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Abstract

While traditional approaches to dietary analysis in athletes have focused on total daily energy and macronutrient intake, it is now thought that daily distribution of these parameters can also influence training adaptations. Using seven-day food diaries, we quantified the total daily macronutrient intake and distribution in elite youth soccer players from the English Premier League in U18 (*n*=13), U15/16 (*n*=25) and U13/14 squads (*n*=21). Total energy (43.1±10.3, 32.6±7.9, 28.1±6.8 $kcal \cdot kg^{-1} \cdot day^{-1}$), CHO (6±1.2, 4.7±1.4, 3.2±1.3 $g \cdot kg^{-1} \cdot day^{-1}$) and fat (1.3±0.5, 0.9±0.3, 0.9±0.3 $g \cdot kg^{-1} \cdot day^{-1}$) intake exhibited hierarchical differences ($P<0.05$) such that U13/14>U15/16>U18. Additionally, CHO intake in U18s was lower ($P<0.05$) at breakfast, dinner and snacks when compared with both squads but no differences were apparent at lunch. Furthermore, the U15/16s reported lower relative daily protein intake than the U13/14s and U18s (1.6±0.3 vs. 2.2±0.5, 2.0±0.3 $g \cdot kg^{-1}$). A skewed distribution ($P<0.05$) of daily protein intake was observed in all squads, with a hierarchical order of dinner (~0.6 $g \cdot kg^{-1}$) > lunch (~0.5 $g \cdot kg^{-1}$) > breakfast (~0.3 $g \cdot kg^{-1}$). We conclude elite youth soccer players do not meet current CHO guidelines. Although daily protein targets are achieved, we report a skewed daily distribution in all ages such that dinner>lunch>breakfast. Our data suggest that dietary advice for elite youth players should focus on both total daily macronutrient intake and optimal daily distribution patterns.

Introduction

The function of soccer academies is largely to produce players who can progress to and represent the club's senior first team, and thereby reduce the requirement for clubs to buy or sell players in an attempt to achieve financial targets (Wrigley *et al.,* 2014). To support the high training loads (Wrigley *et al.,* 2012) and developmental goals such as muscle hypertrophy (Milsom *et al.,* 2015), it is essential players consume the correct quantity and type of macronutrients. Few studies have investigated habitual energy intakes and dietary habits of elite youth soccer players (Boisseau *et al.,* 2002 & 2007; LeBlanc *et al.,* 2002; Ruiz *et al.,* 2005; Iglesias-Gutierrez *et al.,* 2005) with just two in the UK (Russell and Pennock, 2011; Briggs *et al.,* 2015). These studies have typically been limited to reports of total daily energy and macronutrient intake, often concluding that elite youth soccer players habitually don't meet their energy requirements (Boisseau *et al.* 2002; LeBlanc *et al.*, 2002; Ruiz *et al.,* 2005; Russell and Pennock, 2011; Briggs *et al.*, 2015).

In addition to the quantification of daily energy and macronutrient intake, it is important to consider timing of intake in relation to training sessions (Burke, 2010; Mori, 2014), main meals (Garaulet and Gomez-Abellan, 2014; Johnston, 2014) and sleep (Lane *et al.,* 2015). Whilst this is most well documented for carbohydrate (CHO) intake in order to fuel training and matches (Goedecke *et al.,* 2013; Jeukendrup, 2014) and promote glycogen re-synthesis (Zehnder *et al.,* 2001; Gunnarsson *et al.,* 2013), recent data suggests that the daily distribution of protein intake is critical for optimizing components of training adaptations such as muscle protein synthesis (MPS) (Areta *et al.,* 2013; Mamerow *et al.,* 2014). Recent data has highlighted the importance of quantity and timing of protein intake in elite youth soccer players. Milsom *et al.* (2015) demonstrated that such populations typically present with approximately 6 kg less lean muscle mass than adult professional soccer players. When taken together, these data suggest that dietary surveys of elite youth soccer players should not only quantify total daily energy and macronutrient intake but should also report the timing of nutrient ingestion, thereby having important practical implications for fuelling adequately, promoting training adaptations and optimizing recovery.

Therefore, the aims of the present study were two-fold: 1) to quantify the total daily energy and macronutrient intakes of elite youth UK academy players of different ages (U13/14, U15/16 and U18 playing squads) and 2) to quantify the daily distribution of energy and macronutrient intake. In accordance with the higher absolute body masses and training loads of the U18 squads (Wrigley *et al.*, 2012), we hypothesised that this squad would report higher absolute daily energy and macronutrient intakes in comparison to the U13/14s and U15/16s. Furthermore, based on the habitual eating patterns of both athletic and non-athletic populations (Mamerow *et al.*, 2014), we hypothesised that all squads would report an uneven daily distribution of macronutrient intakes, particularly for daily protein intake.

