Energy intake and expenditure of professional soccer players of the English Premier League: evidence of carbohydrate periodization

Liam Anderson[1], Patrick Orme[1], Robert J Naughton[2], Graeme L Close[1], Jordan Milsom[1,3], David Rydings[1,3], Andy O'Boyle[1,3], Rocco Di Michele[4], Julien Louis[1], Catherine Hambly[5], John Roger Speakman[5], Ryland Morgans[6], Barry Drust[1] and James P Morton[1]

[1]Research Institute for Sport and Exercise Sciences
Liverpool John Moores University
Tom Reilly Building
Byrom St Campus
Liverpool
L3 3AF
UK

[2]School of Human and Health Sciences
Harold Wilson Building
University of Huddersfield
Queensgate
Huddersfield
HD1 3DH
UK

[3]Liverpool Football Club
Melwood Training Ground
Deysbrook Lane
Liverpool
L12 8SY
UK

[4]Department of Biomedical and Neuromotor Sciences
University of Bologna
Bologna
Italy

[5]Institute of Biological and Environmental Sciences
University of Aberdeen
Aberdeen
UK

[6]Cardiff City Football Club
Leckwith Road
Cardiff
CF11 8AZ
UK

Running head: Energy intake and expenditure in soccer

Address for correspondence:
Dr James Morton
Research Institute for Sport and Exercise Sciences
Liverpool John Moores University
Tom Reilly Building
Byrom St Campus
Liverpool
L3 3AF
United Kingdom
Email: J.P.Morton@ljmu.ac.uk
Tel: +44 151 904 6233

Abstract

In an attempt to better identify and inform the energy requirements of elite soccer players, we quantified the energy expenditure (EE) of players from the English Premier League (n=6) via the doubly labeled water method (DLW) over a 7-day in-season period. Energy intake (EI) was also assessed using food diaries, supported by the remote food photographic method and 24 h recalls. The 7-day period consisted of 5 training days (TD) and 2 match days (MD). Although mean daily EI (3186 ± 367 kcals) was not different from ($P>0.05$) daily EE (3566 ± 585 kcals), EI was greater ($P<0.05$) on MD (3789 ± 532 kcal; 61.1 ± 11.4 $kcal.kg^{-1}$ LBM) compared with TD (2956 ± 374 kcal; 45.2 ± 9.3 $kcal.kg^{-1}$ LBM, respectively). Differences in EI were reflective of greater ($P<0.05$) daily CHO intake on MD (6.4 ± 2.2 $g.kg^{-1}$) compared with TD (4.2 ± 1.4 $g.kg^{-1}$). Exogenous CHO intake was also different ($P<0.01$) during training sessions (3.1 ± 4.4 $g.h^{-1}$) versus matches (32.3 ± 21.9 $g.h^{-1}$). In contrast, daily protein (205 ± 30 g, $P=0.29$) and fat intake (101 ± 20 g, $P=0.16$) did not display any evidence of daily periodization. Although players readily achieve current guidelines for daily protein and fat intake, data suggest that CHO intake on the day prior to and in recovery from match play was not in accordance with guidelines to promote muscle glycogen storage.

Keywords: glycogen, training load, soccer, GPS

Introduction

Despite four decades of research examining the physical demands of soccer match play (Reilly & Thomas, 1976; Bush et al., 2015; Russell et al., 2016), the quantification of the customary training loads completed by elite professional soccer players have only recently been examined (Anderson et al., 2015; Anderson et al., 2016; Malone et al., 2015; Akenhead et al., 2016). Such data suggest that absolute training loads are not as high as those experienced in match play. This is the case for parameters such as total distance (e.g. <7 km v ~10-13 km) (Bangsbo et al., 2006), high speed running distance (e.g. <300 m v >900 m) (Bradley et al., 2009), sprint distance (e.g. <150 m v >200 m) (Di Salvo et al., 2010) and average speed (e.g. <80 m/min v ~100-120 m/min) (Anderson et al. 2015). Daily training load during the weekly micro-cycle also displays evidence of periodization, the pattern of which appears dependent on proximity to the game itself (Anderson et al., 2015) as well as the number of games scheduled (Morgans et al., 2014).

Given the apparent daily fluctuations in training load, it follows that energy expenditure (EE) may vary accordingly and hence, energy intake (EI) could also be adjusted to account for the goals of that particular day. Indeed, the concept of "fuelling for the work required" has recently been suggested as a practical framework for which to apply nutritional periodization strategies to endurance athletes (Impey et al., 2016). Such strategies are intended to concomitantly promote components of training adaptation (e.g. activation of regulatory cell signaling pathways) but yet, also ensure adequate carbohydrate (CHO) (and energy) availability to promote competitive performance, reduce injury risk and aid recovery (Burke et al., 2011; Chamari et al., 2012; Burke et al., 2006). Despite such theoretical rationale, however, it is currently difficult to prescribe accurate nutritional guidelines for professional soccer players owing to a lack of study that has provided direct assessments of energy expenditure in the modern professional adult player (Ebine et al., 2002).

Therefore, the aim of the present study was to simultaneously quantify EI, EE, training load and match load in professional soccer players. To this end, we studied a cohort of professional players from the English Premier League (EPL) during a 7-day in season period in which two match days (MD) and five training days (TD) were completed. Self reported EI and direct measurement of EE was assessed using food diaries (supported by remote food photographic method and 24 h diet recalls) and the doubly labeled water (DLW) method, respectively.

