

Significant Changes in Resting Metabolic Rate Over a Competitive Match Week Are Accompanied by an Absence of Nutritional Periodization in Male Professional Soccer Players.

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1 **Introduction**

2 During professional soccer matches, the ability to maintain high intensity running and levels of
3 skill proficiency are key attributes of a top-class player and successful teams (Mohr et al., 2003). It
4 has long been established that speed, agility, strength, and a combination of aerobic and anaerobic
5 abilities are vital in soccer (Bangsbo, 1994), whilst Allen et al. (2023) suggest that the physical
6 demands (total distance, high-intensity distance, and sprinting distance) of elite soccer have
7 increased further in recent years. Thus, due to these high physiological demands, the influence of
8 nutritional intake on soccer performance has been well documented, particularly in relation to energy
9 and carbohydrate (CHO) requirements, and plays a key role in optimising fuelling and recovery from
10 training and matches (Collins et al., 2021).

11 Resting metabolic rate (RMR) is a major component of total daily energy expenditure (TDEE)
12 and is the energy required to maintain homeostasis at rest and can be used as an indicator of energy
13 availability (Ihle & Loucks, 2004). Thus, determining RMR and energy expenditure (EE) is essential
14 because it provides crucial information to develop nutritional strategies and sets the target for daily
15 energy requirements (Burke et al., 2006). Within the context of professional soccer, sufficient energy
16 is critical to support the demands of training and competition, support growth and development
17 (Spear, 2002), promote training adaptations and optimise performance (Petrie et al., 2004). Long-term
18 energy restriction can cause impaired physiological function; increased risk of fatigue, illness and
19 injury; and maladaptation to the prescribed training (Mountjoy et al., 2014). A range of predictive
20 equations have been developed to estimate RMR, however these equations may be limited as they
21 are often developed from non-athletic populations (Cunningham, 1980) and may not consider Fat
22 Free Mass (FFM) (Schofield et al., 2019). Hannon et al. (2020) found common prediction equations
23 significantly underestimate RMR in youth professional soccer players (by as much as $-844 \text{ kcal}\cdot\text{day}^{-1}$)
24 suggesting that they are not fit for purpose. Consequently, the use of improper prediction equations
25 could potentially be detrimental to a player if used to advise energy requirements, given the effects of
26 chronic low energy availability (Mountjoy et al., 2018), and it is therefore crucial that RMR is
27 accurately measured instead. The most precise method of assessing RMR is indirect calorimetry
28 requiring both oxygen ($\dot{V}O_2$) and carbon dioxide ($\dot{V}CO_2$) to be measured (Fullmer et al., 2015). Limited
29 research has been conducted on assessing RMR using indirect calorimetry within professional male
30 soccer players. Hannon et al. (2020) reported RMR values of $1875 \pm 180 \text{ kcal}\cdot\text{day}^{-1}$ and 1941 ± 197

31 kcal·day⁻¹ for U18s and U23s male professional soccer players, respectively, which to our knowledge
32 is the only study to assess RMR in professional soccer players. Despite there being apparent
33 fluctuations in training load in both academy (Hannon et al., 2021) and senior players (Anderson et
34 al., 2016), to date, no research has investigated whether RMR varies across the competitive week in
35 professional soccer players. Interestingly, within senior professional rugby union players Hudson et al.
36 (2020) reported significant mean increases in RMR the day after a match, compared with the day
37 before the match. They suggested this may be due to the number of collisions experienced in a rugby
38 match. Whilst soccer does not involve collisions, there are some similarities between the two sports,
39 therefore it would be of interest to identify whether similar observations are seen in professional
40 soccer players because, if so, this could have important fuelling and recovery implications for soccer
41 players.

42 In addition to understanding how RMR may vary across the competitive week, it would also
43 be beneficial to understand how energy and CHO intake varies within professional soccer players. As
44 periodisation is evident in training programs (Anderson et al., 2016), energy intake (EI) should be
45 adjusted to account for the energy demands of a particular day. Determining the current dietary
46 practices and intakes of professional soccer players is important to enable practitioners to develop
47 programs that will improve nutritional intake and therefore, enhance health and performance.
48 However, very few studies have assessed whether professional male soccer players periodise their
49 nutritional intake across the competitive week to reflect alterations in training or match demands
50 (Anderson et al., 2017; Brinkmans et al., 2019). Previous research has assessed the EI in senior
51 (Anderson et al., 2017) and professional academy soccer players (Briggs et al., 2015; Hannon et al.,
52 2021) demonstrating that intake is inadequate to meet the demands of training and competition
53 (Briggs et al., 2015; Brinkmans et al., 2019). Anderson et al. (2017) reported mean daily EI of senior
54 professional soccer players was greater on match day compared to training day. Additionally, there
55 was a greater daily CHO intake on match day (6.4 ± 2.2 g·kg⁻¹ BM·day⁻¹) compared with training days
56 (4.2 ± 1.4 g·kg⁻¹ BM·day⁻¹), similar to the findings of a subsequent study by Brinkmans et al., (2019).
57 However, players did not consume sufficient CHO to optimize muscle glycogen storage in the day
58 before (<5 g·kg⁻¹ BM·day⁻¹), or in recovery (<4 g·kg⁻¹ BM·day⁻¹) from matches (Anderson et al.,
59 2017). Therefore, if professional male soccer players are consuming insufficient CHO intake following

60 a match, coupled with the possibility of elevations in RMR causing an increased energy requirement,
61 this could have a detrimental impact on exercise recovery.

