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1 Title: The physical demands of professional soccer goalkeepers throughout a week-long  
2 competitive microcycle and transiently throughout match-play

3

4 Running Title: Physical demands of soccer goalkeepers

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33

34 **ABSTRACT**

35 The physical demands of English Premier League soccer goalkeepers were quantified during training  
36 and match-play in a two-part study. Goalkeeper-specific micromechanical electrical systems (MEMS)  
37 devices, profiled training and match-day activities throughout one competitive week ( $n=8$ ; part A).  
38 Changes in MEMS-derived outputs were also profiled throughout match-play (100 matches;  $n=8$ ,  
39  $18\pm 14$  observations per goalkeeper; part B). In part A, goalkeeping-training elicited the most dives  
40 ( $51\pm 11$ ) versus all activities (all  $p\leq 0.030$ ) except shooting-training ( $p=0.069$ ). Small-sided games  
41 elicited the fewest ( $5\pm 3$ ) dives (all  $p\leq 0.012$ ). High-speed distance covered in match ( $103\pm 72$  m) was  
42 similar to goalkeeping-training ( $p=0.484$ ), while exceeding shooting-training, small-sided games, pre-  
43 match shooting, and pre-match warm-up (all  $p=0.012$ ). Most changes of direction ( $34\pm 12$ ) and  
44 explosive efforts ( $70\pm 18$ ) occurred during goalkeeping-training, with values exceeding match (both  
45  $p=0.012$ ). In part B, between-half reductions in total distance, but increased high-speed changes of  
46 direction and explosive efforts, occurred (both  $p\leq 0.05$ ). Excluding the number of high jumps, all  
47 variables differed from 0-15-min during at least one match epoch, with more dives ( $1.3\pm 1.4$  vs  $1.0\pm 1.1$ )  
48 and explosive efforts ( $2.5\pm 2.4$  vs  $2.0\pm 1.8$ ) performed between 75-90-min versus 0-15-min (all  $p<0.05$ ).  
49 These data highlight the differing physical demands of various activities performed by professional  
50 soccer goalkeepers throughout a competitive week.

51

52 **KEY WORDS:** Goalkeeping, performance, team sport

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## 59 INTRODUCTION

60 The physical demands of soccer have been extensively characterized, primarily with respect to the  
61 movement responses of outfield players during training and match-play (2, 15). However, comparable  
62 information relating to the unique positional demands of goalkeepers is currently lacking (26). The  
63 goalkeeper's primary role in soccer is to protect their team's goal, whilst a secondary purpose lies in  
64 ball-distribution during the initiation of an attack. As the ultimate objective of soccer is to out-score the  
65 opposition, it stands to reason that the demands placed upon goalkeepers have the potential to directly  
66 influence the outcome of a match.

67 Adaptive responses to training are realized through progressive manipulation of key training variables,  
68 including (but not limited to) the volume, intensity and type of exercise stimuli applied (9). Indeed,  
69 empirical observations highlight that the designs of soccer conditioning sessions are often predicated  
70 on the basis of practitioners' *a priori* knowledge of the specific demands elicited by the various  
71 components of the training and competitive week, alongside the associated recovery requirements. It is  
72 therefore likely that characterization of goalkeepers' match-play and training demands would benefit  
73 practitioners seeking to optimize training prescription for this bespoke playing population (26). Given  
74 their distinct tactical responsibilities, goalkeepers possess a bespoke skillset when compared with  
75 players occupying outfield positions (26, 27). Indeed, empirical observations suggest that professional  
76 goalkeepers conduct much of their training and preparatory activities typically under the guidance of  
77 position-specific coaches. We are aware of only one published study to have investigated the demands  
78 of goalkeeper-specific training sessions during a competitive microcycle (13). Whilst Malone et al. (13)  
79 highlighted that a professional goalkeeper covered up to ~3.7 km at ~45 m·min<sup>-1</sup> during certain training  
80 sessions in the four days preceding a match (compared with up to ~6.9 km for professional outfield  
81 players; 12, 18), information concerning position-specific performance indicators, and details regarding  
82 the specific content of the training sessions were omitted; the authors merely presenting data as a  
83 function of a session's proximity to match-day.

