$). All data was collated using physical activity diaries converted using METs. [a]Denotes significant difference from U12, [b]denotes significant difference from U13, [c]denotes significant difference from U14, [d]denotes significant difference from U15/16, [e]denotes significant difference from U18, and [f]denotes significant difference from U23 (all $P < 0.05$). Data are presented as means ± SD.

players describe a culture of ‘carbohydrate fear’ where players consciously under-consume CHO in the belief that excessive CHO intake leads to gains in fat mass (McHaffie et al. 2022). To this end, a continuation of the qualitative methodology employed by previous researchers appears warranted (Bentley et al. 2019; Carter et al. 2022; McHaffie et al. 2022), so as to inform potential behaviour change interventions that could address the sub-optimal fuelling and recovery practices reported here. Indeed, Carter et al. (2022) suggested that the use of ‘role modelling’ (i.e., presenting senior players as positive role models) and ‘performance implications’ (i.e., presenting the performance consequences of sub-optimal and/or optimal fuelling) could also aid players’ motivation to engage in the desired behaviour.

The external training metrics reported here (see Figure 5) are comparable to that previously reported by our group (Hannon et al. 2021a, 2021b), as assessed from academy players that were also playing within another Category One academy from the EPL. Interestingly, we observed that players of the youth development phase (i.e., U12-U16) tended to complete more total distance during training when compared with players from the professional development phase (i.e., U18-U23) (see Figure 5a). In keeping with our previous approach (Hannon et al. 2021a), we deliberately chose to report absolute speed thresholds (i.e., high-speed running) that are typically used within the adult game. When considered this way, our data further demonstrate that academy soccer players from the youth development phase are not capable of achieving the same absolute physical loading patterns as adult players (e.g., high-speed running, average speed, frequency of accelerations and decelerations, etc.) until they are physically mature (Anderson et al. 2022). In contrast, the U18–23 players studied here produced external training load metrics (see Figure 5b–f) that are comparable to elite adult players (Anderson et al. 2022).

When considering the external training demands (i.e., 1.5 and 2 hours for U18-U23 and U12-U16 players, respectively), it is noteworthy that players did not report consuming any form of CHO during training (though it is noted that the host club only provided access to CHO during training for the U18-U23 players). Given the ergogenic effects of CHO feeding during soccer-specific activity on both physical (Rodriguez-Giustiniani et al. 2019) and technical performance (Currell et al. 2009; Russell et al. 2012), our data suggest that academy players would likely benefit from the consumption of 30–60 g of CHO per hour, in accordance with recommended guidelines (Collins et al. 2021). Additionally, the provision of CHO during training may also exert positive influences on bone turnover (de Sousa MV et al. 2014; Sale et al. 2015), especially in those instances where individual players have ‘under-fuelled’ in the four hours before training. As alluded to previously, both players and stakeholders (e.g., coaches) should therefore be educated on the requirement to consume CHO during training so as to inform behaviour change strategies (e.g., scheduled ‘fuel’ breaks during training) that result in the desired behaviour (e.g., consumption of a specific quantity of CHO at specific time-points during training).

In the four hours after training, self-reported physical activity levels demonstrated distinct differences between groups. For example, U18–23 players reported less time engaged in very light activities and more time engaged in heavy activities when compared with the U12-U16 players. Such data are likely a reflection of the timing of training sessions in that the younger players are returning home after training to commence their sleeping schedules whereas the older players finish training at 12 noon and hence, have more opportunity to engage in further physical activity throughout the remainder of the day. We also observed that PDP players spent less time travelling to and from training, likely as a result of club funded ‘host family’ accommodation being physically closer to the training ground when compared with homes of the players from the YDP. This point highlights how the type of training programme which players are engaged in (i.e., full-time or part-time) can influence a player’s life (i.e., moving into host family accommodation or time spent travelling) thereby potentially impacting their ability to appropriately fuel for and recover from training sessions. In this regard, it is noteworthy that Carter et al. (2022) also reported that ‘living status’ may facilitate nutritional adherence, given that players perceived that living with parents or host families could make it easier to adopt a ‘healthy diet’.

In relation to post-training energy and macronutrient intake, we observed that players within all squads reported recovery practices that could also be considered sub-optimal. For example, although data demonstrate that the majority of players achieved sufficient post-training protein intake of 0.3 $g.kg^{-1}$ body mass (Collins et al. 2021) (see Figures 3 and 4f), we observed CHO intakes that are likely sub-optimal in relation to promoting muscle and liver glycogen re-synthesis (see Figures 2 and 4e). Indeed, it is well documented that rates of muscle glycogen re-synthesis are greatest when CHO is consumed immediately post-exercise (Ivy et al. 1988) and accordingly, post-exercise intakes of 1 $g.kg^{-1}$ per hour (for several hours) are now recommended to promote muscle glycogen storage (Burke et al. 2016). However, the present data demonstrate that mean post-training timing and quantity of CHO intake across groups ranged between 39 and 70 minutes and 0.8–1.6 $g.kg^{-1}$ (see Figures 2 and 4b, respectively), the majority of which was achieved within one to two eating occasions (see Figure 2). Interestingly, evaluation of mean and individual data from the U23 players highlighted what could be considered as the ‘poorest’ post-training CHO practices (i.e., delayed feeding until 70 minutes after training and mean intakes of only 0.9 $g.kg^{-1}$), this despite the increased physical opportunity (i.e., on-site food provision and time available) to recover in the afternoon period after training. It is acknowledged, however, that U23 players were also restricted to access to the club’s canteen facilities until 30 min after training, as due to a staggering of access to accommodate players from other squads, a common logistical challenge within professional soccer clubs. In contrast, players from the U12 and U13 players reported the highest relative post-training CHO intakes despite spending significantly more time travelling home from training in the late evening period (up to 60 min). When taken together, such data further demonstrate the requirement for targeted player and stakeholder education programmes that result in behaviour change interventions to increase CHO intake in the post-training period.

As with all dietary assessment studies, an obvious limitation of the present data set is the potential for under-reporting from participants, in addition to the measurement error associated with researcher assessment when using the RFPM. Indeed, we recently observed that both experienced and inexperienced nutrition practitioners underestimated total 'daily' CHO intake by 54 and 66 g, respectively, as obtained from 2-days of dietary assessment comprising 4 meals per day (Stables et al. 2021). Nonetheless, when considering that we observed no significant differences between two researcher assessments and the potentially smaller margin for error (i.e., 2 × 4-h assessments as opposed to 2 × 24-h assessments), we consider that the present data are still indicative of sub-optimal fuelling and recovery practices. Furthermore, our assessments were also strengthened by the use of known 'in-house' dietary databases, prior training on data collection and the onsite presence of the researcher to assist participants where required.

In summary, we report for the first time the acute fuelling and recovery practices of male academy soccer players from across the academy pathway (i.e., U12-U23 players). We observed an apparent under-consumption of CHO before, during and after training, the result of which could impair physical performance and development if performed long-term. Future studies should now explore the reasons underpinning the nutritional choices reported here, so as to provide the basis for player and stakeholder education programmes and behaviour change interventions that promotes increased CHO intake.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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