62 To the authors knowledge, no research has yet assessed the daily variations in RMR across
63 a competitive week in professional soccer players. Additionally, there are very few studies that have
64 investigated the EI of professional soccer players across the competitive week. Thus, the aims of the
65 present study were to: a) assess RMR; b) assess energy and CHO intake; and c) assess alterations
66 in training load, match load, and muscle soreness; in male professional soccer players throughout an
67 in-season competitive week. Understanding how energy requirements and energy intakes may vary
68 over the competitive week will support nutrition practitioners in developing optimal nutrition strategies
69 for fuelling and recovery.

70 **Methods**

71 **Participants**

72 A convenience sample of twenty-four professional soccer players from the Professional Development
73 Phase in the English Premier League were recruited for this study (mean \pm SD, age: 18 ± 1.6 years;
74 body mass: 77.1 ± 7.5 kg; fat-free mass: 62.7 ± 6.7 kg; stature: 1.80 ± 0.07 m). All playing positions
75 were included (midfielder $n = 5$; defender $n = 12$; forward $n = 5$; goalkeeper $n = 2$). All participants
76 gave their written informed consent to participate in the investigation following approval from the
77 Ethics Committee of Birmingham City University, UK.

78 **Research Design**

79 RMR and EI was measured in-season from November 2021 to May 2022 during a micro-cycle to
80 ensure players were accustomed to the training load and rigors of match play. Timepoints throughout
81 the study are described relative to match day (MD) using +/- symbols for days before (-) or after (+)
82 MD. The first measurement started on MD-3 and measurements were repeated daily (consecutively)
83 following this, except for MD RMR as this was deemed too disruptive to the player's pre-match
84 routine. Training and match load, and muscle soreness were recorded throughout the week. See
85 Table 1 for a typical training week schedule.

86 ***INSERT TABLE 1 HERE***

87 **Resting Metabolic Rate**

88 RMR was measured a total of six times for each participant. All measures were undertaken at the
89 same time between 7.30-9.30 am and players arrived at the training ground following an overnight
90 fast, with their last meal at least 8 hours prior to the measurement. It was ensured participants
91 abstained from caffeine, alcohol, and nicotine overnight, and avoided physical activity for 14 hours
92 prior to measurement (Fullmer et al., 2015). A private, quiet room was utilized to conduct the
93 measurements with temperature maintained at an ambient condition of 20-22°C (Fullmer et al., 2015).
94 Players lay in a comfortable supine position and were reminded to stay awake throughout the
95 assessment. Prior to measurement players rested for 20 minutes (Fullmer et al., 2015). Following this,
96 RMR was measured for 20 minutes. The ventilated hood was located over the participant's head and
97 expired gas was collected via the dilution canopy method (Vyntus CPX canopy, CareFusion,
98 Hoechberg, Germany). A visual check every 5 minutes ensured no gas was escaping. The gas
99 analyser was calibrated daily using the manufacturer's automated flow and digital volume transducer
100 calibration (15.92 % O₂ and 5.03 % CO₂). Following best practice guidelines, the first 5 minutes of
101 measurements were discarded (Fullmer et al., 2015). Measurements were subsequently recorded for
102 15 minutes continuously at 10 second intervals for $\dot{V}O_2$ and $\dot{V}CO_2$. $\dot{V}O_2$ and $\dot{V}CO_2$ were determined
103 using the Haldane transformation (Haldane, 1918) and energy expenditure (kcal·day⁻¹) calculated
104 using the Weir equation (Weir, 1949). **CHO and fat oxidation rates were calculated according to**
105 **standard equations (Zuntz, 1901)**. The coefficient of variance for our protocol was measured at 1.59%
106 for RMR which was similar to previous work using identical methods (1.13%; Hudson et al., 2020).
107 **The limits of agreement were 188.6 kcal·day⁻¹ above and below the mean of the reliability data.**

108 **Anthropometric measures**

109 Body mass (kg) (SECA, model-875, Hamburg, Germany), and stature (m) (SECA, model-217,
110 Hamburg, Germany) were measured on the first day of assessment, according to The International
111 Society for the Advancement of Kinanthropometry (ISAK) guidelines (Esparza-Ros et al., 2019), in the
112 morning with minimal clothing and items such as jewelry removed. Fat free mass was measured using
113 Dual-Energy X-Ray Absorptiometry (DXA) (Hologic QDR Series, Discovery W, Bedford, MA, USA)
114 which has been acknowledged as gold standard in the assessment of body composition (Haarbo et
115 al., 1991). The same trained operator performed and analysed all DXA scans, which were completed
116 in a fasted state in the morning and in accordance with best practice guidelines (Nana et al., 2016).
117 Whole body and regional fat-free and fat mass was included for analysis. These measures were

118 recorded as a sub-total (whole-body minus the head) similar to previous research (Hannon et al.,
119 2020).

