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1 **Case study:**

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3 **Assessment of energy expenditure of a professional**
4 **goalkeeper from the English Premier League using the**
5 **doubly labeled water method**
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37 **Running head:** Energy expenditure in a goalkeeper

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51 **Abstract**

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53 **Purpose:** To better understand the energy and carbohydrate (CHO)
54 requirements of a professional goalkeeper (GK) in elite soccer, we
55 quantified physical loading, energy expenditure (EE) and energy
56 intake (EI) during a two game per week in-season micro-cycle.

57

58 **Methods:** Daily training and match loads were assessed in a
59 professional GK (age, 26 years; height, 191 cm; body mass, 86.1 kg)
60 from the English Premier League using global positioning systems
61 (GPS) and ProZone®, respectively. Assessments of EE (using the
62 doubly labelled water method) and EI (using food diaries supported
63 by the remote food photographic method and 24-h recalls) were also
64 completed.

65

66 **Results:** Physical loading was greater on match days (MD) versus
67 training days (TD) as inferred from total distance (4574 ± 432 vs
68 1959 ± 500 m), average speed (48 ± 5 v 40 ± 4 m/min) and distance
69 completed when jogging (993 ± 194 v 645 ± 81 m) and running (138
70 ± 16 v 21 ± 20 m). Average daily energy and macronutrient intake
71 appear reflective of a self-selected “low CHO” diet (Energy: $3160 \pm$
72 381 kcal, CHO: 2.6 ± 0.6 ; Protein: 2.4 ± 0.4 ; Fat: 1.9 ± 0.3 g.kg⁻¹
73 body mass). Mean daily EE was 2894 kcal.

74

75 **Conclusions:** The average daily EE of this professional GK was
76 approximately 600 kcal.d⁻¹ lower than that previously reported in
77 outfield players from the same team. Such data suggest the
78 nutritional requirements of a GK should be carefully considered
79 depending on the required daily and weekly loading patterns.

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81 **Keywords:** goalkeeper, carbohydrate, energy expenditure, soccer,
82 training load

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106 **Introduction**

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108 The goalkeeper (GK) position in soccer is unique to the team
109 and is one that often demonstrates distinct physical qualities
110 when compared with outfield players^{1,2,3}. For example, in
111 contrast to the ability to perform the locomotive load inherent
112 to outfield players, GKs are typically assessed on their ability
113 to perform explosive, short duration movements such as diving,
114 catching and accelerating and decelerating sharply¹. Indeed, in
115 relation to locomotive match demands, it is well documented
116 that GKs cover 50% of the total distance and <10% of the
117 distance completed within the high-intensity speed zones
118 ($>19.8 \text{ km} \cdot \text{h}^{-1}$) typically completed by outfield players^{2,3}.

119

120 Given the marked differences in the absolute and distribution of
121 locomotive demands, it follows that the training demands of
122 GKs should be tailored accordingly. In this regard, Malone et
123 al.⁴ observed total distances during training of approximately 3
124 km, considerably lower than that typically observed (e.g. 5-7
125 km) in outfield players⁵. This reduction in training load is
126 expected as GKs often train in small groups and areas (focusing
127 on the development of position specific attributes) with limited
128 involvement in outfield player drills⁵. Given that GKs are
129 usually taller, heavier and display higher levels of body fat than
130 outfield players⁶, there could be a requirement to also focus
131 training and nutritional strategies to achieve a body
132 composition that the GK coach desires. Such rationale is
133 presented in the context that excess fat mass acts as a dead
134 mass in activities in which the body is lifted against gravity and
135 too much of it could negatively impact performance⁷.
136 Nonetheless, despite the apparent reduction in absolute training
137 loads compared with outfield players (as suggested through
138 locomotive metrics) and the rationale to optimise body
139 composition, it is currently difficult to provide position specific
140 nutritional guidelines owing to the lack of direct assessments of
141 energy expenditure (EE).

142

143 With this in mind, the aim of the present case-study was to
144 quantify the EE of a professional GK of the English Premier
145 League (EPL) using the doubly labelled water method (DLW).
146 The use of this technique is advantageous as it takes into
147 account the total daily EE of players therefore encompassing
148 those energetic actions (e.g. diving, jumping, isometric
149 contractions etc.) that are not often considered when using
150 global positioning system (GPS) data to make inferences of
151 daily EE.

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157 **Methods**

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159 *Overview of The Player*

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161 The player is a 27-year old male professional GK (body mass:
162 85.6 kg, height: 191 cm, percent body fat: 11.9 %, fat mass: 9.8
163 kg, lean mass: 69.5 kg) who is internationally capped and
164 currently competing in the EPL. He had been a regular starter
165 at his club for 2.5 seasons prior to this study commencing.