Methods

Participants

Six male professional soccer players (who have all played international standard) from an EPL first team squad (mean ± SD; age 27 ± 3 years, body mass 80.5 ± 8.7 kg, height 180 ± 7 cm, body fat 11.9 ± 1.2 %, fat mass 9.2 ± 1.6 kg, lean mass 65.0 ± 6.7 kg) volunteered to take part in the study. All players remained injury free for the duration of the study. The study was conducted according to the Declaration of Helsinki and was approved by the University Ethics Committee of Liverpool John Moores University.

Study Design

Data collection was conducted during the 2015-2016 EPL in-season across the months of November and December. Players continued with their normal in-season training that was prescribed by the club's coaching staff and were available to perform in two competitive games on days 2 and 5 during data collection. The last competitive game where players were able to take part in was 3 days prior to the commencement of data collection. During data collection, game 1 kicked off at 20:05 hours and game 2 kicked off at 16:15 hours, both being home fixtures in European and domestic league competitions, respectively. The next competitive game players were due to take part in was the day after the study concluded (i.e. Day 8).

One day before the study commenced all players underwent a whole body fan beam Duel-energy X-ray absorptiometry (DXA) measurement scan (Hologic QDR Series, Discovery A, Bedford, MA, USA) in order to obtain body composition, in accordance with the procedures described by Milsom et al. (2015).

Quantification of Training and Match Load

Pitch based training sessions were monitored using portable global positioning systems (GPS) units (Viper pod 2, STATSports, Belfast, UK) using methods described previously (Anderson et al., 2015; Anderson et al., 2016). Players' match data were examined using a computerized semi-automatic video match-analysis image recognition system (Prozone Sports Ltd®, Leeds, UK) and were collected using the same methods as Bradley et al. (2009). This system has previously been independently validated to verify the capture process and subsequent accuracy of the data (Di Salvo et al., 2006; Di Salvo et al., 2009).

Variables from the training and match data that were selected for analysis included duration of activity, total distance covered, the average speed and distance covered inside 3 different speed categories that were divided into the following thresholds: running (14.4-19.7 km · h^{-1}), high-speed running (19.8-25.1 km · h^{-1}), and sprinting (>25.1 km · hr^{-1}).

Measurement of Energy Expenditure Using Doubly Labelled Water

Energy expenditure was determined by using the DLW method. On the day prior to start of data collection of the study, between the hours of 1400 to 1600, players were weighed to the nearest 0.1kg (SECA, Birmingham, UK). Baseline urine samples were then provided and collected into a 35ml tube. Following collection of baseline samples, players were administered orally with a single bolus dose of hydrogen (deuterium ^{2}H) and oxygen (^{18}O) stable isotopes in the form of water ($^{2}H_2{}^{18}O$) before they left the training ground. Isotopes were purchased from Cortecnet (Voisins-Le-Bretonneux-France). The desired dose was 10% ^{18}O and 5% Deuterium and was calculated according to each participants body mass measured to the nearest decimal place at the start of the study, using the calculation:

$$^{18}O \text{ dose} = [0.65 \text{ (body mass, g) x DIE}]/\text{IE},$$

where DIE is the desired initial enrichment (DIE = 618.923 x body mass (kg)$^{-0.305}$) and IE is the initial enrichment (10%) 100,000 parts per million.

To ensure the whole dose was administered, the glass vials were refilled with additional water which players were asked to consume. The following morning (between 09:00-10:00) baseline weight samples were taken (SECA, Birmingham, UK). Approximately every 24-hour, when players entered the training ground (or hotel on the morning of game 2) they were weighed and provided a urine sample in a 35 ml tube. This urine sample could not be the first sample of the day after waking as this was acting as a void pass throughout the study. Urine samples were stored and frozen at -80°C in airtight 1.8 ml cryotube vials for later analysis.

For the DLW analysis, urine was encapsulated into capillaries, which were then vacuum distilled (Nagy, 1983), and water from the resulting distillate was used. This water was analysed using a liquid water analyser (Los Gatos Research; Berman et al., 2012). Samples were run alongside three laboratory standards for each isotope and three International standards (Standard Light Artic Precipitate, Standard Mean Ocean Water and Greenland Ice Sheet Precipitation; Craig, 1961, Speakman, 1997) to correct delta values to parts per million. Isotope enrichments were converted to EE using a two-pool model equation (Schoeller et al., 1986) as modified by Schoeller (1988) and assuming a food quotient of 0.85. The results from the energy expenditure data are expressed as a daily average from the 7-day data collection period.

Total Energy Intake

Self reported EI was assessed from 7-day food diaries for all players and reported in kilocalories (kcal) and kilocalories per kilogram of lean body mass ($kcal \cdot kg^{-1}$ LBM). Macronutrient intakes were also analysed and reported in grams (g) and grams per kilogram of body mass ($g \cdot kg^{-1}$). The period of 7 days is considered to provide reasonably accurate estimations of habitual energy and nutrient consumptions whilst reducing variability in coding error (Braakhuis et al., 2003). On the day prior to data collection, food diaries were explained to players by the lead researcher and an initial dietary habits questionnaire (24 h food recall) was also performed. These questionnaires were used to establish habitual eating patterns and subsequently allow follow up analysis of food diaries. Additionally, they helped to retrieve any potential information that players' may have missed on their food diary input. In addition, EI was also cross referenced from the remote food photographic method (RFPM) in order to have a better understanding of portion size and/ or retrieve any information that players' may have missed on their food diary input. This type of method has been shown to accurately measure the EI of free-living individuals (Martin et al., 2009). To further enhance reliability, and ensure that players missed no food or drink consumption, food diaries and RFPM were reviewed and cross-checked using a 24-hour recall by the lead researcher after one day of entries (Thompson & Subar, 2008). To obtain energy and macronutrient composition, professional dietary analysis software (Nutritics Ltd, Ireland) was used.