Methodology

Participants

Elite youth soccer players were recruited from a local English Premier League (EPL) club's academy. Researchers provided a presentation and participant information sheets to invite players from the U13-18s to participate in the study. Ninety-one players were initially recruited, however 32 were withdrawn due to incomplete diary entry, leaving a sample size of 59. All participants gave informed consent and ethical permission was obtained from the Liverpool John Moores University Ethics Committee.

Participants were subsequently categorised into the following squads; U18s (*n*=13), U15/16 (*n*=25) and U13/14 (*n*=21). The mean (±SD) body mass (determined by scale mass – Seca, Hamburg, Germany) and height (determined by stadiometry) were recorded to the nearest 0.1kg and cm, respectively, for each squad and are displayed in Table 1, along with habitual training time albeit collected 2-3 weeks after this study period (Brownlee *et al.* Unpublished Data). Data collection occurred during a 7 day training period of the 2014-15 season, during which no competitive matches took place.

Dietary Intake

Participants were asked to record everything they consumed in a food diary for 7-consecutive days. This time frame was justified by previous research suggesting that 7-days provides a more accurate estimation of habitual nutritional intake than a single- or 4-day recording (Magkos & Yannakoulia, 2003). Additionally, unpublished pilot research on the current study's population displayed a high completion rate (75%) over the 7-days. To promote high ecological validity, researchers made no attempt to influence the player's diets. Upon giving consent, players attended a presentation that gave detailed instructions on how to fill out the dietary diary. Parents and guardians of the U13/14s also attended, as it was evidenced from pilot research that they were likely to be responsible for completion of the diaries at this age. Participants were asked to provide as much detail as possible, including the type of day it was with respect to their soccer activity (rest, match, or training day), the commercial brand names of the food/drink, cooking/preparation methods, and time of consumption.

Time of consumption was used to distinguish between meals; breakfast (main meal consumed between 6-9.30am), lunch (main meal consumed between 11.30-1.30pm), dinner (main meal consumed between 5-8pm), and snacks (foods consumed between main meals). Additionally in table 2 the time and frequency of snack consumption for each team is displayed. Supplements were defined as foods/drinks/powders that were purposefully taken to provide an additional source of any one or combination of macronutrients (e.g. Whey Protein). Participants were asked to quantify the portion of the foods and fluids consumed by using standardised household measures or, where possible, referring to the weight/volume provided on food packages, or by providing the number of items of a predetermined size. Upon return of the food diary the primary researcher checked for any cases of missing data and asked participants for clarification.

Data Analysis

Food diary data was analysed using Nutritics software (version 3.74 professional edition, Nutritics Ltd., Co. Dublin, Ireland). All analyses were carried out by a single trained researcher so that potential variation of data interpretation was minimised (Deakin, 2000). Total absolute, and relative to body mass (BM), intakes of energy (kcal), CHO, protein and fats were calculated. All data were assessed for normality of distribution according to the Shapiro-Wilk's test. Statistical comparisons between squads' total energy and macronutrient intakes were performed according to a one-way between-groups analysis of variance (ANOVA) or, for non-parametric data, the Kruskal-Wallis test. Where significant differences of the ANOVA were present, Tukey post-hoc analysis was conducted to locate specific differences. For non-normal data, post-hoc analysis was performed using multiple Mann-Whitney U tests with a Bonferroni adjustment. For energy and macronutrient distribution across separate meals, a two-way ANOVA was employed and a Tukey post-hoc analysis was conducted where appropriate. Where a significant main difference for age was reported, a one-way ANOVA or, the Kruskal-Wallis test was performed, to assess at which meal the difference occurred. All analyses were completed using SPSS for Windows (version 20, SPSS Inc., Chicago, IL) where $P<0.05$ was indicative of statistical significance.

Data is presented as mean±SD. In the results section, *absolute* refers to the total absolute daily intake and *relative* refers to when the absolute data has been normalized to each participants' BM (i.e. $g \cdot kg^{-1}$ BM).