166

167 *Study Design and Data Analysis*

168

169 Data collection was conducted during a 7-day in-season period
170 of the 2015-2016 English Premier League season. Body
171 composition (dual energy absorptiometry, DXA), training load
172 (GPS device), match load (Prozone), EE (DLW) and energy
173 and macronutrient intakes (using food diaries supported by the
174 remote food photographic method and 24-h recalls) were all
175 collected and analysed as described previously by Anderson et
176 al.^{8,9} However, although the same methods were used for data
177 collection, a specific GK global positioning system (GPS)
178 device was used to assess external training load (GPS;
179 Optimeye G5; firmware version 717; Catapult Sports,
180 Australia). An additional variable of PlayerLoad™ was
181 included for analysis that presents an arbitrary unit derived
182 from the tri-axial accelerometer that measures instantaneous
183 change in acceleration⁴. Throughout the study period, the
184 player took part in six training sessions and two competitive
185 games. The study was conducted according to the requirements
186 of the Declaration of Helsinki and was approved by the
187 university ethics committee of Liverpool John Moores
188 University.

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191 **Results**

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193 *Quantification of Daily and Accumulatively Weekly Load*

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195 An overview of the individual daily training and match load
196 and the accumulative weekly load is presented in Table 1.

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198 *Quantification of Daily Energy Expenditure, Energy Intake 199 and Macronutrient Intake*

200

201 Mean daily EE and energy intake was 2894 and 3160 ± 381
202 kcal, respectively. A day-by-day assessment of energy and
203 macronutrient intake is also displayed in Table 2. The GK
204 consumed no form of CHO during training sessions or games
205 and fluid intake was water consumed ad libitum.

206

207 **Discussion**

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209 Using the DLW method, we report for the first time that the
210 average daily EE of an elite Premier League GK is <2900
211 kcal.d⁻¹. When considered with previous reports of EE of
212 outfield players from the same team during the same 7-day
213 microcycle (approximately 3500 kcal.d⁻¹), our data suggest that
214 the energetic demands and nutritional requirements of elite
215 GKs are not readily comparable. Whilst we acknowledge that
216 the EE reported here is specific to the athlete of this case-study,
217 our data outline the unique positional and energy demands of
218 an elite GK. The data provides reasoning for further
219 investigation into EI and EE into elite level GKs.

220

221

222 In relation to the external physical loading parameters reported
223 here, we observed lower external loading than that reported in a
224 previous case-study account of a professional GK from the top
225 division of the Dutch league⁴. For example, total distances
226 completed in training were approximately 1 km lower (i.e. <2.5
227 versus >3.5 km) and also reflective of 20-30 minutes less
228 training time. Such differences between studies are likely due
229 to the two games per week schedule versus the one game per
230 week schedule, hence the focus of the micro-cycle studied here
231 was more related to recovery and preparation between games.
232 Alternatively, differences in external loading patterns may be
233 due to the different coaching and conditioning philosophy of
234 the individual GK coach. When the two games per week
235 schedule is taken into consideration, it is therefore unsurprising
236 that the external training load (e.g. total distances of
237 approximately 2 km) reported here is similar to those outfield
238 players studied previously in the same micro-cycle⁸. In this
239 regard, comparable markers of loading between positions are
240 likely due to the fact that the outfield players have markedly
241 reduced their training load when compared with the traditional
242 one game per week schedule⁵.

243

244 A limitation of the DLW technique is that it is unable to
245 provide daily assessments of EE. As such, it is therefore
246 important to consider the total accumulative load experienced
247 by both GKs and outfield players during the week. When
248 considered this way, differences between outfield players⁸ and
249 the GK studied here were observed for total distance (26.4
250 versus 20.9 km), running distance (3.4 versus 0.4 km), high
251 speed running (1.3 versus 0.02 km) and sprinting (0.43 versus
252 0.004 km). Ultimately, this difference in accumulative weekly
253 load likely contributes to the reduced mean daily EE (i.e. 2894
254 kcal.d⁻¹) when compared with those outfield players⁸ studied
255 previously (n=6, 3566 ± 585, range 3047-4400 kcal.d⁻¹).

256

257 In relation to the mean daily EI (3160 ± 381 kcal), it is
258 noteworthy that the GK self-selected a low daily carbohydrate
259 (CHO) intake (2.6 g.kg^{-1} body mass) in combination with high
260 protein and fat intakes (2.4 and 1.9 g.kg^{-1} body mass,
261 respectively) in the belief that it would facilitate favorable body
262 composition changes. The player adhered to this diet when
263 joining the club and liaising with the sports nutritionist to
264 initially alter his body composition. However, at the present
265 time he was under no guidance from either the nutritionist or
266 any of the teams support staff with regards to his nutritional
267 nutritional intake. Interestingly, CHO intakes were increased
268 from training (approximately 2.5 g.kg^{-1} body mass) to match
269 days (3.5 g.kg^{-1} body mass), but not to as greater extent of the
270 CHO periodisation strategies practiced by outfield players who
271 increase their CHO intake on match days to $> 6 \text{ g.kg}^{-1}$ per day⁸.
272 It is difficult to ascertain if the CHO strategy adopted by the
273 GK studied here is conducive to optimal performance and
274 hence further studies are required to examine the effects of
275 specific dietary interventions on performance indices specific
276 to elite GKs. In relation to daily protein intakes, it is
277 noteworthy that the GK consistently adhered to daily intakes $>$
278 2 g.kg^{-1} , thus in keeping with the well accepted role of protein
279 and resistance training in facilitating muscle hypertrophy and
280 strength^{10,11,12}. This GK frequently performed additional
281 resistance training and upon dietary assessment of the athlete,
282 he frequently commented on his belief in the efficacy of a high
283 protein diet and strength training for maintenance and growth
284 of muscle mass. However, due to the lack of research around
285 top level GK it is not known if an increase in muscle mass
286 would relate to an increase in physical performance.

