

1 **Daily distribution of carbohydrate, protein and fat intake in elite youth academy**
2 **soccer players over a 7-day training period**

3 Robert J. Naughton¹, Barry Drust^{2,3}, Andy O'Boyle³, Ryland Morgans³, Julie
4 Abayomi¹, Ian G. Davies¹, James P. Morton² and Elizabeth Mahon¹

5 ¹School of Sports Studies, Leisure and Nutrition

6 Liverpool John Moores University

7 Liverpool

8 L17 6BD

9 UK

10

11 ²Research Institute for Sport and Exercise Sciences

12 Liverpool John Moores University

13 Tom Reilly Building

14 Byrom St Campus

15 Liverpool

16 L3 3AF

17 UK

18

19 ³Liverpool Football Club

20 Melwood Training Ground

21 Deysbrook Lane

22 Liverpool

23 L12 8SY

24 UK

25

26 **Running head:** Nutrition, youth soccer, exercise metabolism

27 **Word Count:** 3250

28 Address for correspondence:

29 Robert Naughton

30 ¹School of Sports Studies, Leisure and Nutrition

31 Liverpool John Moores University

32 Liverpool

33 L17 6BD

34 United Kingdom

35 Email: R.Naughton@2008.ljmu.ac.uk

36

37

38

39

40

41

42

43

44

45

46

47 **Abstract**

48 While traditional approaches to dietary analysis in athletes have focused on total daily
49 energy and macronutrient intake, it is now thought that daily distribution of these
50 parameters can also influence training adaptations. Using seven-day food diaries, we
51 quantified the total daily macronutrient intake and distribution in elite youth soccer
52 players from the English Premier League in U18 ($n=13$), U15/16 ($n=25$) and U13/14
53 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
54 (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 $^{-1}$)
55 intake exhibited hierarchical differences ($P<0.05$) such that U13/14>U15/16>U18.
56 Additionally, CHO intake in U18s was lower ($P<0.05$) at breakfast, dinner and snacks
57 when compared with both squads but no differences were apparent at lunch.
58 Furthermore, the U15/16s reported lower relative daily protein intake than the
59 U13/14s and U18s (1.6 ± 0.3 vs. 2.2 ± 0.5 , 2.0 ± 0.3 g \cdot kg $^{-1}$). A skewed distribution
60 ($P<0.05$) of daily protein intake was observed in all squads, with a hierarchical order
61 of dinner (~ 0.6 g \cdot kg $^{-1}$) > lunch (~ 0.5 g \cdot kg $^{-1}$) > breakfast (~ 0.3 g \cdot kg $^{-1}$). We conclude
62 elite youth soccer players do not meet current CHO guidelines. Although daily protein
63 targets are achieved, we report a skewed daily distribution in all ages such that
64 dinner>lunch>breakfast. Our data suggest that dietary advice for elite youth players
65 should focus on both total daily macronutrient intake and optimal daily distribution
66 patterns.

67

68

69

70 **Introduction**

71 The function of soccer academies is largely to produce players who can progress to
72 and represent the club's senior first team, and thereby reduce the requirement for
73 clubs to buy or sell players in an attempt to achieve financial targets (Wrigley *et al.*,
74 2014). To support the high training loads (Wrigley *et al.*, 2012) and developmental
75 goals such as muscle hypertrophy (Milsom *et al.*, 2015), it is essential players
76 consume the correct quantity and type of macronutrients. Few studies have
77 investigated habitual energy intakes and dietary habits of elite youth soccer players
78 (Boisseau *et al.*, 2002 & 2007; LeBlanc *et al.*, 2002; Ruiz *et al.*, 2005; Iglesias-
79 Gutierrez *et al.*, 2005) with just two in the UK (Russell and Pennock, 2011; Briggs *et*
80 *al.*, 2015). These studies have typically been limited to reports of total daily energy
81 and macronutrient intake, often concluding that elite youth soccer players habitually
82 don't meet their energy requirements (Boisseau *et al.* 2002; LeBlanc *et al.*, 2002; Ruiz
83 *et al.*, 2005; Russell and Pennock, 2011; Briggs *et al.*, 2015).