120 **Assessment of energy and macronutrient intake**

121 EI was assessed using the remote food photographic method (RFPM), known as 'Snap-N-Send'
122 which has been shown to be a valid and reliable dietary assessment tool in athletes (Costello et al.,
123 2017) and utilised in previous research (Anderson et al., 2017; Hannon et al., 2021). Dietary intake
124 was recorded for 7 days (consisting of: MD-3, MD-2, MD-1, MD, MD+1, MD+2, MD+3) which is
125 considered a reasonable period to provide precise estimations of habitual energy and nutrient intake
126 while reducing variability in coding error (Braakhuis et al., 2003). In addition, this enabled assessment
127 of how EI may vary across the competitive week. On the day before data collection, players were
128 informed by the lead researcher (a Sport and Exercise Nutrition Register (SENr) Practitioner) how to
129 accurately and comprehensively complete the Snap-n-Send tool, ensuring accurate recording of the
130 time of food consumption, amount (weighed amount or household measures such as tablespoons,
131 teaspoons, cups), and description of food (cooking and preparation methods, ingredients, and
132 brands). Photographs were sent through an instant messaging application (WhatsApp). To increase
133 accuracy and avoid underestimation associated with the RFPM (Stables et al., 2021), if the photo or
134 food descriptions were unclear, the player would be contacted in real time to clarify details.
135 Additionally, where food was consumed within the training ground, the lead researcher assisted
136 participants with dietary recording (descriptions, investigating cooking methods and recipes with chefs
137 etc.). If there was any food or drink left following consumption, participants would send a photo of
138 what had not been consumed. A 24 h recall was also undertaken with each participant each morning
139 prior to their RMR assessment to cross reference, check for missing data, confirm amounts, and seek
140 further clarity if required, which was then added to the participants record.

141 Energy and macronutrient intake was obtained using a professional dietary analysis software
142 (Nutritics Ltd, v5, Ireland). All the dietary information was inputted into the software by the lead
143 researcher to ensure consistency. Due to previous research reporting poor inter-practitioner reliability
144 upon analysing nutritional intake (Stables et al., 2021), a second SENr nutritionist also analysed a
145 sample of dietary logs to ensure reliability of nutrition intake data. Inter-rater reliability was determined
146 via an independent t-test. No significant differences were observed between researchers for energy (p

147 = 0.823, 95% CI -120 to 148) or CHO ($p = 0.799$, 95% CI -17.4 to 22.2) intake. Meals were either
148 consumed at: the club's training ground (where a buffet breakfast, lunch, pre and post-match meals,
149 drinks, snacks and supplements are provided); a hotel (where players may be on MD); on the coach
150 during travel on MD or; the players' home environment or restaurants. For the meals provided at the
151 training ground, at the hotel or on the coach, menus were provided on a buffet style basis. All meals
152 were consumed ad libitum by players during the study, and it was not mandatory to eat the meals
153 provided by the club.

154 **Quantification of training and match load**

155 Global positioning system (GPS) technology (Apex Pro Series, STATSports, Belfast, UK) was used to
156 measure pitch-based training and match load. This has been demonstrated to produce valid and
157 reliable estimates of instantaneous and constant velocity movements during linear, multidirectional,
158 and soccer-specific activities (Beato et al., 2018). The total distance (m) covered, high speed running
159 ($> 7\text{m}\cdot\text{s}^{-1}$ (m)), and number of accelerations ($> 3.3\text{m}\cdot\text{s}^{-1}$) and decelerations ($< 3.3\text{m}\cdot\text{s}^{-1}$) were
160 recorded at 18 Hz, providing a valid and reliable assessment of soccer specific movement (Beato et
161 al., 2018). Muscle soreness was self-reported daily (except for MD) from a Visual Analogue Scale of
162 1-10 (1 being extreme soreness, 10 being no soreness).