Throughout the duration of this study, meals were consumed at the club's training ground or home ground, a nearby hotel (where the players often reside on match day) or alternatively, the players' own homes or restaurants / cafes. For meals provided at the training ground, home ground or hotel, menus are provided on a buffet style basis where the options provided are dictated by the club nutritionist and catering staff. Throughout the duration of the study, all meals were consumed ad libitum and it was not compulsory to eat the meals provided at the training / home ground or hotel. Whenever the team stayed in a hotel, the club's chef would travel and oversee the food preparation in order to ensure consistency of service provision.

On days 3 and 6, players were provided with breakfast and lunch at the training ground whilst on days 1 and 4 players were provided with lunch and dinner at the training ground. On day 2, players were provided with breakfast at the training round and lunch and pre-match meal at a nearby hotel, which the club uses for each home game. On day 5, players were provided with breakfast and pre-match meal at the hotel. On day 7, players were provided with a lunch and post training snack at the training ground and an evening meal at an away game hotel.

Breakfast options available daily included: eggs, beans, toast, porridge, muesli, fruits and yoghurts. Lunch and dinner had different options that included 1 x red meat option, 1 x poultry option, 1 x fish option, 3-4 carbohydrate options (e.g. pasta, rice, potatoes, quinoa), 2 x vegetable options alongside a salad bar and snacks such as yoghurts, nuts, cereal bars and condiments. During training sessions, players were provided with low calorie isotonic sports drinks (Gatorade G2), water and upon request, isotonic energy gels (Science in Sport GO Istonic Gels). During games, players were provided with sports drinks (Gatorade Sports Fuel), water and isotonic energy gels (Science in Sport GO Istonic Gels). All carbohydrate provided during training and matches were consumed ad libitum.

Statistical Analysis

All data are presented as the mean ± standard deviation (SD). Training load data are shown for descriptive purposes only. Daily energy and macronutrient intake were analysed using one-way repeated measures ANOVAs. When there was a significant ($P < 0.05$) effect of "day", Tukey post-hoc pairwise comparisons were performed to identify which day differed. The normal distribution of differences between data pairs was verified with Shapiro-Wilk tests ($P>0.05$ for all variables).

Paired Student's t tests (with statistical significance set at $P<0.05$) were then used to assess the differences between the average daily EI and EE, the difference between CHO intake during training and matches, the difference between EI and CHO intake on match days vs. training days, and changes in body mass from before to after the study period. In all the analyses, the mean difference standardized by the between-subject standard deviation was used as the effect size (ES). The magnitude of the ES was evaluated as trivial (>0.2), small (>0.2 to 0.6), moderate (>0.6 to 1.2), large (>1.2 to 2.0), very large (>2.0 to 4.0), and extremely large (>4.0) (Hopkins et al., 2009). The statistical analysis was carried out with R, version 3.3.1.

Results

Quantification of Daily and Accumulative Weekly Load

An overview of the individual daily training and match load and the accumulative weekly load is presented in Tables 1 and 2, respectively.

Quantification of Energy and Macronutrient Intake

A comparison of daily energy and macronutrient intake is presented in Figure 1. Daily absolute and relative EI and CHO intake was significantly different across the 7-day period (all $P<0.05$). Specifically, players reported greater absolute and relative EI on day 2 (i.e. match day 1) compared with days 1 (both $P<0.05$ and both ES = 1.0, moderate) and 3 (both $P<0.05$ and both ES = 1.1, moderate). On day 5 (i.e. match day 2), players reported higher absolute and relative EI compared with days 1, 3, 4 and 6 (all $P<0.05$; ES for absolute EI equal to 1.9 (large), 1.9 (large), 1.8 (large), and 2.1 (very large); ES for relative EI equal to 1.4, 1.5, 1.6, 1.6 (all large)). Additionally, players reported higher absolute and relative EI on day 7 compared with day 4 (both $P<0.05$; ES = 0.9 (moderate) for absolute EI and 0.6 (small) for relative EI) as well as higher absolute EI on day 5 compared to day 2 ($P=0.03$; ES = 0.9, moderate).

In relation to CHO intake, both absolute (all $P<0.01$) and relative intake (all $P<0.01$) was greater on day 2 compared to days 1 (ES = 1.1 and 0.9 (both moderate), respectively for absolute and relative intake), 3 (ES = 1.5 and 1.3 (both large) respectively for absolute and relative intake), 4 (ES = 1.4 (large) and 1.2 (moderate), respectively for relative and absolute intake), and 6 (ES = 1.6 and 1.4 (both large), respectively for absolute and relative intake). On day 5, both absolute and relative CHO intakes were higher than days 1 (both $P<0.02$; ES = 1.5 and 1.3 respectively for absolute and relative intake, both large) and 6 (both $P<0.02$; ES = 1.1 and

1.1 respectively for absolute and relative intake, both moderate). Absolute CHO intake was also higher on day 5 compared to day 4 (P=0.05; ES = 2.0, large), but did not achieve significance when expressed relatively (P=0.06).