84 It is well documented that for outfield players, indices of physical and technical performance decline  
85 progressively throughout 90-min of soccer-specific exercise (16, 21, 22), with further decrements

86 reported during matches continuing to extra-time (i.e., 120 min; 10, 11, 24). Such declines are primarily  
87 attributed to increases in physical fatigue during the latter stages of match-play, and the existence of  
88 conscious or subconscious self-pacing strategies (2, 4, 15). However, consistent with their unique  
89 tactical role, goalkeepers appear to face vastly different match-demands when compared with their  
90 outfield counterparts. Indeed, professional goalkeepers may cover ~50% (i.e., 4-6 km) of the match-  
91 distances of outfield players, whilst performing only ~2 short (i.e., typically <10 m) sprints (6, 13, 26).  
92 To the authors knowledge, no study has investigated whether goalkeepers experience transient changes  
93 in position-specific physical demands over the course of 90-min of competitive match-play as has been  
94 reported for outfield players (7, 15, 23). This is made more surprising by the disproportionate number  
95 of goals scored during the final 15-min of a match (17), alongside empirical observations suggesting  
96 that goalkeepers are rarely substituted, except for in the case of injury.

97 Therefore, this two-part study used position-specific physical performance indicators to quantify the  
98 movement demands elicited during goalkeeper-specific training throughout a competitive microcycle  
99 (part A), and profiled transient changes in the movement responses of professional soccer goalkeepers  
100 during 90-min of match-play (part B). Such findings may have important implications for the  
101 preparatory and/or tactical game-management strategies employed in relation to soccer goalkeepers.  
102 Based on empirical evidence and inferring from previous literature, it was hypothesized that the  
103 movement demands would vary according to the type of the session being performed, and that transient  
104 changes in physical demands would be experienced over the course of soccer match-play.

105

106

**107 MATERIALS AND METHODS***108 Study design*

109 To quantify the movement demands, professional soccer goalkeepers were monitored via goalkeeper-  
110 specific micromechanical electrical systems (MEMS) sampling at 10 Hz (model G5, version 1.15.0;  
111 Catapult innovations Ltd., Australia) worn during normal training and on match-day during the 2017/18  
112 season. In part A, all participants completed the demands of each activity and a within-subject design  
113 was implemented to allow comparison between the different activities performed throughout a  
114 competitive week-long microcycle. Part B assessed transient changes across 90-min of match-play using  
115 linear mixed modelling.

116

*117 Subjects*

118 Following institutional ethical approval , professional, male soccer goalkeepers (part A: n=8, age: 24 ±  
119 7 years, stature: 1.84 ± 0.08 m, mass: 89.8 ± 6.0 kg; part B: n=8, age: 19 ± 2 years, stature: 1.84 ± 0.08  
120 m, mass: 86.8 ± 3.0 kg) from an English Premier League soccer club (the highest tier of professional  
121 soccer in the United Kingdom) volunteered to participate. Retrospective power analyses using obtained  
122 effect sizes, alpha values and sample sizes indicated that beta values >0.8 were obtained for continuous  
123 variables in both parts A and B (G\*Power version 3.1.9.2). Players were informed about the risks and  
124 benefits of participation before being invited to provide written consent (in addition to parental consent  
125 and player assent where players were <18 years of age) prior to data-collection, and all were considered  
126 by club medical staff to be healthy and injury-free throughout the duration of the study. For part A, data  
127 represents activities performed by each goalkeeper within a single week during the first half of the  
128 2017/18 season, whilst data for part B reflects 100 matches (18 ± 14 matches·goalkeeper<sup>-1</sup>).