163 **Statistical Analysis**

164 EI and RMR were recorded as absolute kilocalories (kcal) per day and relative to kilogram (kg) of FFM
165 ($\text{kcal}\cdot\text{kg}^{-1}\text{FFM}\cdot\text{day}^{-1}$) (one participant was excluded as FFM data was missing due to absence of DXA
166 scan), whilst carbohydrate intake was recorded as relative to total body mass ($\text{g}\cdot\text{kg}^{-1}\text{BM}\cdot\text{day}^{-1}$). The
167 sample size varied each day as a small number of participants failed to attend some testing sessions
168 due to varying reasons (e.g., travelling to matches; the wide-ranging schedule demands on
169 professional soccer players; and other unforeseen circumstances).

170 Participants were considered missing at random therefore a linear mixed model was used to
171 avoid list-wise deletion and to account for the hierarchal structure of each participant having
172 observations across numerous days. For each dependent variable, the "lme4" package in R (R
173 Foundation for Statistical Computing, Vienna, Austria. URL <http://www.R-project.org/>) examined the
174 fixed effect of "Match Day" with each participant assigned a random intercept. This is similar to the
175 approach used by Budzynski-Seymour et al. (2021). The model for each measure was: $\text{lmer}(\text{dv} \sim \text{MD}$

176 + (1 | Participant ID)). Estimated marginal means for the variables on each day were obtained using
177 the “emmeans” package. Pairwise contrasts were used to assess differences between individual
178 days. A Bonferroni correction was applied to contrasts for RMR and Soreness measures, whereas a
179 Sidak adjustment was applied to Dietary Intake and GPS variables as these were assumed to be
180 independent between observations. The alpha threshold for significance for all variables was set at
181 $p < 0.05$.

182 **Results**

183 **RMR**

184 Daily RMR across the match week is displayed in Figure 1 (absolute) and Figure 2 (relative to FFM).

185 ***INSERT FIGURE 1 HERE***

186 ***INSERT FIGURE 2 HERE***

187 RMR following the match was significantly higher than pre-match values (MD+1 = 2234 ± 226
188 $\text{kcal}\cdot\text{day}^{-1}$ vs. MD-3 = $2010 \pm 235 \text{kcal}\cdot\text{day}^{-1}$; $p = 0.0075$, $+224 \text{kcal}\cdot\text{day}^{-1}$; $3.5 \text{kcal}\cdot\text{kg}^{-1} \text{FFM}\cdot\text{day}^{-1}$;
189 MD+1 vs. MD-2 = $2017 \pm 241 \text{kcal}\cdot\text{day}^{-1}$; $p = 0.0096$, $+217 \text{kcal}\cdot\text{day}^{-1}$, $+3.5 \text{kcal}\cdot\text{kg}^{-1} \text{FFM}\cdot\text{day}^{-1}$; and
190 MD+1 vs. MD-1 = $1973 \pm 186 \text{kcal}\cdot\text{day}^{-1}$; $p = 0.0004$, $+261 \text{kcal}\cdot\text{day}^{-1}$, $+3.9 \text{kcal}\cdot\text{kg}^{-1} \text{FFM}\cdot\text{day}^{-1}$). In
191 comparison to MD+1, RMR did not significantly decrease by MD+2 (MD+1 vs. MD+2 = 2133 ± 230
192 $\text{kcal}\cdot\text{day}^{-1}$; $p = 1.0000$, $-101 \text{kcal}\cdot\text{day}^{-1}$, $-1.59 \text{kcal}\cdot\text{kg}^{-1} \text{FFM}\cdot\text{day}^{-1}$), however did significantly
193 decrease by MD+3 (MD+1 vs. MD+3 = $1993 \pm 176 \text{kcal}\cdot\text{day}^{-1}$; $p = 0.0036$, $-241 \text{kcal}\cdot\text{day}^{-1}$, -3.9
194 $\text{kcal}\cdot\text{kg}^{-1} \text{FFM}\cdot\text{day}^{-1}$). There were no significant differences on all other days ($p > 0.05$).

195 **$\dot{V}O_2$ and $\dot{V}CO_2$**

196 $\dot{V}O_2$ and $\dot{V}CO_2$ across the match week is displayed in Figures 3 and 4, respectively.

197 ***INSERT FIGURE 3 HERE***

198 Post-match $\dot{V}O_2$ was significantly higher when compared to pre-match values (MD+1 = 0.323 ± 0.032
199 $\text{L}\cdot\text{min}^{-1}$ vs. MD-3 = $0.277 \pm 0.040 \text{L}\cdot\text{min}^{-1}$; $p = 0.0001$, $+0.046 \text{L}\cdot\text{min}^{-1}$; MD+1 vs. MD-2 = $0.290 \pm$
200 $0.033 \text{L}\cdot\text{min}^{-1}$; $p = 0.0071$, $+0.033 \text{L}\cdot\text{min}^{-1}$; and MD+1 vs. MD-1 = $0.282 \pm 0.030 \text{L}\cdot\text{min}^{-1}$; $p =$
201 0.0002 , $+0.041 \text{L}\cdot\text{min}^{-1}$). In comparison to MD+1, $\dot{V}O_2$ did not significantly decrease by MD+2 (MD+1

202 vs. MD+2 = $0.304 \pm 0.036 \text{ L}\cdot\text{min}^{-1}$; $-0.019 \text{ L}\cdot\text{min}^{-1}$, $p = 0.6158$), although did significantly decrease by
203 MD+3 (MD+1 vs. MD+3 = $0.283 \pm 0.044 \text{ L}\cdot\text{min}^{-1}$; $-0.040 \text{ L}\cdot\text{min}^{-1}$, $p = 0.0009$).