Results

Daily Energy and macronutrient total and relative daily intake

No significant difference was found for absolute daily energy ($P=0.92$), CHO ($P=0.70$) or fat ($P=0.18$) intake between squads. However, absolute daily intake of protein showed a significant difference ($P<0.01$) between squads, both the U13/14s and U15/16s squads reported lower intakes than the U18 squad ($P=0.01$). In contrast to the absolute data, significant differences were observed for all variables when expressed in relative amounts ($P<0.05$). For relative energy, CHO and fat intake, the U13/14s values were significantly higher compared to both the U15/16s and U18s ($P<0.01$ for all comparisons). The U13/14 and U18 squads were both significantly higher in relative protein compared to the U15/16s ($P<0.01$). Additionally, the U15/16s had a significantly higher relative CHO intake in comparison to the U18s ($P=0.01$) (Table 3).

The distribution of energy and macronutrients across separate meals

A significant difference for distribution across meals was found for all variables for both absolute and relative intake (*P*<0.01). For energy, both absolute and relative intake at breakfast was significantly lower than intake at lunch and dinner (*P*<0.01). Dinner was significantly higher (*P*<0.01) than snacks whether expressed as absolute or relative. CHO intake at breakfast was significantly lower than lunch and snacks for both absolute and relative intake (*P*<0.05), and for absolute dinner intake (*P*=0.03), but not for relative intake (*P*=0.06) (Figure 1).

Protein distribution was found to be significant between all meals (*P*<0.05) for absolute intake, and PRO at breakfast was significantly lower compared to both lunch and dinner for relative intake (*P*<0.01). Additionally, relative protein intake at dinner was significantly higher compared to snacks (*P*<0.01). For fat distribution, both absolute and relative intake at dinner was significantly higher (*P*<0.01) than both breakfast and snacks (*P*<0.01) (Figure 1).

A significant difference was observed between-squads for distribution of absolute CHO and PRO intake (*P*<0.01). Specifically, for breakfast and lunch the U18s reported a significantly higher intake of absolute PRO intake compared with the U13/14s and U15/16s (*P*<0.01), but when considering relative protein, the U13/14s had a significantly higher (*P*<0.05) intake at dinner and snacks compared to their older counterparts, which was also true for relative fat intake. Furthermore, a significantly lower intake of both absolute and relative CHO in comparison to the U15/16s at breakfast was observed (*P*<0.01), and with dinner and snacks but only for relative intake compared to the younger groups (Figure 1). The U13/14s have a significantly higher intake of relative energy for every meal compared to the U15/16s and U18s (*P*<0.05).

Supplements.

No statistical analysis was performed for supplements as intake within the U13/14 and U15/16 (*n*=3) was negligible. Within the U18s mean daily intake from supplements were: Energy 89.2±110.4 kcal, CHO 2.5±6.5 g, Protein 15.1±17.3 g, and Fat 0.8±1.1 g.

Discussion

The aims of the present study were to simultaneously quantify the total daily macronutrient intake and daily distribution in elite youth soccer players of differing ages. With the exception of protein, we observed no significant difference in total absolute energy and macronutrient intake between squads. However, differences in macronutrient intake were readily apparent when expressed relative to BM. We also report for the first time a skewed daily distribution of macronutrient intakes in elite male youth soccer players (irrespective of age), an effect that was especially pertinent for protein intake. Given the requirement for young soccer players to gain lean muscle mass, such data may have practical implications for helping to promote training adaptations.

The values reported here for both total daily energy and CHO intake compare well to those previously reported for players of similar ages (Boisseau *et al.,* 2002; Ruiz *et al.,* 2007). For example, Boisseau *et al*. (2002) reported energy intakes of 38.9±4.4 kcal·kg^{-1}·day^{-1} and Ruiz *et al.* (2007) reported CHO intakes of 5.9±0.4 g·kg^{-1}·day^{-1}, both of which are similar to the U15/16s in the present study (Table 3). A consistent theme within the literature appears to be that elite youth soccer players consume lower energy intakes than likely daily energy requirements, thus potentially compromising performance. While no differences between absolute energy and CHO intake between squads were observed, large differences were apparent when expressed relative to BM. Indeed, higher CHO intakes in the U13/14 squads (6±1.2 $g\cdot kg^{-1}\cdot day^{-1}$) compared with both the U15/16s (4.7±1.4 $g\cdot kg^{-1}\cdot day^{-1}$) and U18s (3.2±1.3 $g\cdot kg^{-1}\cdot day^{-1}$) were found. Carbohydrate requirements for adult athletes are an evolving topic within sports nutrition and there is debate within the literature of the optimal approach. Currently, soccer players are recommended to consume 6-10 $g\cdot kg^{-1}\cdot day^{-1}$ to support training and match demands (Burke *et al.*, 2006). Conversely, recent evidence has suggested that athletes (albeit adult populations) may benefit from strategically training with lower CHO availability during carefully chosen sessions (through manipulation of CHO intake and/or timing of training) to enhance training adaptations (i.e. increased mitochondrial biogenesis) (Bartlett *et al.*, 2013; 2015). Given the obvious developmental goals of youth soccer players and the low CHO intakes reported here and previously (Ruiz *et al.*, 2007), these data suggest that youth soccer players are likely under consuming daily CHO and do not meet current daily targets. However, given that these guidelines are for adult populations and there are currently no available CHO guidelines for elite youth athletes, further research is required.