129

130

131

132 *Procedures*

133 For part A, the activities of ‘match,’ ‘personal pre-match warm-ups’, and ‘pre-match shooting’ all  
134 occurred on a match-day, whilst all other activities (i.e., ‘goalkeeping-training’, ‘shooting-training’, and  
135 ‘small-sided games’) were performed at the club’s training facility on non-match-days. Goalkeepers’  
136 personal pre-match warm-ups included players’ own self-selected activities, which typically  
137 encompassed ball handling skills, replication of match scenarios, and individual crossing and  
138 distribution preparations. Goalkeeping-training involved a group of between two and six goalkeepers  
139 who were supervised by at least one goalkeeping coach, whereas small-sided games (i.e., 7v7, 8v8 and  
140 9v9 scenarios) and shooting-training also incorporated outfield players and coaches. All matches were  
141 ~90-min in duration and fixtures from both domestic league and cup competitions were included (i.e.,  
142 under 18, under 21, FA cup, League Cup, and Southern Premier soccer competitions). For part B, the  
143 potential influence of the duration of competitive match-play on goalkeepers’ movement responses were  
144 analyzed by dividing match data separately into 45-min halves and into six 15-min epochs. All data after  
145 the scheduled end of each half (i.e., stoppage time) were omitted from analysis. All training and match  
146 activities were performed on natural outdoor grass pitches in accordance with English Football  
147 Association rules.

148

149 *Micromechanical electrical system (MEMS) analysis*

150 Players’ movements were monitored throughout the study using goalkeeper-specific 10 Hz MEMS units  
151 (model G5, version 1.15.0; Catapult innovations Ltd., Australia) harnessed centrally between the  
152 scapulae in a specifically designed vest designed to minimize movement artefact. Sampling at 10 Hz  
153 has demonstrated coefficient of variation (CV%) values of 2.0-5.3% for measuring instantaneous  
154 velocity (25), whilst the accelerometers within the specific devices used have produced good intra- and  
155 inter-unit reliability (CV%: 0.9-1.1) in both laboratory and field test environments (3). The MEMS units  
156 were activated according to the manufacturer’s guidelines ~40-min before commencing each activity,  
157 and players wore the same device throughout the study in order to avoid inter-unit variability. Data



158 were exported following completion of each activity using the manufacturer's specialist software  
159 (OpenField, version 1.15.0 Build #26615 - Installer Release; Catapult innovations Ltd., Australia).  
160 Eight indices of physical performance were analyzed, being; the number of dives, the number of high  
161 (i.e., >0.4 m in height), medium (i.e., 0.2-0.4 m), and low (i.e., <0.2 m) jumps, high-speed changes of  
162 direction (i.e., changes of direction at speeds >3.5 m·s<sup>-1</sup>), and explosive efforts (i.e., combined number  
163 of: high-speed changes of direction, high jumps, and instances in which a dive was followed by a  
164 goalkeeper returning to standing within 1 s), and the distance covered in total and at high-speed (i.e.,  
165 >4.17 m·s<sup>-1</sup>). To support the use of such thresholds, unpublished observations suggest that in isolated  
166 performance tests, the players involved attain maximal countermovement jump heights >0.4 m (i.e.,  
167 0.50±0.06 m). When considering the high-speed running threshold that is typically employed when  
168 monitoring outfield players (i.e., >5.5 m·s<sup>-1</sup>), only ~0.8% of total distance covered by professional  
169 goalkeepers may be categorized as high-speed (unpublished observations the same professional club  
170 recruited to the study); a value which increases to ~2.6% when a modified threshold of >4.17 m·s<sup>-1</sup> is  
171 used.

172

### 173 *Statistical analyses*

174 Statistical analyses were conducted using both Statistical Package For Social Sciences (SPSS; Version  
175 21.0; SPSS Inc., Chicago, IL, USA), and R statistical software (V3.3.1). Data are presented as mean ±  
176 standard deviation (SD) unless otherwise stated. For Part A, as all players completed the demands of all  
177 activities, a Friedman's analyses of variance (ANOVA) was used to assess the influence of session-type  
178 on the specific movement demands observed. Where significant effects were identified (p≤0.05),  
179 differences between individual session-types were assessed using Wilcoxon post-hoc tests. Effect sizes  
180 (d) were calculated according to Cohen (5), and interpreted as trivial (d <0.2), small (0.2≤ d <0.6),  
181 moderate (0.6≤ d <1.2), large (1.2≤ d <2.0), very large (2.0≤ d <4.0), and extremely large (d ≥4.0). For  
182 part B, following removal of any outliers identified from consulting residual plots, mixed models used  
183 the lme4 package within R statistical software to estimate the effect of time on the outcome variables  
184 profiled during match-play. Due to the lack of independence between repeated measurements of players