In contrast to energy and CHO intake, there was no significant difference between days in the reported absolute protein (P=0.29), relative protein (P=0.31), absolute (P=0.16) and relative fat (P=0.16) intake.

Energy and Macronutrient Intake on Training vs. Match Days

EI and EI relative to LBM were also greater (both P<0.05; ES = 2.2 (very large) and 1.7 (large), respectively for absolute and relative EI) on match days (3789 ± 532 kcal; 61.1 ± 11.4 $kcal \cdot kg^{-1}$ LBM) compared with training days (2956 ± 374 kcal; 45.2 ± 9.3 $kcal \cdot kg^{-1}$ LBM, respectively). Additionally, CHO intake and CHO intake relative to body mass were also greater (both P<0.05; ES = 1.8 (large) and 4.2 (very large), respectively for absolute and relative CHO, respectively, both large) on match days (330 ± 98 g; 6.4 ± 2.2 $g \cdot kg^{-1}$) compared with training days (508 ± 152 g; 4.2 ± 1.4 $g \cdot kg^{-1}$).

Carbohydrate intake during training and games

The mean quantity of CHO consumed during the two competitive matches (32.3 ± 21.9 $g.h^{-1}$; Player 1-6 data: 25.1, 24.8, 70.9, 29.9, 38.3 and 4.9 $g.h^{-1}$, respectively) was significantly higher ($P<0.05$) than that consumed during training sessions (3.1 ± 4.4 $g.h^{-1}$; Player 1-6 data: 0, 0.3, 11, 0, 5.7 and 1.6 $g.h^{-1}$, respectively), with an ES of 6.6 (extremely large). During training, 80 and 20% of the CHO consumed was provided from gels and fluid, respectively. During match play, 63 and 37% of the CHO consumed was provided from gels and fluids, respectively.

Energy Expenditure vs. Energy Intake

There were no significant differences ($P=0.16$; see Table 3) between average daily EE (3566 ± 585 kcal) and EI (3186 ± 367 kcal), although one player did exhibit markedly lower self-reported EI compared with EE (see player 6). Accordingly, players' body mass did not significantly change ($P=0.84$) from before (80.4 ± 7.9 kg) to after the 7-day study period (80.3 ± 7.9 kg).

Discussion

The aim of the present study was to simultaneously quantify EI, EE, training and match load across a 7-day in-season period. In order to study a weekly playing schedule representative of elite professional players, we studied players competing in the EPL during a weekly micro-cycle consisting of two match days and five training days. To our knowledge, we are also the first to report direct assessments of EE (using the DLW method) in an elite soccer team competing in the EPL and European competitions over a 7-day period. In relation to the specific players studied herein, our data suggest that elite players' daily energy expenditure can range from 3047 to 4400 kcal per day. Additionally, players also practice elements of CHO periodization such that absolute daily CHO intake and exogenous CHO feeding is greater on match days compared with training days.

Key parameters of the physical loading reported here is similar to that previously observed by our group during a two game per week micro-cycle (Anderson et al., 2015), albeit where five days was present between games as opposed to the two-day period studied here. Indeed, similar accumulative weekly high-speed running (1322 v 1466 m, respectively) and sprint (430 v 519 m, respectively) distance were observed. This result was expected given that such high-intensity loading patterns are largely reflective of game time as opposed to training time (Anderson et al., 2016). Interestingly, the weekly accumulative total distance reported here was less than that observed previously (26.4 v 32.5 km), a finding likely attributable to the greater frequency of training sessions completed by each player during the five-day interim period (Anderson et al., 2015). Such data reiterate how subtle alterations to the match and training schedule affects weekly loading patterns.

The mean daily EI and EE data reported here suggest that elite players are capable of matching overall weekly energy requirements. It is noteworthy, however, that despite no player experiencing body mass loss or gain during the study period, two players appeared to be under-reporting EI as evidenced by a mismatch between EI versus EE data. The mean daily EE (3566 ± 585 kcals) and EI (3186 ± 367 kcals) observed here agrees well that previously observed in professional Japanese players (3532 ± 432 and 3113 ± 581 kcal, respectively) where both DLW and 7-day food diaries were also used as measurement tools (Ebine et al., 2002). Although these authors did not provide any data related to physical loading, the similarity between studies is likely related to these researchers also studying a two-game per week playing schedule where consecutive games were also separated by two days. Interestingly, our EE data are much lower than that reported by our group for professional rugby players (5378 ± 645 kcal), thereby providing further evidence that nutritional guidelines for team sports should be specific to the sport and athlete in question (Morehen et al., 2016)