84 In addition to the quantification of daily energy and macronutrient intake, it is
85 important to consider timing of intake in relation to training sessions (Burke, 2010;
86 Mori, 2014), main meals (Garaulet and Gomez-Abellan, 2014; Johnston, 2014) and
87 sleep (Lane *et al.*, 2015). Whilst this is most well documented for carbohydrate
88 (CHO) intake in order to fuel training and matches (Goedecke *et al.*, 2013;
89 Jeukendrup, 2014) and promote glycogen re-synthesis (Zehnder *et al.*, 2001;
90 Gunnarsson *et al.*, 2013), recent data suggests that the daily distribution of protein
91 intake is critical for optimizing components of training adaptations such as muscle
92 protein synthesis (MPS) (Areta *et al.*, 2013; Mamerow *et al.*, 2014). Recent data has
93 highlighted the importance of quantity and timing of protein intake in elite youth
94 soccer players. Milsom *et al.* (2015) demonstrated that such populations typically

95 present with approximately 6 kg less lean muscle mass than adult professional soccer
96 players. When taken together, these data suggest that dietary surveys of elite youth
97 soccer players should not only quantify total daily energy and macronutrient intake
98 but should also report the timing of nutrient ingestion, thereby having important
99 practical implications for fuelling adequately, promoting training adaptations and
100 optimizing recovery.

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

111 **Methodology**

112 *Participants*

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

118 permission was obtained from the Liverpool John Moores University Ethics
119 Committee.

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

128 *Dietary Intake*

129 Participants were asked to record everything they consumed in a food diary for 7-
130 consecutive days. This time frame was justified by previous research suggesting that
131 7-days provides a more accurate estimation of habitual nutritional intake than a single-
132 or 4-day recording (Magkos & Yannakoulia, 2003). Additionally, unpublished pilot
133 research on the current study's population displayed a high completion rate (75%)
134 over the 7-days. To promote high ecological validity, researchers made no attempt to
135 influence the player's diets. Upon giving consent, players attended a presentation that
136 gave detailed instructions on how to fill out the dietary diary. Parents and guardians of
137 the U13/14s also attended, as it was evidenced from pilot research that they were
138 likely to be responsible for completion of the diaries at this age. Participants were
139 asked to provide as much detail as possible, including the type of day it was with
140 respect to their soccer activity (rest, match, or training day), the commercial brand
141 names of the food/drink, cooking/preparation methods, and time of consumption.

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

154 *Data Analysis*

155 Food diary data was analysed using Nutritics software (version 3.74 professional
156 edition, Nutritics Ltd., Co. Dublin, Ireland). All analyses were carried out by a single
157 trained researcher so that potential variation of data interpretation was minimised
158 (Deakin, 2000). Total absolute, and relative to body mass (BM), intakes of energy
159 (kcal), CHO, protein and fats were calculated. All data were assessed for normality of
160 distribution according to the Shapiro-Wilk's test. Statistical comparisons between
161 squads' total energy and macronutrient intakes were performed according to a one-
162 way between-groups analysis of variance (ANOVA) or, for non-parametric data, the
163 Kruskal-Wallis test. Where significant differences of the ANOVA were present,
164 Tukey post-hoc analysis was conducted to locate specific differences. For non-normal
165 data, post-hoc analysis was performed using multiple Mann-Whitney U tests with a
166 Bonferroni adjustment. For energy and macronutrient distribution across separate

167 meals, a two-way ANOVA was employed and a Tukey post-hoc analysis was
168 conducted where appropriate. Where a significant main difference for age was
169 reported, a one-way ANOVA or, the Kruskal-Wallis test was performed, to assess at
170 which meal the difference occurred. All analyses were completed using SPSS for
171 Windows (version 20, SPSS Inc., Chicago, IL) where $P < 0.05$ was indicative of
172 statistical significance.