204 ***INSERT FIGURE 4 HERE***

205 There were no significant differences in $\dot{V}\text{CO}_2$ across the match week ($p > 0.05$).

206 **CHO and Fat Oxidation**

207 There were no significant differences in resting CHO oxidation rates across the match week (MD-3 =
208 $0.221 \pm 0.032 \text{ g}\cdot\text{min}^{-1}$; MD-2 = $0.204 \pm 0.020 \text{ g}\cdot\text{min}^{-1}$; MD-1 = $0.246 \pm 0.023 \text{ g}\cdot\text{min}^{-1}$; MD+1 = $0.186 \pm$
209 $0.026 \text{ g}\cdot\text{min}^{-1}$; MD+2 = $0.240 \pm 0.027 \text{ g}\cdot\text{min}^{-1}$; MD+3 = $0.271 \pm 0.035 \text{ g}\cdot\text{min}^{-1}$; $p > 0.05$). Similarly,
210 there were no significant differences in resting fat oxidation rates (MD-3 = $0.050 \pm 0.007 \text{ g}\cdot\text{min}^{-1}$; MD-
211 $2 = 0.062 \pm 0.005 \text{ g}\cdot\text{min}^{-1}$; MD-1 = $0.040 \pm 0.005 \text{ g}\cdot\text{min}^{-1}$; MD+1 = $0.085 \pm 0.006 \text{ g}\cdot\text{min}^{-1}$; MD+2 =
212 $0.054 \pm 0.006 \text{ g}\cdot\text{min}^{-1}$; MD+3 = $0.030 \pm 0.008 \text{ g}\cdot\text{min}^{-1}$; $p > 0.05$).

213 **Energy Intake**

214 Absolute and relative EI across the match week is displayed in Figures 5 and 6, respectively.

215 ***INSERT FIGURE 5 HERE***

216 ***INSERT FIGURE 6 HERE***

217 There were no significant differences in daily absolute or relative EI across the match week (Absolute
218 EI ($\text{kcal}\cdot\text{day}^{-1}$): MD-3 = 2597 ± 843 ; MD-2 = 2679 ± 641 ; MD-1 = 2743 ± 1143 ; MD = 2582 ± 867 ;
219 MD+1 = 2580 ± 934 ; MD+2 = 2714 ± 931 ; MD+3 = 2295 ± 817 , $p > 0.05$. Relative EI ($\text{kcal}\cdot\text{kg}^{-1}$
220 $\text{FFM}\cdot\text{day}^{-1}$): MD-3 = 42.2 ± 14.5 ; MD-2 = 43.2 ± 11.6 ; MD-1 = 44.7 ± 19.2 ; MD = 42.1 ± 14.7 ; MD+1 =
221 42.1 ± 16.5 ; MD+2 = 44.1 ± 16.8 ; MD+3 = 37.5 ± 14.9 , $p > 0.05$).

222 **Carbohydrate Intake**

223 Relative carbohydrate intake across the match week is displayed in Figure 7.

224 ***INSERT FIGURE 7 HERE***

225 There were no significant differences in daily relative carbohydrate intake across the competitive
226 match week (MD-3 = 3.5 ± 1.5 ; MD-2 = 3.5 ± 1.1 ; MD-1 = 3.9 ± 1.9 ; MD = 4.2 ± 1.6 ; MD+1 = $3.6 \pm$
227 1.7 ; MD+2 = 4 ± 2.0 ; MD+3 = $3.3 \pm 1.5 \text{ g}\cdot\text{kg}^{-1} \text{ BM}\cdot\text{day}^{-1}$; $p > 0.05$).

228 Training and match demands, and muscle soreness

229 All GPS and muscle soreness data can be found in Table 2.

230 ***INSERT TABLE 2 HERE***

231 Total Distance Covered

232 The total distance covered was significantly higher on MD compared to all other days ($p < 0.001$).

233 High Speed Running

234 The distance of high-speed running covered was significantly higher on MD compared to all other
235 days ($p < 0.001$).

236 Accelerations

237 The number of accelerations was significantly higher on MD than MD-3, MD-2, MD-1, MD+1, and
238 MD+2 ($p < 0.001$). There was no significant difference in the number of accelerations on MD and
239 MD+3 ($p > 0.05$).