A limitation of the DLW technique is the inability to provide day-to-day EE assessments hence data are expressed as mean daily EE for the 7-day data collection period. Nonetheless, the players studied here appear to adopt elements of CHO periodization in accordance with the upcoming physical load and likely differences in day-to-day EE. For example, both absolute and relative daily energy and CHO intake was greater on match days (3789 ± 532 kcal and 6.4 ± 2.2 $g \cdot kg^{-1}$, respectively) compared with training days (2948 ± 347 kcal and 4.2 ± 1.4 $g \cdot kg^{-1}$, respectively). Such differences in daily EI also agrees with recent observations from adult professional players of the Dutch league (Bettonviel et al., 2016) where subtle differences were observed between match days, training days and rest days (3343 ± 909, 3216 ± 834 and 2662 ± 680 kcal, respectively). It is also noteworthy that we observed greater energy intake on day 7 (prior to another match undertaken on day 8) versus day 4 (prior to match day 2). Such differences may reflect additional energy intake that is consumed prior to and during travelling (i.e. snacks provided on the bus) to the away game on day 8. We also observed CHO ingestion was significantly lower during training sessions (3.1 ± 4.4 $g.min^{-1}$) compared with matches (32.3 ± 21.9 $g.min^{-1}$). It is, of course, difficult to ascertain whether such alterations to CHO fuelling patterns were a deliberate choice of the player and/or a coach (sport scientist) led practice or moreover, an unconscious choice.

In the context of a two game week, it is likely that players did not consume adequate CHO to optimize muscle glycogen storage in the day prior to and in recovery from the games (Bassau et al., 2002; Krustrup et al., 2006). This point is especially relevant considering the inability to fully replenish muscle glycogen content in type II fibres 48 h after match play, even when CHO intake is > 8 $g \cdot kg^{-1}$ body mass per day (Gunnarsson et al., 2013). In relation to match day itself, it is noteworthy that four players did not meet current CHO guidelines (30-60 $g.h^{-1}$) for which to optimize aspects of physical (Burke et al., 2011), technical (Ali & Williams, 2009; Russell et al., 2012) and cognitive (Welsh et al., 2002) performance. Interestingly, CHO intake during match play was highest in players 3 and 5 who also tended to be the players (midfielders) with the greatest physical load on match days. Positional differences may therefore contribute to habitual fuelling strategies. When taken together, data suggest that players may benefit from consuming greater amounts of CHO in the day prior to and in recovery from match play (so as to optimize muscle glycogen storage) as well as consumer greater amounts of CHO during exercise to maximize the aforementioned components of soccer performance.

Although we observed evidence of CHO periodization during the week, players reported consistent daily protein and fat intakes. Interestingly, absolute and relative daily protein intakes were higher (205 ± 30 g) than that reported two decades ago in British professional players (108 ± 26 g), whereas both CHO and fat intake were relatively similar (Maughan, 1997). Our observed daily protein intakes also agree well with those reported recently (150-200 g) in adult professional players from the Dutch league (Bettonviel et al., 2016). Such differences between eras are potentially driven by the increased scientific research and resulting athlete (and coach) awareness of the role of protein in facilitating training adaptations and recovery from both aerobic and strength training (Moore et al., 2014; McNaughton et al., 2016).

In summary, we simultaneously quantified for the first time the daily physical loading, EI and EE during a weekly micro-cycle of elite level soccer players from the English Premier League. Although players appear capable of matching daily energy requirements to EI, we also observed elements of CHO periodization in that players consumed higher amounts of CHO on match days versus training days. Whilst daily protein intake was consistent throughout the week, absolute daily protein intake was greater than previously reported in the literature. Moreover, CHO intakes were below that which is currently recommended for when players are completing 2 competitive games in close proximity to one another.

Acknowledgements

The authors would like to thank all of the participating players for the cooperation and commitments during all data collection procedures. We would also like to thank the team's coaches for cooperation during data collection.

Author Contributions

Each author contributed as follows: LA, GLC, RM, BD and JPM conceived and designed the experiments. LA, PO, JM, DR, AOB, JL performed sample collection. LA, PO, RJN, JM, RDM, CH, JRS performed analytical measures and related data analysis. LA and JPM wrote the manuscript and all authors revised and critically evaluated the manuscript for important intellectual content. All authors approved the final version of the manuscript prior to submission and are accountable for data accuracy and integrity.

References

Akenhead, R., Harley, J. A., & Tweddle, S.P. (2016). Examining the external training load of an English premier league football team with special reference to acceleration. *J Strength Cond Red*, *30*, 2424-2432.

Ali, A., & Williams, C. (2009). Carbohydrate ingestion and soccer skill performance during prolonged intermittent exercise. *J Sports Sci, 27*, 1499-1508.

Anderson, L., Orme, P., Di Michele, R., Close, G.L., Morgans, R., Drust, B., & Morton, J.P. (2015). Quantification of training load during one-, two- and three-game week schedules in professional soccer players from the English Premier League: implications for carbohydrate periodization. *J Sports Sci*, *4*, 1-10.

Anderson, L., Orme, P., Di Michele, R., Close, G.L., Milsom, J., Morgans, R., Drust, B., & Morton, J.P. (2016). Quantification of Seasonal Long Physical Load in Soccer Players With Different Starting Status From the English Premier League: implications for Maintaining Squad Physical Fitness. *Int J Sports Physiol Perform, epub ahead of print.*

Areta, J.L., Burke, L.M., Ross, M.L., Camera, D.M., West, D.W., Broad, E.M., Coffey, V.G. (2013). Timing and distribution of protein ingestion during prolonged recovery from resistance exercise alters myofibrillar protein synthesis. *J Physiol, 591,* 2319-2331.