Distribution of CHO intake showed a typically lower intake at breakfast, particularly for the U18s, who would have a protein (e.g. eggs) based breakfast in comparison to the schoolboys (U13/14s and U15/U16s), who typically had cereal/toast. In the two schoolboy squads, bread and cereal were the most common CHO choices, similar to the findings of Iglesias-Gutierrez *et al.* (2012). These CHO choices were often chosen at breakfast (cereal), lunch (sandwiches) and snacks (toast). In contrast, the U18s would have cooked meals at breakfast and lunch, therefore not relying on a school / homemade meal.

In relation to protein, marked differences in the total absolute daily intake were observed between squads where the U18s were higher than the U13/14s and U15/16s (142±24 vs. 97±21 vs. 96±24 g, respectively). However, when this value was standardised for BM, the U13/14s reported higher values than the U15/16s and U18s (2.2±0.4 vs. 1.6±0.3 vs. 2.0±0.3 $g \cdot kg^{-1}$, respectively) (Table 3). Such absolute and relative values are comparable to previous findings in similar populations (Boisseau *et al.*, 2002; Ruiz *et al.*, 2007; Russell & Pennock, 2011; Briggs *et al.*, 2015) and are also considerably higher than current national dietary reference values of 0.8 $g \cdot kg^{-1} \cdot day^{-1}$ (Department of Health, 1991). The most popular source of protein for all ages was poultry while eggs were only a main choice for the U18s. Similar to the CHO choices, this is likely a reflection of the U18s being provided with a cooked breakfast daily at the academy whereas the younger squads tended to consume cereal based breakfasts at home. To the authors' knowledge, only one research group has assessed the protein requirements of adolescent soccer players (Boisseau *et al.*, 2002 & 2007), using a nitrogen balance methodology. Results demonstrated that protein requirements of players aged 13-15 years range between 1.4-1.6 $g \cdot kg^{-1} \cdot day^{-1}$ (Boisseau *et al.*, 2002 & 2007), which is similar to current guidelines for adult athletes (1.3–1.8 $g \cdot kg^{-1} \cdot day^{-1}$) (Phillips and Van Loon, 2014). Therefore, in contrast to CHO, it appears that elite youth soccer players are successful in achieving daily protein requirements.

The distribution of daily protein intake may be a more important aspect of an athlete's nutritional strategy than the total daily intake. Recent data has highlighted that distorted protein intake distribution across meals (skewed to higher intake at dinner) in an adult population results in reduced MPS stimulation in comparison to a stable protein intake (~30 g) at each main meal (breakfast, lunch and dinner) even when total absolute intake is matched (Mamerow *et al.*, 2014). The distribution of protein intake at different meals was skewed for all squads in a hierarchical order of dinner>lunch>breakfast (Figure 1). In relation to optimal absolute protein dose, Witard *et al.* (2013) has previously reported that a single meal of ≥20g high quality fast-digesting protein is necessary to induce maximal rates of MPS. Therefore, it could be suggested that some players were under-consuming protein at specific meal times. For example, the U13/14s and U15/16s consumed 17±5 g and 15±4 g, respectively, at breakfast in comparison to the U18s who consumed 25±5 g. Conversely, Murphy *et al.* (2014) recently suggested that a protein content of 0.25-0.3 $g \cdot kg^{-1}$ BM per meal, that has high leucine content and is rapidly digestible, can achieve optimal MPS. Therefore, all squads would be achieving that value at each meal and consequently, the finding of <20 g absolute doses at certain meals may be inconsequential. However, a caveat to this paper is that the sources of habitual protein intakes for some squads would likely result in sub-optimal leucine contents. For example, whereas the U18s consume a protein based breakfast (i.e. eggs), the U13/14s and U15/16s intake of protein at breakfast was largely derived from adding milk to a predominantly CHO based breakfast (e.g. cereals, bread). Such pattern of breakfast choices in these squads is also in accordance with breakfast choices of children from the general population (Alexy *et al.*, 2010). Therefore, the schoolboys have not yet adopted a more sports specific diet. Similar to breakfast, the U18s have a significantly higher absolute protein intake at lunch in comparison to their younger counterparts (46±11 vs. 27±7 vs 29±9 g, respectively), but CHO intake was similar across all squads for lunch and dinner (Figure 1).