240 Decelerations

241 The number of decelerations was significantly higher on MD compared to all other days ($p < 0.001$).

242 Muscle Soreness

243 Perception of muscle soreness was significantly higher post-match vs. pre-match values (MD+1 vs.
244 MD-3: $p = 0.021$; MD+1 vs. MD-2: $p = 0.009$; and MD+1 vs. MD-1: $p < 0.001$). This remained
245 significantly elevated on MD+2 vs. MD-1 ($p = 0.035$), but significantly reduced by MD+3 vs. MD+1 (p
246 $= 0.002$).

247 Discussion

248 The purpose of the current study was to: (a) assess RMR; (b) assess energy and CHO intake and; (c)
249 assess training load, match load, and muscle soreness; in male professional soccer players
250 throughout an in-season competitive week. Our data shows that despite increases in resting
251 metabolic rate of $\sim 12.4\%$ ($261 \text{ kcal}\cdot\text{day}^{-1}$) in the day immediately following a soccer match,
252 professional soccer players do not periodise their energy and CHO intake throughout the competitive

253 week to account for these potential increases in energy demands. This finding agrees with previous
254 work which has also reported significant elevations in RMR in the days immediately following intense
255 exercise (Hackney et al., 2008; Hudson et al., 2020). To the authors' knowledge, our study is the first
256 of its kind to report this observation specifically in professional soccer players, thereby highlighting an
257 important consideration for practitioners when implementing effective recovery nutrition strategies.
258 Furthermore, although statistically insignificant, MD+2 identified a $\sim 160 \text{ kcal}\cdot\text{day}^{-1}$ (7.8%) mean daily
259 increase in RMR from MD-1, which demonstrates that elevations in RMR persist 36-48hrs after a
260 match. It was not until MD+3 that RMR levels returned to the status observed pre-match.

261 $\dot{V}O_2$ was also significantly increased on MD+1 ($\sim 13.6\%$) when compared to MD-1 and, similar
262 to the trend observed for RMR, did not return to pre-match levels until MD+3. This finding is in
263 agreement with that of Hudson et al (2020) who, albeit in a different sport, reported RMR and $\dot{V}O_2$ to
264 be significantly increased following a match in senior professional rugby union players. They
265 proposed that the elevated RMR was a consequence of a raised energy requirement due to a
266 combination of either prolonged excessive post-exercise oxygen consumption (EPOC) (Kolkhorst et
267 al., 1994), or a high eccentric-focussed physical load (Hackney et al., 2008) inducing the degradation
268 and resynthesis of damaged muscle fibres (Burt et al., 2014). This proposed mechanism aligns to the
269 current study within soccer as research by Silva et al. (2013) suggests that muscle damage markers
270 (creatine kinase) in professional soccer players are increased for up to 48 hrs following a competitive
271 match. Interestingly, the current study shows that players reported muscle soreness to be significantly
272 higher on MD+1 and MD+2 compared to pre-match values, which further supports this proposed
273 mechanism. Additionally, physical load was significantly higher on MD compared to training days,
274 which we propose may be the cause of increased muscle soreness observed, and potentially
275 increased RMR.

276 In terms of $\dot{V}CO_2$, it is interesting that despite reporting very similar increases in RMR and
277 $\dot{V}O_2$, the present study differs from that of Hudson et al (2020) where they also reported significant
278 increases in $\dot{V}CO_2$ in the 48-72hrs after rugby match play. In their work, Hudson et al (2020) attribute
279 the elevations in $\dot{V}CO_2$ to the volume and intensity of collisions encountered during match-play, as the
280 greatest increases were seen in the forwards, who underwent more physical collisions during the
281 game. In the current study no changes were observed in $\dot{V}CO_2$ and thus it is possible that the differing
282 demands of football match play - larger running distances with a higher number of

283 accelerations/decelerations, but a lower volume and intensity of collisions – induces a different
284 muscle damage response which does not sufficiently elevate $\dot{V}CO_2$. This may indicate that, despite
285 observing similar elevations in post-match RMR, there are different aetiologies of muscle damage
286 experienced within the two sports which induce this, but further research is needed to fully verify this
287 theory.

288 Our findings show that training load varies throughout the competitive week, which aligns with
289 previous research (Anderson et al., 2016). However, there are no significant differences in EI
290 throughout the competitive week, for both absolute values and when FFM is considered. For example,
291 we show that mean EI on MD-3 ($2595 \text{ kcal}\cdot\text{day}^{-1}$) was similar to that of MD ($2582 \text{ kcal}\cdot\text{day}^{-1}$). Previous
292 work has emphasised the need for soccer players to adapt their EI to account for the changes in
293 energy demands across the week (Collins et al., 2021), but our findings would suggest that
294 professional players within our population were not adhering to this recommendation. In contrast,
295 Anderson et al. (2017) and Brinkmans et al. (2019) reported mean daily EI of senior professional
296 soccer players were significantly greater on MD compared to training day. To note, the mean age of
297 players was higher in these latter studies (27 ± 3 and 23 ± 4 years, respectively) which may suggest
298 senior players are better at periodising EI, when compared to younger professional players in our
299 study. To our knowledge, our research is the first to assess whether there are any alterations in EI to
300 reflect changes in RMR across the competitive match week in professional soccer players. The
301 outcomes of the present study suggest that younger players may need more dedicated nutrition
302 support (e.g., education) to fully understand the importance of periodising EI to account for potential
303 increases in energy demands.