Bartlett, J.D., Hawley, J.A., & Morton, J.P. (2015). Carbohydrate availability and exercise training adaptation: Too much of a good thing? *Eur J Sport Sci, 15,* 3-12.

Bussau, V.A., Fairchild, T.J., Rao, A., Steele, P., & Fournier, PA. (2002). Carbohydrate loading in human muscle: an improved 1 day protocol. *Eur J Appl Physiol, 87,* 290-295.

Bettonviel, A.EO., Brinkmans, N.Y.J., Russcher, K., Wardenaar, F.C., & Witard, O.C. (2016). Nutritional status and daytime pattern of protein intake on match, post-match, rest and training days in senior professional and youth elite soccer players. *Int J Sport Nutr Exerc Metab, epub ahead of print.*

Berman, E.S., Fortson, S.L., Snaith, S.P., Gupta, M., Baer, D.S., Chery, I., Blanc, S., Melanson, E.L., Thompson, P.J., & Speakman, J.R. (2012). Direct analysis of delta2H and delta180 in natural and enriched human urine using laser-based, off-axis integrated cavity output spectroscopy. *Anal Chem*, *84*, 9768-9773.

Braakhuis, A.J., Meredith, K., Cox, G.R., Hopkins, W.G., & Burke, L.M. (2003). Variability in estimation of self-reported dietary intake data from elite athletes resulting from coding by different sports dietitians. *International Journal of Sport Nutrition*, *13,* 152-165.

Bradley, P.S., Sheldon, W., Wooster, B., Olsen, P., Boanas, P., & Krustrup, P. (2009). High-intensity running in English FA Premier League soccer matches. *J Sports Sci, 27,* 159-168.

Burke, L.M., Hawley, J.A., Wong, S.H., & Jeukendrup, A.E. (2011). Carbohydrates for training and competition. *J Sports Sci*, *29,* 17-27.

Burke, L.M., Loucks, A.B., & Broad, N. (2006). Energy and carbohydrate for training and recovery. *J Sports Sci, 24,* 675-685.

Bush, M., Barnes, C., Archer, D.T., Hogg, B., & Bradley, P.S. (2015). Evolution of match performance parameters for various playing positions in the English Premier League. *Hum Mov Sci, 39,* 1-11.

Chamari, K., Haddad, M., Wong del, P., Dellal, A., & Chaouachi, A. (2012). Injury rates in professional soccer players during Ramadan. *J Sports Sci, 30,* 93-102.

Craig, H. (1961). Standard for Reporting Concentrations of Deuterium and Oxygen-18 in Natural Waters. *Science, 133,* 1833-1834.

Di Salvo, V., Collins, A., McNeil, B., & Cardinale, M. (2006). Validation of ProZone®: A new video-based performance analysis system. *Int J Perf Anal Sport, 6,* 108-109.

Di Salvo, V., Gregson, W., Atkinson, G., Tordoff, P., & Drust, B. (2009). Analysis of high intensity activity in Premier League soccer. *Int J Sports Med, 30*, 205-212.

Di Salvo, V., Baron, R., González-Haro, Gormasz, C., Pigozzi, F., & Bachl, N. (2010). Sprinting analysis of elite soccer players during European Champions League and UEFA Cup matches. *J Sports Sci*, *28,* 1489-1494.

Ebine, N., Rafamantanantsoa, H.H., Nayuki, Y., Yamanaka, K., Tashima, K., Ono, T., Saitoh, S., & Jones, P.J. (2002). Measurement of total energy expenditure by the doubly labeled water method in professional soccer players. *J Sports Sci, 20,* 391-397.

Gunnarsson, T.P., Bendiksen, M., Bischoff, R., Christensen, P.M., Lesivig, B., Madsen, K., … Bangsbo, J. (2013). Effect of whey protein- and carbohydrate-enriched diet on glycogen resynthesis during the first 48 h after a soccer game. *Scand J Med Sci Sports*, *23*, 508-515.

Hawley, J.A., & Morton, J.P. (2014). Ramping up the signal: promoting enurance training adaptation in skeletal muscle by nutritional manipulation. *Clin Exp Pharmacol Physiol, 41, 608-613.*

Impey, S.G., Hammon, K.M., Shepherd, S.O., Sharples, A.P., Stewart, C., Limb, M., Smith, K., Philp, A., Jeromson, S., Hamilton, D.L., Close, G.L., & Morton, J.P. (2016). Fuel for the work required: a practical approach to amalgamating train-low paradigms for endurance athletes. *Physiol Rep, 4,* e12803.

Jeukendrup, A. (2014). A step towards personalized sports nutrition: carbohydrate intake during exercise. *Sports Med, 44,* 25-33.

Krustrup, P., Mohr, M., Steensberg, A., Bencke, J., Kjer, M., & Bangsbo, J. (2006). Muscle and blood metabolites during a soccer game: Implications for sprint performance. *Med Sci Sports Exerc, 38,* 1165-1174.

Malone, J.J., Di Michele, R., Morgans, R., Burgess, D., Morton, J.P., & Drust, B. (2015). Seasonal training-load quantification in elite English premier league soccer players. *Int J Sports Physiol Perform, 10,* 489-497.

Martin, C.K., Han, H., Coulon, S.M., Allen, H.R., Champagne, C.M., & Anton, S.D. (2009). A novel method to remotely measure food intake of free-living people in real-time: The remote food photography method (RFPM). *B J Nutr, 101,* 446-456.