Potential reasons for this difference in macronutrient intake and distribution between squads is likely related to the fact that the U18s are full-time soccer players and it is mandatory for players to consume breakfast and lunch at the academy on days they attend (5/6 days·week^{-1}). Consequently, the club has greater control over the food and beverages the U18s can choose from. In contrast, the schoolboys will have meals provided by the school they attend or packed lunches from home, so the influence of the club is considerably reduced. When youth players are promoted to full-time U18 squad status, muscle hypertrophy is a key training goal (Milsom et al., 2015), which may result in players being encouraged to increase protein consumption to support resistance-training hypertrophy programmes (Phillips et al., 2014).

Distribution of snacks differed between squads (Table 2) and it would appear that this is consequence of differing training times between squads. The fulltime U18s trained in the morning (~10.30am) and only consumed 6% of their snacks during this period. In comparison, the school boy squads habitually train in the evening (~5pm) and consumed ~25% of their snacks during the morning period. This disparity of snack distribution across squads in the morning period may simply be due to the U18s being out training and are therefore restricted in what they can consume.

A limitation of the current study is the use of food dairies to analyze nutritional habits, and indeed, previous research has shown a potential under-reporting effect of up to 20% (Burke *et al.,* 2001). However, even when accounting for potential under-reporting effects, it would appear that the current populations would still be under-fueling for performance in accordance with current literature (Burke *et al.*, 2006). To address this hypothesis, future research should accurately quantify the energy expenditure within elite youth soccer players through a variety of techniques such as doubly labeled water and accurate monitoring of training load through GPS technology. Additionally, the sample population for the present study was taken from a single EPL academy, and therefore may not be truly representative of elite players based at other clubs.

In conclusion, we provide novel data by simultaneously reporting both the total and daily distribution of macronutrient intakes in elite youth soccer players of differing ages. In agreement with previous authors, we report that soccer players are not meeting current CHO guidelines (especially U18s) though daily protein targets are readily achieved. However, we also report a skewed daily macronutrient distribution in all ages, an effect that was particularly evident for daily protein targets. In this regard, the smallest protein intakes were typically reported at breakfast and snacks whereas the largest intakes were reported in the evening meal. Given the requirement for both optimal energy availability and protein intake to support muscle hypertrophy, our data have important practical implications and suggest that key dietary goals for elite youth players should focus on both total daily macronutrient intake and optimal daily distribution patterns.

Acknowledgments

All authors contributed to the design of the study; RN collected and analyzed all data; RN, JA, IGD, JPM, & EM drafted the manuscript; All authors critically revised the manuscript; All authors approved the final manuscript for publication. There are no conflicts of interest to disclose.

References

Alexy, U., Wicher, M., & Kersting, M. (2010). Breakfast trends in children and adolescents: frequency and quality. *Public Health Nutrition, 13(11)*, 1795–1802.

Areta, J. L., Burke, L. M., Ross, M. L., Camera, D. M., West, D. M., Broad, E. M., Jeacocke, N. A., Moore, D. R., Stellingwerff, T., Phillips, S. M., Hawley, J. A., & Coffey, V. G. 2013. Timing and distribution of protein ingestion during prolonged recovery from resistance exercise alters myofibrillar protein synthesis. *The Journal of physiology*, *591(9)*, 2319–31.

Bartlett, J. D., Hawley, J. A, & Morton, J. P. (2015). Carbohydrate availability and exercise training adaptation: Too much of a good thing? *European Journal of Sport Science*, *15 (1)*, *3–12*.

Bartlett, J. D., Louhelainen, J., Iqbal, Z., Cochran, A. J., Gibala, M. J., Gregson, W., Close, G. L., Drust, B., and Morton, J. P. (2013). Reduced carbohydrate availability enhances exercise-induced p53 signaling in human skeletal muscle : implications for mitochondrial biogenesis. *American Journal of Physiologyical : Regulatory, Integative and Compaative Physiology, 304 (6),* 450-458.

Boisseau, N., Le Creff, C., Loyens, M., & Poortmans, J. R. (2002). Protein intake and nitrogen balance in male non-active adolescents and soccer players. *European Journal of Applied Physiology, 88(3),* 288–293.