304 The importance of CHO for soccer performance has been acknowledged since the 1970s
305 (Saltin, 1973). Similar to EI, CHO intake should be periodised throughout the competitive week to
306 account for the changes in energy demands (Anderson et al., 2022). In our study, the average training
307 day CHO intake was $3.5 \text{ g}\cdot\text{kg}^{-1} \text{ BM}\cdot\text{day}^{-1}$, similar to previous research within professional soccer
308 players ($4 \text{ g}\cdot\text{kg}^{-1} \text{ BM}\cdot\text{day}^{-1}$, Anderson et al., 2017). Given the lower absolute daily loads on typical
309 training days, such daily intakes may be sufficient to support fueling and recovery during training
310 (Collins et al., 2021). The recommended CHO intake one day prior to, on MD and the day post-match
311 are $6\text{-}8 \text{ g}\cdot\text{kg}^{-1} \text{ BM}\cdot\text{day}^{-1}$ to elevate glycogen stores (Collins et al., 2021). However, the current study
312 shows that the average CHO intake the day prior to the match was $3.9 \text{ g}\cdot\text{kg}^{-1} \text{ BM}\cdot\text{day}^{-1}$, on MD was

313 4.2 g·kg⁻¹ BM·day⁻¹, and the day post-match was 3.6 g·kg⁻¹ BM·day⁻¹. This is far below the
314 recommendation by Collins et al. (2021), indicating that the players from our study may be
315 insufficiently fuelled for the increased physical and recovery demands of matches. Although
316 Brinkmans et al. (2019) and Anderson et al. (2017) reported significantly higher CHO intake on MDs
317 compared with training days in professional senior soccer players, intakes were inadequate to
318 optimise fuelling and recovery. Given a primary objective following a match is to reduce the time
319 needed to fully recover and rapidly replenish glycogen stores (Collins et al., 2021) this is of key
320 concern due to the impairment on recovery. CHO intake on MD+1 would be even more paramount
321 during periods of congested fixtures where energy demands, and the risks of low energy availability
322 are likely to be higher (Collins et al., 2021). Given muscle soreness (indicating muscle damage) was
323 significantly higher on MD+1 in our study, this may impair glycogen synthesis (Costill et al., 1990)
324 which further highlights the need for additional CHO. To add more context to average CHO intakes, it
325 should be noted that high inter-player variability is evident. For example, on MD-1 CHO intake ranged
326 from 1.5 g·kg⁻¹ BM·day⁻¹ to 7.5 g·kg⁻¹ BM·day⁻¹, meaning some players are significantly under-
327 fuelling whilst others are sufficiently fuelling, which further highlights the importance of individualised
328 nutrition support for soccer players. It is evident nutritional interventions should focus on improving
329 professional soccer players energy and CHO intakes in the day before, day of, and day after a match.
330 These interventions should consider the barriers and enablers to nutritional adherence previously
331 identified within professional soccer players (Carter et al., 2022).

332 Future studies should assess the impact of congested fixtures on RMR to investigate whether
333 this is further elevated, as meeting energy requirements is even more crucial during this period to
334 support recovery (Ranchordas et al., 2017). Additionally, it would be useful to compare RMR within
335 different playing positions to assess whether there are differences. Furthermore, it would of interest to
336 assess whether changes in RMR are as magnified when players meet energy and carbohydrate
337 requirements leading up to and following the match.

338 **Limitations**

339 We are aware the findings are based on one Premier League soccer club; however, training and
340 match schedules are typical in other clubs. Additionally, although training load was captured within the
341 soccer club, physical activity outside of the club was not recorded. Another limitation is the potential of

342 participants under-reporting dietary intake on the RFPM and 24 h recall. However, as outlined in the
343 methods, robust steps were undertaken to minimise this. Finally, we did not measure markers of
344 muscle damage and inflammation, however, given that our data were collected in a professional
345 setting this is not always feasible as coaches typically limit the invasiveness of data collection on
346 professional athletes.