Maughan, R.J. (1997). Energy and macronutrient intakes of professional football (soccer) players. *Br J Sports Med*, *31*, 45-47.

Morehen, C.M., Bradley, W.J., Clarke, J., Twist, C., Hambly, C., Speakman, J.R., Morton, J.P., & Close, G.L. (2016). The assessment of total energy expenditure during a 14-day 'in-season' period of profressional rugby league players using the Doubly Labelled Water method. *Int J Sport Nutr Exerc Metab, epub ahead of print.*

Macnaughton, L.S., Wardle, S.L., Witard, O.C., McGlory, C., Hamilton, D.L., Jeromson, S., Lawrence, C.E., Wallis, G.A., & Tipton, K.D. (2016). The response of muscle protein synthesis following whole-body resistance exercise is greater following 40 g than 20 g of ingested whey protein. *Physiol Rep*, *4*, e12893.

Milsom, J., Naughton, R., O'Boyle, A., Iqbal, Z., Morgans, R., Drust, B., & Morton, J.P. (2015). Body composition assessment of English Premier League soccer players: a comparative DXA analysis of first team, U21 and U18 squads. *J Sports Sci*, *33*, 1799-1806.

Moore, D.R., Churchward-Venne, T.A., Witard, O., Breen, L., Burd, N.A., Tipton, K.D., & Phillips, S.M. (2014). Protein ingestion to stimulate myofibrillar protein synthesis requires greater relative protein intakes in healthy older versus younger men. *J Gerontol A Biol Sci Med Sci, 70*, 57-62.

Morgans, R., Orme, P., Anderson, L., Drust, B., & Morton, J.P. (2014). An intensitve Winter fixture schedule induces a transient fall in salivary IgA in English premier league soccer players. *Res Sports Med, 22,* 346-354.

Nagy, K. (1983). *The Doubly Labelled Water (3HH180) Method: a Guide to its Use.* Los Angeles, CA: UCLA Publication 12-1417.

Reilly, T., & Thomas, V. (1979). Estimated daily energy expenditures of professional association footballers. *Ergonomics, 22,* 541-548.

Russell, M., Benton, D., & Kingsley, M. (2012). Influence of carbohydrate supplementation on skill performance during a soccer match simulation. *J Sci Med Sport, 15,* 348-354.

Russell, M., Sparkes, W., Northeast, J., Cook, C.J., Love, T.D., Bracken, R.M., & Kilduff, L.P. (2016). Changes in acceleration and deceleration capacity throughout professional soccer match play. *J Strength Cond Res, 30,* 2839-2844.

Schoeller, D.A. (1988). Measurement of energy expenditure in free-living humans by using doubly labeled water. *J Nutri, 118,* 1278-1289.

Schoeller, D. A., Ravussin, E., Schutz, Y., Acheson, K. J., Baertschi, P., & Jequier, E. (1986). Energy expenditure by doubly labeled water: validation in humans and proposed calculation. *Am J Physiol, 250,* R823-830.

Speakman, J.R. (1997). *Doubly Labelled Water; Theory and Practice.* London: Chapman & Hall.

Thompson, F., & Subar, A. (2008). Dietary assessment methodology. In A. M. Coulston & C.J. Boushey (Eds.), *Nutrition in the prevention and treatment of disease* (pp. 3-39). San Diego, CA: Academic Press.

Welsh, R.S., Davis, J.M., Burke, J.R., & Williams, H.G. (2002). Carbohydrates and physical/mental performance during intermittent exercise to fatigue. *Med Sci Sports Exerc, 34,* 723-731.

Table 1. Training and match load variables (representative of average daily data in bold and individual data from players 1-6) completed in the 7-day testing period. Running distance = distance covered between 14.4-19.8 km/h, high-speed running distance = distance covered between 19.8-25.2 km/h and sprinting distance = distance covered >25.2 km/h. Each player's position is shown in brackets. CF=Centre Forward, WD=Wide Defender, WM=Wide Midfielder, CDM=Central Defending Midfielder, CAM= Central Attacking Midfielder and CD=Central Defender.