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

176 **Results**

177 *Daily Energy and macronutrient total and relative daily intake*

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

189 *The distribution of energy and macronutrients across separate meals*

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

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

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

214 *Supplements.*

215 No statistical analysis was performed for supplements as intake within the U13/14 and
216 U15/16 ($n=3$) was negligible. Within the U18s mean daily intake from supplements
217 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
218 g.

219 **Discussion**

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

230 The values reported here for both total daily energy and CHO intake compare well to
231 those previously reported for players of similar ages (Boisseau *et al.*, 2002; Ruiz *et*
232 *al.*, 2007). For example, Boisseau *et al.* (2002) reported energy intakes of 38.9 ± 4.4
233 $\text{kcal}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$ and Ruiz *et al.* (2007) reported CHO intakes of 5.9 ± 0.4 $\text{g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$,
234 both of which are similar to the U15/16s in the present study (Table 3). A consistent
235 theme within the literature appears to be that elite youth soccer players consume lower
236 energy intakes than likely daily energy requirements, thus potentially compromising
237 performance. While no differences between absolute energy and CHO intake between

238 squads were observed, large differences were apparent when expressed relative to
239 BM. Indeed, higher CHO intakes in the U13/14 squads ($6\pm 1.2 \text{ g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$) compared
240 with both the U15/16s ($4.7\pm 1.4 \text{ g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$) and U18s ($3.2\pm 1.3 \text{ g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$) were
241 found. Carbohydrate requirements for adult athletes are an evolving topic within
242 sports nutrition and there is debate within the literature of the optimal approach.
243 Currently, soccer players are recommended to consume 6-10 $\text{g}\cdot\text{kg}^{-1}\cdot\text{day}^{-1}$ to support
244 training and match demands (Burke *et al.*, 2006). Conversely, recent evidence has
245 suggested that athletes (albeit adult populations) may benefit from strategically
246 training with lower CHO availability during carefully chosen sessions (through
247 manipulation of CHO intake and/or timing of training) to enhance training adaptations
248 (i.e. increased mitochondrial biogenesis) (Bartlett *et al.*, 2013; 2015). Given the
249 obvious developmental goals of youth soccer players and the low CHO intakes
250 reported here and previously (Ruiz *et al.*, 2007), these data suggest that youth soccer
251 players are likely under consuming daily CHO and do not meet current daily targets.
252 **However, given that these guidelines are for adult populations and there are currently**
253 **no available CHO guidelines for elite youth athletes, further research is required.**

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

262 In relation to protein, marked differences in the total absolute daily intake were
263 observed between squads where the U18s were higher than the U13/14s and U15/16s
264 (142±24 vs. 97±21 vs. 96±24 g, respectively). However, when this value was
265 standardised for BM, the U13/14s reported higher values than the U15/16s and U18s
266 (2.2±0.4 vs. 1.6±0.3 vs. 2.0±0.3 g·kg⁻¹, respectively) (Table 3). Such absolute and
267 relative values are comparable to previous findings in similar populations (Boisseau *et*
268 *al.*, 2002; Ruiz *et al.*, 2007; Russell & Pennock, 2011; Briggs *et al.*, 2015) and are also
269 considerably higher than current national dietary reference values of 0.8 g·kg⁻¹·day⁻¹
270 (Department of Health, 1991). The most popular source of protein for all ages was
271 poultry while eggs were only a main choice for the U18s. Similar to the CHO choices,
272 this is likely a reflection of the U18s being provided with a cooked breakfast daily at
273 the academy whereas the younger squads tended to consume cereal based breakfasts
274 at home. To the authors' knowledge, only one research group has assessed the protein
275 requirements of adolescent soccer players (Boisseau *et al.*, 2002 & 2007), using a
276 nitrogen balance methodology. Results demonstrated that protein requirements of
277 players aged 13-15 years range between 1.4-1.6 g·kg⁻¹·day⁻¹ (Boisseau *et al.*, 2002 &
278 2007), which is similar to current guidelines for adult athletes (1.3–1.8 g·kg⁻¹·day⁻¹)
279 (Phillips and Van Loon, 2014). Therefore, in contrast to CHO, it appears that elite
280 youth soccer players are successful in achieving daily protein requirements.