Boisseau, N., Vermorel, M., Rance, M., Duché, P., & Patureau-Mirand, P. (2007). Protein requirements in male adolescent soccer players. *European Journal of Applied Physiology, 100(1),* 27–33.

Briggs, M., Cockburn, E., Rumbold, P., Rae, G., Stevenson, E., & Russell, M. (2015). Assessment of Energy Intake and Energy Expenditure of Male Adolescent Academy-Level Soccer Players during a Competitive Week. *Nutrients, 7(10),* 8392–8401.

Burke, L.M., Cox, G. R., Cummings, N. K., & Desbrow, D. (2001). Guidelines for daily carbohydrate intake: do athletes achieve them? *Sports Medicine, 31(4),* 267–299.

Burke, L. M., Loucks, A. B., & Broad, N. (2006). Energy and carbohydrate for training and recovery. *Journal of Sports Science, 24(7),* 675-685.

Deakin, V. (2000). Measuring nutritional status of athletes: Clinical and research perspectives. In: *Clinical Sports Nutrition*. Burke, L. and Deakin, V. eds. Sydney, Austraila: McCraw-Hill, 2000. Pp. 30-68.

Department of Health. (1991). Report on Health and Social Subjects: 41. *Dietary Reference Values for Food Energy and Nutrients for the United Kingdom.* Her Majesty's Stationary Office: Norwich.

Garaulet, M., & Gómez-Abellán, P. (2014). Timing of food intake and obesity: a novel association. *Physiology & Behavior*, *134*, 44–50.

Goedecke, J., White, N., Chicktay, W., Mahomed, H., Durandt, J., & Lambert, M. (2013). The Effect of Carbohydrate Ingestion on Performance during a Simulated Soccer Match. *Nutrients, 5(12),* 5193–5204.

Gleeson, M., & Bishop, N.C. (2000). Elite athlete immunology: importance of nutrition. *International Journal Sports Medicine, 21 (1),* S44-50.

Gunnarsson, T. P., Bendiksen, M., Bischoff, R., Christensen, P. M., Lesivig, B., Madsen, K., Stephens, F., Greenhaff, P., Krustrup, P., & Bangsbo, J. (2013). Effect of whey protein- and carbohydrate-enriched diet on glycogen resynthesis during the first 48 h after a soccer game. *Scandinavian Journal of Medicine & Science in Sports*, *23(4),* 508–515.

Iglesias-Gutiérrez, E., García-Rovés, P. M., Rodríguez, C., Braga, S., García-Zapico, P., & Patterson, Á. M. (2005). Food Habits and Nutritional Status Assessment of Adolescent Soccer Players. A Necessary and Accurate Approach. *Canadian Journal of Applied Physiology, 30(1),* 18–32.

Iglesias-Gutiérrez, E., García, Á., García-Zapico, P., Pérez-Landaluce, J., Patterson, Á. M., & García-Rovés, P. M. (2012). Is there a relationship between the playing position of soccer players and their food and macronutrient intake? *Applied Physiology, Nutrition & Metabolism, 37(2),* 225–232.

Jeukendrup, A. (2014). A Step Towards Personalized Sports Nutrition: Carbohydrate Intake During Exercise. *Sports Medicine, 44(1),* 25–33.

Johnston, J. D. (2014). Physiological links between circadian rhythms, metabolism and nutrition. *Experimental Physiology, 99(9),* 1133–1137.

Leblanc, J. C., Le Gall, F., Grandjean, V., & Verger, P. (2002). Nutritional Intake of French Soccer Players at the Clairefontaine Training Center. *International Journal of Sport Nutrition & Exercise Metabolism, 12(3),* 268.

Leidy, H. J., Clifton, P. M., Astrup, A., Wycherley, T. P., Westerterp-Plantenga, M. S., Luscombe-Marsh, N. D., & Mattes, R. D. (2015). The role of protein in weight loss and maintenance. *American Journal of Clinical Nutrition, 101(6),* 1320S–1329.

Magkos, F., & Yannakoulia, M. (2003). Methodology of dietary assessment in athletes: concepts and pitfalls. *Current Opinion in Clinical Nutrition & Metabolic Care, 6(5)*. 539-549.

Mamerow, M. M., Mettler, J. a, English, K. L., Casperson, S. L., Arentson-lantz, E., Sheffield-Moore, M., & Paddon-jones, D. (2014). Dietary Protein Distribution Positively Influences 24-h Muscle Protein Synthesis in Healthy Adults. *The Journal of Nutrition, 144 (6),* 876–880.