287

288 Although this data is extremely novel and the first to examine
289 EI and EE (via the DLW method) in an elite level GK, it is not
290 without it's limitations. Most notably this data only provides an
291 insight into one GK for one week. This may not provide a true
292 representation for this GKs normal and habitual intake nor
293 would it represent all elite level GKs. Additionally, the EI
294 assessments were self reported and estimated. However, this
295 player provided the researchers with as much information as
296 possible and actually weighed out food portions in the food
297 diary in order to increase the accuracy of the EI estimations.

298

299 **Practical Applications**

300

301 Our data demonstrate that the average daily EE of a
302 professional GK during a two game per week in-season
303 microcycle is $< 2900 \text{ kcal.d}^{-1}$. When considered in combination
304 with the lower weekly accumulative locomotive loads
305 compared with the outfield players⁸, our direct assessment of

306 EE suggests that the nutritional requirements of GKs and
307 outfield positions may not be readily comparable. Indeed, this
308 player self-selected a low CHO daily intake (2.5-3.5 g.kg⁻¹
309 body mass), the magnitude of which would not be considered
310 optimal for the physical performance of outfield players. Our
311 data therefore suggest that elite GKs may not require the high
312 CHO intakes traditionally advised to outfield players though
313 we acknowledge that daily intakes should be carefully adjusted
314 in accordance with any fluctuations in daily and weekly loading
315 patterns.

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317

318 **Conclusion**

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320 We provide novel data by simultaneously reporting the daily
321 physical loading, energy intake and energy expenditure of an
322 elite GK from the EPL during a two game weekly micro-cycle.
323 Data demonstrate that average daily energy expenditure is
324 approximately 600 kcal.d⁻¹ less than that observed in outfield
325 players, thereby alluding to position specific nutritional
326 guidelines. Future studies are now required to examine the
327 energy expenditure of GKs and outfield players using larger
328 sample sizes comprised from multiple professional teams.

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Table 1. An overview of the absolute and accumulative training and match external physical loads of the goalkeeper during the 7-day data collection period.

	Day 1	Day 2 am	Day 2 pm (Game 1)	Day 2 Total	Day 3	Day 4	Day 5 (Game 2)	Day 6	Day 7	Training	Match	Total
Duration (mins)	68	36	94	130	45	61	96	32	52	294	190	484
Total Distance (m)	2422	1393	4879	6272	1800	2367	4268	1379	2392	11753	9147	20900
Average Speed (m/min)	35.5	38.8	51.8	48.2*	40.0	38.8	44.3	43.7	46.0	-	-	409
Standing (0-0.6 km . hr⁻¹)	868	400	85	485	374	746	109	431	780	3599	194	3793
Walking (0.7-7.1 km . hr⁻¹)	825	482	3526	4008	686	876	3137	298	989	4156	6663	10819
Jogging (7.2-14.4 km . hr⁻¹)	716	511	1130	1641	712	702	856	607	623	3871	1986	5857
Running (14.4-19.7 km . hr⁻¹)	13	0	126	126	28	42	149	43	0	126	275	401
HSR (19.8-25.2 km . hr⁻¹)	0	0	9	9	0	0	17	0	0	0	26	35
Sprinting (>25.2 km . hr⁻¹)	0	0	4	4	0	0	0	0	0	0	4	4
PlayerLoadTM (AU)	286	148	-	-	171	247	-	137	268	1257	-	415

HSR = High Speed Running, *Combination of the am and pm session total distance/ a combination of the am and pm duration

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Table 2. Daily energy and macronutrient intake expressed in absolute and relative terms during the 7-day data collection period. Days 2 and 5 were match days and days 1, 3, 4, 6 and 7 were training days.

	Day							
	1	2	3	4	5	6	7	Mean ± SD
Energy (kcal)	2698	3607	3330	2931	3342	2695	3516	3160 ± 381
Energy (kcal.kg⁻¹ LBM)	38.8	51.9	47.9	42.2	48.1	38.8	50.6	45.5 ± 5.5
CHO (g)	185	272	222	145	299	187	245	222 ± 54
CHO (g.kg⁻¹)	2.1	3.1	2.6	1.7	3.5	2.2	2.8	2.6 ± 0.6
Protein (g)	194	234	192	167	221	172	266	207 ± 36
Protein (g.kg⁻¹)	2.2	2.7	2.2	1.9	2.6	2.0	3.1	2.4 ± 0.4
Fat (g)	133	181	187	187	127	143	168	161 ± 26
Fat (g.kg⁻¹)	1.5	2.1	2.2	2.1	1.5	1.7	1.9	1.9 ± 0.3

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