281 The distribution of daily protein intake may be a more important aspect of an athlete's
282 nutritional strategy than the total daily intake. Recent data has highlighted that
283 distorted protein intake distribution across meals (skewed to higher intake at dinner)
284 in an adult population results in reduced MPS stimulation in comparison to a stable
285 protein intake (~30 g) at each main meal (breakfast, lunch and dinner) even when total
286 absolute intake is matched (Mamerow *et al.*, 2014). The distribution of protein intake

287 at different meals was skewed for all squads in a hierarchical order of
288 dinner>lunch>breakfast (Figure 1). In relation to optimal absolute protein dose,
289 Witard *et al.* (2013) has previously reported that a single meal of ≥ 20 g high quality
290 fast-digesting protein is necessary to induce maximal rates of MPS. Therefore, it
291 could be suggested that some players were under-consuming protein at specific meal
292 times. For example, the U13/14s and U15/16s consumed 17 ± 5 g and 15 ± 4 g,
293 respectively, at breakfast in comparison to the U18s who consumed 25 ± 5 g.
294 Conversely, Murphy *et al.* (2014) recently suggested that a protein content of 0.25-0.3
295 $\text{g} \cdot \text{kg}^{-1}$ BM per meal, that has high leucine content and is rapidly digestible, can
296 achieve optimal MPS. Therefore, all squads would be achieving that value at each
297 meal and consequently, the finding of < 20 g absolute doses at certain meals may be
298 inconsequential. However, a caveat to this paper is that the sources of habitual protein
299 intakes for some squads would likely result in sub-optimal leucine contents. For
300 example, whereas the U18s consume a protein based breakfast (i.e. eggs), the U13/14s
301 and U15/16s intake of protein at breakfast was largely derived from adding milk to a
302 predominantly CHO based breakfast (e.g. cereals, bread). Such pattern of breakfast
303 choices in these squads is also in accordance with breakfast choices of children from
304 the general population (Alexy *et al.*, 2010). Therefore, the schoolboys have not yet
305 adopted a more sports specific diet. Similar to breakfast, the U18s have a significantly
306 higher absolute protein intake at lunch in comparison to their younger counterparts
307 (46 ± 11 vs. 27 ± 7 vs 29 ± 9 g, respectively), but CHO intake was similar across all
308 squads for lunch and dinner (Figure 1).

309 Potential reasons for this difference in macronutrient intake and distribution between
310 squads is likely related to the fact that the U18s are full-time soccer players and it is
311 mandatory for players to consume breakfast and lunch at the academy on days they

312 attend (5/6 days·week⁻¹). Consequently, the club has greater control over the food and
313 beverages the U18s can choose from. In contrast, the schoolboys will have meals
314 provided by the school they attend or packed lunches from home, so the influence of
315 the club is considerably reduced. When youth players are promoted to full-time U18
316 squad status, muscle hypertrophy is a key training goal (Milsom et al., 2015), which
317 may result in players being encouraged to increase protein consumption to support
318 resistance-training hypertrophy programmes (Phillips et al., 2014).

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

326 A limitation of the current study is the use of food dairies to analyze nutritional habits,
327 and indeed, previous research has shown a potential under-reporting effect of up to
328 20% (Burke *et al.*, 2001). However, even when accounting for potential under-
329 reporting effects, it would appear that the current populations would still be under-
330 fueling for performance in accordance with current literature (Burke *et al.*, 2006). To
331 address this hypothesis, future research should accurately quantify the energy
332 expenditure within elite youth soccer players through a variety of techniques such as
333 doubly labeled water and accurate monitoring of training load through GPS
334 technology. Additionally, the sample population for the present study was taken from
335 a single EPL academy, and therefore may not be truly representative of elite players
336 based at other clubs.