Mori, H. (2014). Effect of timing of protein and carbohydrate intake after resistance exercise on nitrogen balance in trained and untrained young men. *Journal of Physiological Anthropology, 33(1),* 24.

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. *Journal of Sports Science*, *16*, 1-8.

Murphy, C. H., Hector, A. J., & Phillips, S. M. (2014). Considerations for protein intake in managing weight loss in athletes. *European Journal of Sport Science, 15 (1),* 21–28.

Phillips, S. M. (2014). A brief review of critical processes in exercise-induced muscular hypertrophy. *Sports Medicine, 44,* S71-77.

Phillips, S. M., & Van Loon, L. J. C. (2011). Dietary protein for athletes: From requirements to optimum adaptation. *Journal of Sports Sciences, 29(1),* S29–S38.

Ruiz, F., Irazusta, A., Gil, S., Irazusta, J., Casis, L., & Gil, J. (2005). Nutritional intake in soccer players of different ages. *Journal of Sports Sciences, 23(3),* 235–242.

Russell, M., & Pennock, A. (2011). Dietary analysis of young professional soccer players for 1 week during the competitive season. *Journal of Strength and Conditioning Research / National Strength & Conditioning Association, 25(7),* 1816–1823.

Wrigley, R., Drust, B., Stratton, G., Scott, M., & Gregson, W. (2012). Quantification of the typical weekly in-season training load in elite junior soccer players. *Journal of Sports Sciences, 30(15),* 1573–1580.

Zehnder, M., Rico-Sanz, J., Kuhne, G., & Boutellier, U. (2001). Resynthesis of muscle glycogen after soccer specific performance examined by 13C-magnetic resonance spectroscopy in elite players. *European Journal of Applied Physiology, 84(5),* 443–447.

Table 1. A comparison of age, body mass, height, BMI, soccer and non-soccer training between elite youth soccer players from an EPL academy from the U13/14s, U15/16s and U18s squads. Training data adapted from Brownlee *et al.* (Unpublished data).

Squad	**Age (years)**	**Body Mass (kg)**	**Height (cm)**	**BMI (kg/m^2)**	**Soccer Training (mins)**	**Non-Soccer Training (mins)**
U13/14s	12.7 ± 0.6	44.7 ± 7.2	157.8 ± 11.0	17.9 ± 1.3	436 ± 29	33 ± 28
U15/16s	14.4 ± 0.5	60.4 ± 8.1	173.1 ± 7.8	20.1 ± 1.5	212 ± 57	81 ± 39
U18s	16.4 ± 0.5	70.6 ± 7.6	180.1 ± 7.3	21.7 ± 0.9	224 ± 38	89 ± 21

Values are mean ± SD.

Table 2. A breakdown of frequency of snack consumption for all squads.

Time Point	Percentage of snacks consumed within Time Point (%)		
	U13/14s	U15/16s	U18s
Morning Snack (Between Breakfast & Lunch)	24	25	6
Afternoon Snack (Between Lunch & Dinner)	40	49	59
Late Snack (After Dinner)	36	26	35

Table 3. A comparison of daily energy and macronutrient intake between elite youth soccer players from an EPL academy from the U13/14s, U15/16s and U18s squads expressed as absolute and relative.