	Day						
	1	**2**	**3**	**4**	**5**	**6**	**7**
Duration (min)	**52 ± 26**	**97 ± 42**	**17 ± 29**	**46 ± 0**	**76 ±39**	**8 ± 20**	**24 ± 0**
1 (CF)	63	125	0	46	71	0	24
2 (WD)	63	125	0	46	96	0	24
3 (WM)	63	55	34	46	96	0	24
4 (CDM)	63	125	0	46	0	48	24
5 (CAM)	63	125	0	46	96	0	24
6 (CD)	0	32	68	46	96	0	24
Total Distance (m)	**2865 ± 1494**	**9746 ± 5098**	**1036 ± 1758**	**2187 ± 355**	**8827 ± 4874**	**715 ± 1751**	**1061 ± 186**
1 (CF)	3266	11631	0	1964	6981	0	1076
2 (WD)	2679	11798	0	2162	10302	0	1022
3 (WM)	3384	4562	1978	2727	12793	0	1092
4 (CDM)	3603	13513	0	1680	0	4290	737
5 (CAM)	4258	14730	0	2356	13153	0	1306
6 (CD)	0	2243	4240	2234	9733	0	1131
Av. Speed (m/min)	**45.9 ± 23.8**	**100.7 ± 50.7**	**20.1 ± 31.2**	**47.8 ± 7.8**	**95.8 ± 49.7**	**14.9 ± 36.6**	**45.2± 5.0**
1 (CF)	52.1	105.7	0	42.8	97.9	0	44.2
2 (WD)	44.1	109.4	0	47.5	106.8	0	42.5
3 (WM)	54.0	132.6	57.4	59.8	132.7	0	46.4
4 (CDM)	57.5	122.2	0	36.6	0	89.5	38.4
5 (CAM)	68	134.2	0	51.4	136.4	0	53.6
6 (CD)	0	0	63.4	48.8	100.9	0	46.4
Running Distance (m)	**171 ± 122**	**1528 ± 1033**	**66 ± 114**	**91 ± 77**	**1483 ± 1061**	**67 ± 163**	**0**
1 (CF)	186	1490	0	43	845	0	0
2 (WD)	115	1754	0	108	1646	0	0
3 (WM)	166	717	123	225	2606	0	0
4 (CDM)	184	2513	0	3	0	399	1
5 (CAM)	375	2686	0	107	2732	0	0
6 (CD)	0	6	275	57	1067	0	0
High-Speed Running Distance (m)	**27 ± 25**	**637 ± 446**	**5 ± 8**	**24 ± 35**	**614 ± 421**	**15 ± 37**	**0**
1 (CF)	31	739	0	8	473	0	0
2 (WD)	21	906	0	36	665	0	0
3 (WM)	4	317	12	90	1081	0	0
4 (CDM)	34	592	0	0	0	90	0
5 (CAM)	70	1270	0	8	1081	0	0
6 (CD)	0	0	17	0	386	0	0
Sprinting Distance (m)	**2 ± 4**	**196 ± 146**	**0**	**5 ± 7**	**273 ± 167**	**0**	**0**
1 (CF)	0	332	0	0	157	0	0
2 (WD)	0	226	0	14	325	0	0
3 (WM)	0	113	0	14	379	0	0
4 (CDM)	0	119	0	0	0	0	0
5 (CAM)	10	386	0	0	406	0	0
6 (CD)	0	0	0	0	95	0	0

Table 2. Accumulative training and match load variables (representative of average data in bold and individual data from players 1-6) completed in the 7-day testing period. Running distance = distance covered between 14.4-19.8 km/h, high-speed running distance = distance covered between 19.8-25.2 km/h and sprinting distance = distance covered >25.2 km/h. Each player's position is shown in brackets. CF=Centre Forward, WD=Wide Defender, WM=Wide Midfielder, CDM=Central Defending Midfielder, CAM= Central Attacking Midfielder and CD=Central Defender.

	Matches	**Training**	**Total**
Duration (min)	**142 ± 45**	**178 ± 22**	**321 ± 33**
1 (CF)	166	163	328
2 (WD)	191	163	353
3 (WM)	117	202	319
4 (CDM)	94	211	305
5 (CAM)	191	162	353
6 (CD)	96	169	266
Total Distance (m)	**16677 ± 5914**	**9760 ± 1852**	**26438 ± 5408**
1 (CF)	16937	7981	24918
2 (WD)	20602	7362	27963
3 (WM)	15489	11047	26536
4 (CDM)	11511	12311	23823
5 (CAM)	25792	10012	35804
6 (CD)	9733	9849	19582
Running Distance (m)	**2920 ± 1403**	**485 ± 202**	**3405 ± 1501**
1 (CF)	2257	307	2564
2 (WD)	3361	263	3624
3 (WM)	3182	655	3837
4 (CDM)	2400	701	3101
5 (CAM)	5253	647	5900
6 (CD)	1067	338	1405
High-Speed Running Distance (m)	**1218 ± 682**	**104 ± 46**	**1322 ± 717**
1 (CF)	1151	100	1251
2 (WD)	1519	108	1628
3 (WM)	1383	122	1505
4 (CDM)	592	124	716
5 (CAM)	2276	153	2429
6 (CD)	386	17	403
Sprinting Distance (m)	**423 ± 269**	**7 ± 7**	**430 ± 274**
1 (CF)	489	1	490
2 (WD)	552	14	566
3 (WM)	493	14	507
4 (CDM)	119	0	119
5 (CAM)	793	10	803
6 (CD)	95	0	95

Table 3. Individual differences of average daily energy intake vs. average daily energy expenditure and body mass changes from Day 0 to Day 8. Each player's position is shown in brackets. CF=Centre Forward, WD=Wide Defender, WM=Wide Midfielder, CDM=Central Defending Midfielder, CAM= Central Attacking Midfielder and CD=Central Defender.

Player	**Energy Intake (kcals)**	**Energy Expenditure (kcals)**	**Body Mass Day 0 (kg)**	**Body Mass Day 8 (kg)**
1 (CF)	2817	3047	90.1	89.2
2 (WD)	2905	3050	73.2	73.7
3 (WM)	3563	4140	71.0	71.1
4 (CDM)	3166	3179	80.1	79.1
5 (CAM)	3701	3580	78.9	78.1
6 (CB)	2961	4400	89.0	88.9
Mean ± SD	**3186 ± 367**	**3566 ± 585**	**80.4 ± 7.9**	**80.0 ± 7.6**