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

349 **Acknowledgments**

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

354

355

356

357

358

359

360

361

362

363

364

365

366

367

368 **References**

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

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

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

- 379 Bartlett, J. D., Louhelainen, J., Iqbal, Z., Cochran, A. J., Gibala, M. J., Gregson, W.,
380 Close, G. L., Drust, B., and Morton, J. P. (2013). Reduced carbohydrate availability
381 enhances exercise-induced p53 signaling in human skeletal muscle : implications for
382 mitochondrial biogenesis. *American Journal of Physiological : Regulatory,*
383 *Integrative and Compaative Physiology, 304 (6), 450-458.*
- 384 Boisseau, N., Le Creff, C., Loyens, M., & Poortmans, J. R. (2002). Protein intake and
385 nitrogen balance in male non-active adolescents and soccer players. *European Journal*
386 *of Applied Physiology, 88(3), 288–293.*
- 387 Boisseau, N., Vermorel, M., Rance, M., Duché, P., & Patureau-Mirand, P. (2007).
388 Protein requirements in male adolescent soccer players. *European Journal of Applied*
389 *Physiology, 100(1), 27–33.*
- 390 Briggs, M., Cockburn, E., Rumbold, P., Rae, G., Stevenson, E., & Russell, M. (2015).
391 Assessment of Energy Intake and Energy Expenditure of Male Adolescent Academy-
392 Level Soccer Players during a Competitive Week. *Nutrients, 7(10), 8392–8401.*
- 393 Burke, L.M., Cox, G. R., Cummings, N. K., & Desbrow, D. (2001). Guidelines for
394 daily carbohydrate intake: do athletes achieve them? *Sports Medicine, 31(4), 267–299.*
- 395 Burke, L. M., Loucks, A. B., & Broad, N. (2006). Energy and carbohydrate for
396 training and recovery. *Journal of Sports Science, 24(7), 675-685.*
- 397 Deakin, V. (2000). Measuring nutritional status of athletes: Clinical and research
398 perspectives. In: *Clinical Sports Nutrition*. Burke, L. and Deakin, V. eds. Sydney,
399 Australia: McCraw-Hill, 2000. Pp. 30-68.

- 400 Department of Health. (1991). Report on Health and Social Subjects: 41. *Dietary*
401 *Reference Values for Food Energy and Nutrients for the United Kingdom*. Her
402 Majesty's Stationary Office: Norwich.
- 403 Garaulet, M., & Gómez-Abellán, P. (2014). Timing of food intake and obesity: a
404 novel association. *Physiology & Behavior*, *134*, 44–50.
- 405 Goedecke, J., White, N., Chicktay, W., Mahomed, H., Durandt, J., & Lambert, M.
406 (2013). The Effect of Carbohydrate Ingestion on Performance during a Simulated
407 Soccer Match. *Nutrients*, *5*(12), 5193–5204.
- 408 Gleeson, M., & Bishop, N.C. (2000). Elite athlete immunology: importance of
409 nutrition. *International Journal Sports Medicine*, *21* (1), S44-50.
- 410 Gunnarsson, T. P., Bendiksen, M., Bischoff, R., Christensen, P. M., Lesivig, B.,
411 Madsen, K., Stephens, F., Greenhaff, P., Krstrup, P., & Bangsbo, J. (2013). Effect of
412 whey protein- and carbohydrate-enriched diet on glycogen resynthesis during the first
413 48 h after a soccer game. *Scandinavian Journal of Medicine & Science in Sports*,
414 *23*(4), 508–515.
- 415 Iglesias-Gutiérrez, E., García-Rovés, P. M., Rodríguez, C., Braga, S., García-Zapico,
416 P., & Patterson, Á. M. (2005). Food Habits and Nutritional Status Assessment of
417 Adolescent Soccer Players. A Necessary and Accurate Approach. *Canadian Journal*
418 *of Applied Physiology*, *30*(1), 18–32.
- 419 Iglesias-Gutiérrez, E., García, Á., García-Zapico, P., Pérez-Landaluce, J., Patterson,
420 Á. M., & García-Rovés, P. M. (2012). Is there a relationship between the playing
421 position of soccer players and their food and macronutrient intake? *Applied*
422 *Physiology, Nutrition & Metabolism*, *37*(2), 225–232.