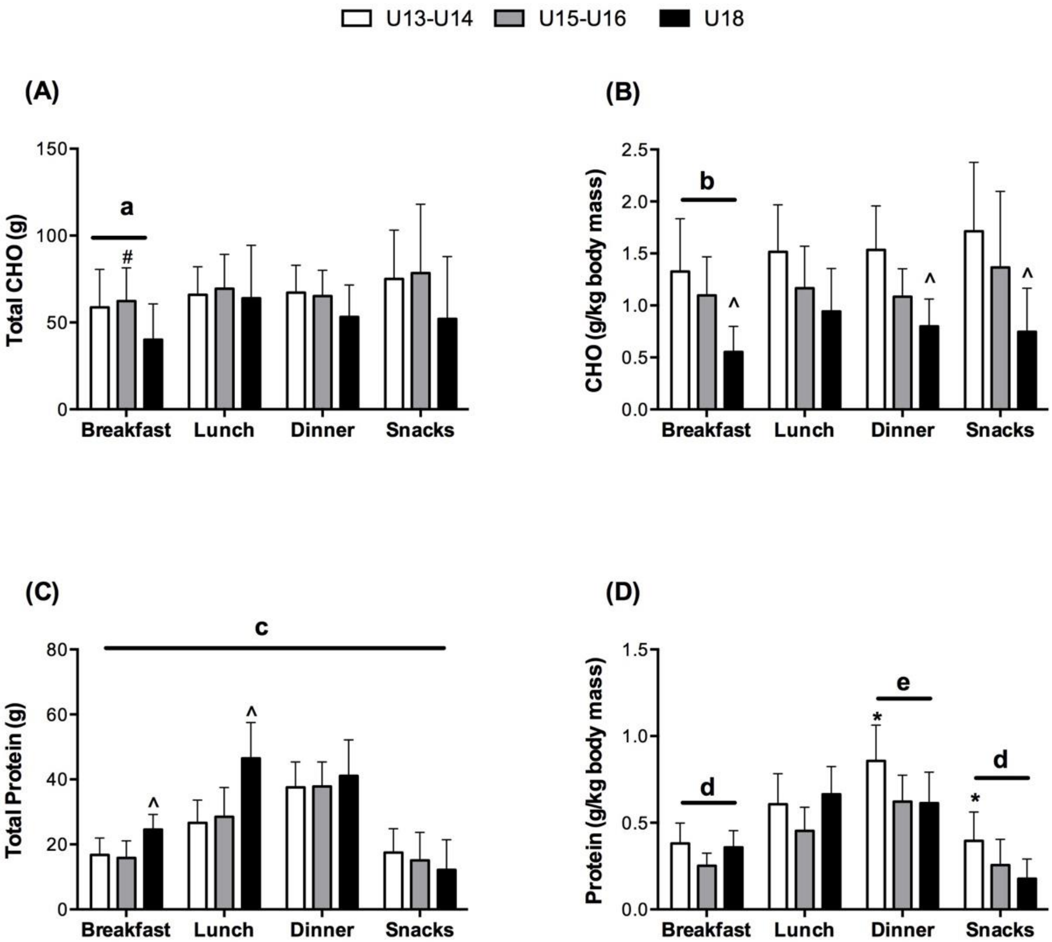
	U13/14s	**U15/16s**	**U18s**
Absolute Energy (kcal)	1903 ± 432.4	1926.7 ± 317.2	1958.2 ± 389.5
Relative Energy (kcal·kg^{-1})	43.1 ± 10.3[a]	32.6 ± 7.9	28.1 ± 6.8
Absolute CHO (g)	266.3 ± 58.4	275.1 ± 61.9	223.7 ± 79.9
Relative CHO (g·kg^{-1})	6.0 ± 1.2[a]	4.7 ± 1.4[b]	3.2 ± 1.3
Absolute Protein (g)	97.3 ± 21.0	96.1 ± 13.7	142.6 ± 23.6[c]
Relative Protein (g·kg^{-1})	2.2 ± 0.5	1.6 ± 0.3[d]	2.0 ± 0.3
Absolute Fat (g)	56.1 ± 17.5	55.2 ± 10.6	60.0 ± 14.7

Relative Fat ($g{\cdot}kg^{-1}$)	1.3 ± 0.5[a]	0.9 ± 0.3	0.9 ± 0.3

[a] Denotes significant difference from both U15/16s and U18s. [b] Denotes significant difference from U18s. [c] Denotes significant difference from both U13/14s and U15/16s. [d] Denotes significant difference from both U13/14s and U18s. Values are mean±SD.

Figure 1. – Comparison of total and relative CHO and protein intake for each squad across different meals. White bars represent U13/14s, grey bars represent U15/16s and black bars represent U18s. All values are mean ± SD. [a] Denotes significant difference from lunch, dinner and snacks. [b] Denotes significant difference from both lunch and snacks. [c] Denotes significant difference from all meals. [d] Denotes significant difference from both lunch and dinner. [e] Denotes significant difference from lunch. # Denotes significant difference from U18s. ^ Denotes significant difference from U13/14s and U15/16s. * Denotes significant difference from U15/16s and U18s.

Figure 1


U13-U14
U15-U16
U18
(A)
Total CHO (g)
150
100
50
0
a
#
Breakfast
Lunch
Dinner
Snacks
(B)
CHO (g/kg body mass)
2.5
2.0
1.5
1.0
0.5
0.0
b
^
^
^
Breakfast
Lunch
Dinner
Snacks
(C)
Total Protein (g)
80
60
40
20
0
c
^
^
Breakfast
Lunch
Dinner
Snacks
(D)
Protein (g/kg body mass)
1.5
1.0
0.5
0.0
d
e
d
*
*
Breakfast
Lunch
Dinner
Snacks

541

542