347 **Conclusion**

348 In summary we report for the first time the changes in RMR over the competitive week in professional
349 soccer players. We observed a significant increase of 12.4% in RMR, and an increase in $\dot{V}O_2$ on
350 MD+1 compared to MD-1 which may have a significant impact on nutritional practice. We determined
351 that players do not periodise nutritional intake across the competitive week, consuming inadequate
352 CHO on MD-1, MD and MD+1 which could impair physical performance. Moreover, during periods of
353 fixture congestion, inadequate EI may further compromise performance and recovery. Therefore,
354 nutrition practitioners should focus on implementing behaviour change interventions to promote
355 effective fuelling and recovery nutrition practice in the day prior to the match, MD and within the 1-2
356 days following a match.

357

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363 **Conflicts of Interest**

364 The authors declare no conflicts of interest.

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500 **Figure Legends**

501 **Figure 1.** Absolute changes in RMR ($\text{kcal}\cdot\text{day}^{-1}$) across the competitive match week (Mean \pm SD).

502 *Significantly higher than MD-3, MD-2, and MD-1 ($p<0.01$). #Significantly lower than MD+1 ($p<0.01$).

503 Key: MD = match day.

504 **Figure 2:** Relative changes in RMR ($\text{kcal}\cdot\text{kg}^{-1}\text{FFM}\cdot\text{day}^{-1}$) across the competitive match week (Mean
505 \pm SD). *Significantly higher than MD-3, MD-2, and MD-1 ($p<0.01$). #Significantly lower than MD+1

506 ($p<0.01$). Key: MD = match day.

507 **Figure 3:** Changes in $\dot{V}\text{O}_2$ ($\text{L}\cdot\text{min}^{-1}$) across the competitive match week (Mean \pm SD). *Significantly

508 higher than MD-3, MD-2, and MD-1 ($p<0.01$). #Significantly lower than MD+1 ($p<0.001$). Key: MD =

509 match day.

510 **Figure 4:** Changes in $\dot{V}\text{CO}_2$ ($\text{L}\cdot\text{min}^{-1}$) across the competitive match week (Mean \pm SD). Key: MD =

511 match day.

512 **Figure 5:** Absolute energy intake ($\text{kcal}\cdot\text{day}^{-1}$) across the competitive match week (Mean \pm SD). Key:

513 MD = match day.

514 **Figure 6:** Relative energy intake ($\text{kcal}\cdot\text{kg}^{-1}\text{FFM}\cdot\text{day}^{-1}$) across the competitive match week (Mean \pm

515 SD). Key: MD = match day.

516 **Figure 7:** Relative carbohydrate intake ($\text{g}\cdot\text{kg}^{-1}\text{BM}\cdot\text{day}^{-1}$) across the competitive match week (Mean \pm

517 SD). Key: MD = match day.

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Tables526 **Table 1.** An overview of the pitch based and match schedule for each squad.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
U23	Match	Recovery	Day off	Training	Training	Training	Training
(am)		11:00 – 12:00		10:45 – 12:30	10:45 – 12:30	10:45 – 12:30	10:45 – 12:30
(pm)	19:00 Kick Off			Gym 14:00-15:00		Gym 14:00-15:00	
U18	Training	Training	Day off	Training	Training	Match	Day off
(am)	10:45 – 12:30	10:45 – 12:30		10:45 – 12:30	10:45 – 12:30	11:00 Kick Off	
(pm)		Gym 14:00-15:00		Gym 14:00-15:00			

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528 **Table 2.** Comparison of muscle soreness and metrics recorded for training and match play throughout the competitive week

Day	MD-3	MD-2	MD-1	MD	MD+1	MD+2	MD+3
Total distance (m)	3283 ± 1975*	4441 ± 1973*	3491 ± 1214*	12326 ± 1973	98 ± 468*	2936 ± 1991*	7964 ± 4280*
High Speed Running (>7m·s⁻¹ (m))	78 ± 76*	223 ± 144*	74 ± 64*	774 ± 310	0 ± 0*	98 ± 142*	460 ± 409*
Accelerations (< 3.3 m·s⁻¹)	41 ± 31*	52 ± 35*	40 ± 21*	92 ± 31	1 ± 6*	34 ± 25*	69 ± 32
Decelerations (< 3.3 m·s⁻¹)	29 ± 21*	44 ± 29*	34 ± 17*	99 ± 31	1 ± 4*	30 ± 20*	67 ± 37*
Muscle Soreness Score	7.90 ± 1.50 [#]	8.00 ± 1.27 [#]	8.29 ± 0.86 [#]	Not collected	6.88 ± 0.80 [†]	7.31 ± 1.43 [‡]	8.15 ± 1.14

(Lower score = higher soreness)

529 Key: MD = match day

530 *Denotes values significantly different ($p < 0.05$) when compared with match day (shown in bold).531 [#] = significantly different when compared with MD+1 ($p < 0.05$).532 [†] = significantly different when compared with MD+3 ($p < 0.0019$).533 [‡] = significantly different when compared with MD-1 ($p < 0.0351$).