- 423 Jeukendrup, A. (2014). A Step Towards Personalized Sports Nutrition: Carbohydrate
424 Intake During Exercise. *Sports Medicine*, *44*(1), 25–33.
- 425 Johnston, J. D. (2014). Physiological links between circadian rhythms, metabolism
426 and nutrition. *Experimental Physiology*, *99*(9), 1133–1137.
- 427 Leblanc, J. C., Le Gall, F., Grandjean, V., & Verger, P. (2002). Nutritional Intake of
428 French Soccer Players at the Clairefontaine Training Center. *International Journal of*
429 *Sport Nutrition & Exercise Metabolism*, *12*(3), 268.
- 430 Leidy, H. J., Clifton, P. M., Astrup, A., Wycherley, T. P., Westerterp-Plantenga, M.
431 S., Luscombe-Marsh, N. D., & Mattes, R. D. (2015). The role of protein in weight loss
432 and maintenance. *American Journal of Clinical Nutrition*, *101*(6), 1320S–1329.
- 433 Magkos, F., & Yannakoulia, M. (2003). Methodology of dietary assessment in
434 athletes: concepts and pitfalls. *Current Opinion in Clinical Nutrition & Metabolic*
435 *Care*, *6*(5), 539-549.
- 436 Mamerow, M. M., Mettler, J. a, English, K. L., Casperson, S. L., Arentson-lantz, E.,
437 Sheffield-Moore, M., & Paddon-jones, D. (2014). Dietary Protein Distribution
438 Positively Influences 24-h Muscle Protein Synthesis in Healthy Adults. *The Journal of*
439 *Nutrition*, *144* (6), 876–880.
- 440 Mori, H. (2014). Effect of timing of protein and carbohydrate intake after resistance
441 exercise on nitrogen balance in trained and untrained young men. *Journal of*
442 *Physiological Anthropology*, *33*(1), 24.
- 443 Milsom, J., Naughton, R., O’Boyle, A., Iqbal, Z., Morgans, R., Drust, B., & Morton,
444 J.P. (2015). Body composition assessment of English Premier League soccer players:

- 445 a comparative DXA analysis of first team, U21 and U18 squads. *Journal of Sports*
446 *Science*, 16, 1-8.
- 447 Murphy, C. H., Hector, A. J., & Phillips, S. M. (2014). Considerations for protein
448 intake in managing weight loss in athletes. *European Journal of Sport Science*, 15 (1),
449 21–28.
- 450 Phillips, S. M. (2014). A brief review of critical processes in exercise-induced
451 muscular hypertrophy. *Sports Medicine*, 44, S71-77.
- 452 Phillips, S. M., & Van Loon, L. J. C. (2011). Dietary protein for athletes: From
453 requirements to optimum adaptation. *Journal of Sports Sciences*, 29(1), S29–S38.
- 454 Ruiz, F., Irazusta, A., Gil, S., Irazusta, J., Casis, L., & Gil, J. (2005). Nutritional intake
455 in soccer players of different ages. *Journal of Sports Sciences*, 23(3), 235–242.
- 456 Russell, M., & Pennock, A. (2011). Dietary analysis of young professional soccer
457 players for 1 week during the competitive season. *Journal of Strength and*
458 *Conditioning Research / National Strength & Conditioning Association*, 25(7), 1816–
459 1823.
- 460 Wrigley, R., Drust, B., Stratton, G., Scott, M., & Gregson, W. (2012). Quantification
461 of the typical weekly in-season training load in elite junior soccer players. *Journal of*
462 *Sports Sciences*, 30(15), 1573–1580.
- 463 Zehnder, M., Rico-Sanz, J., Kuhne, G., & Boutellier, U. (2001). Resynthesis of
464 muscle glycogen after soccer specific performance examined by ¹³C-magnetic
465 resonance spectroscopy in elite players. *European Journal of Applied Physiology*,
466 84(5), 443–447.

467

468

469

470

471

472

473

474

475

476

477 **Table 1.** A comparison of age, body mass, height, BMI, soccer and non-soccer
 478 training between elite youth soccer players from an EPL academy from the U13/14s,
 479 U15/16s and U18s squads. Training data adapted from Brownlee *et al.* (Unpublished
 480 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

481 Values are mean \pm SD.

482

483

484

485

486

487

488

489

490

491

492 **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

493

494

495

496

497

498

499

500

501

502

503

504

505

506 **Table 3.** A comparison of daily energy and macronutrient intake between elite youth
 507 soccer players from an EPL academy from the U13/14s, U15/16s and U18s squads
 508 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·kg⁻¹)	1.3 ± 0.5 ^a	0.9 ± 0.3	0.9 ± 0.3
---	------------------------	-----------	-----------

509

510 ^a Denotes significant difference from both U15/16s and U18s. ^b Denotes significant difference
 511 from U18s. ^c Denotes significant difference from both U13/14s and U15/16s. ^d Denotes
 512 significant difference from both U13/14s and U18s. Values are mean±SD.

513

514

515

516

517

518

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

527

528

529

530

531

532

533

534

535

536

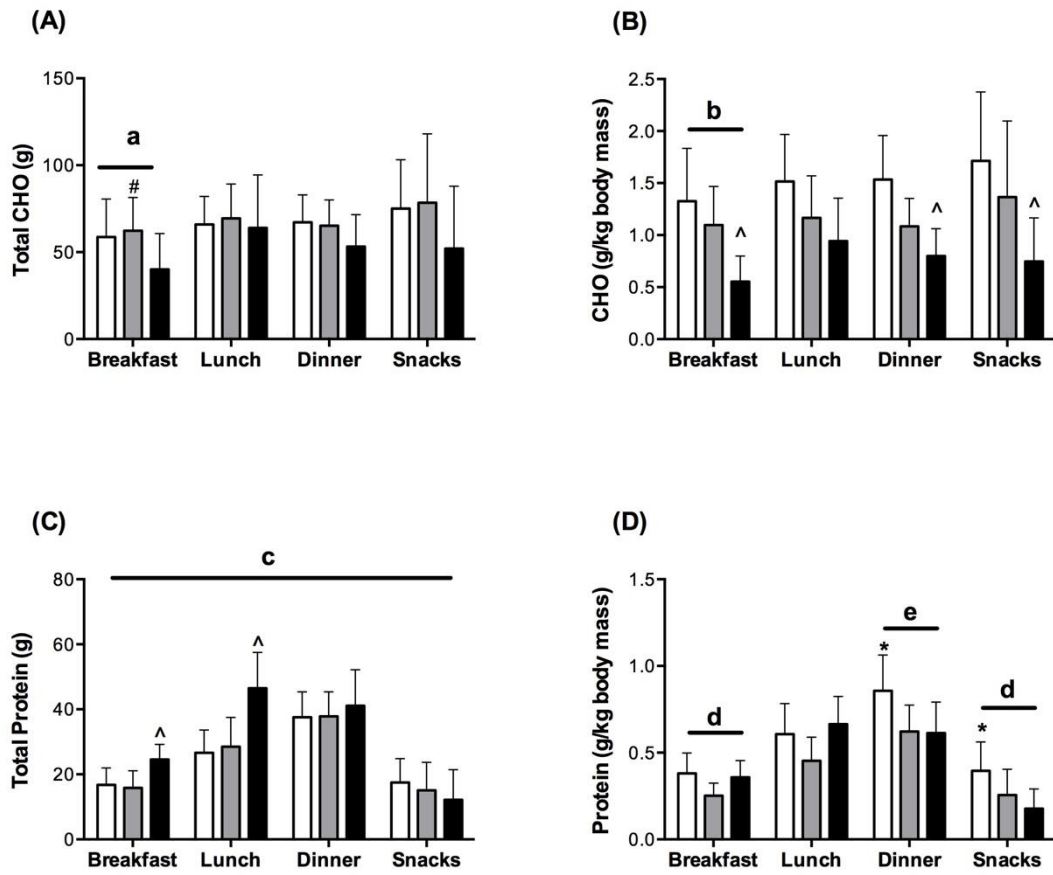
537

538

539

540 **Figure 1**

□ U13-U14 ■ U15-U16 ■ U18



541

542