185 (15-min observations, nested within matches, nested within individual players) over the course of the  
186 season, mixed effect models were used to estimate the effect of time on the movement demands  
187 observed. Time (i.e., 'epoch') was included as a fixed effect with random intercepts modelled separately  
188 for each outcome variable. Linear mixed models (b [95% CI]) were used for continuous outcomes of  
189 distance and high-speed distance, while count data were analysed using a mixed effects Poisson  
190 regression model. To assess changes in performance variables over the course of 90-min, the 0-15-min  
191 epoch was specified as the baseline comparator, and bootstrapped 95% confidence intervals (CI) were  
192 obtained for the exponentiated parameter estimates, which are expressed as incident risk ratios (RR) for  
193 count variables.

194

195

196 **RESULTS**197 *Part A: A comparison of physical demands throughout a week-long competitive microcycle*

198 Table 1 indicates the physical demands elicited by different goalkeeper-specific activities. Activity type  
199 influenced all outcome variables. With the exception of goalkeeping-training ( $p=0.260$ ), the duration  
200 of match exceeded that of all other activities (all  $p\leq 0.012$ , all  $d\geq 9.2$ ; extremely large effects).  
201 Goalkeeping-training elicited the highest number of dives relative to all activities (all  $p\leq 0.030$ , all  
202  $d\geq 1.7$ ; large effects) except for shooting-training ( $p=0.069$ ). The fewest dives were performed in small-  
203 sided games (all  $p\leq 0.012$ ,  $d\geq 2.3$ ; very large effects), whilst goalkeepers covered the greatest total  
204 distances in match (all  $p\leq 0.017$ , all  $d\geq 2.1$ ; very large effects). For high-speed distance, match was  
205 similar to goalkeeping-training ( $p=0.484$ ), but greater than shooting-training, small-sided games, pre-  
206 match shooting, and pre-match warm-up (all  $p=0.012$ , all  $d\geq 1.8$ ; large effects). More high jumps  
207 occurred in goalkeeping-training versus all other activities (all  $p\leq 0.035$ , all  $d\geq 1.4$ ; large effects) except  
208 pre-match warm up ( $p=0.063$ ). The number of high-speed changes of direction and explosive efforts  
209 was greatest in goalkeeping-training with values exceeding match (both  $p=0.012$ , both  $d\geq 3.0$ ; very large  
210 effects) by more than three and four-fold, respectively, whilst the fewest high-speed changes of  
211 direction occurred in small-sided games (all  $p\leq 0.034$ , all  $d\geq 1.1$ ; moderate to large effects).

212 \*\*\*\*\* INSERT TABLE 1 NEAR HERE \*\*\*\*\*

213

214 *Part B: Transient changes in physical demands throughout match-play*

215 Table 2 provides mean $\pm$ SD for physical performance variables per half of match-play. Between-half  
216 declines were observed for total distance, whilst the number of high-speed changes of direction and  
217 explosive efforts increased from the first to second half (both  $p\leq 0.05$ ). High-speed distance and the  
218 number of dives were similar between halves, as was the number of high, medium, and low jumps.

219 \*\*\*\*\* INSERT TABLE 2 NEAR HERE \*\*\*\*\*

220 Table 3 shows descriptive statistics for physical performance variables throughout match-play while  
221 Table 4 presents the linear and mixed effects Poisson regression models assessing changes over time  
222 (i.e., relative to 0-15-min). Except for the number of high jumps, all performance variables differed  
223 from 0-15 min during at least one other match epoch (all  $p \leq 0.05$ ). Relative to the 0-15-min observation,  
224 total distance covered was significantly lower in all subsequent epochs. Likewise, high-speed distance  
225 was lower for all epochs compared with 0-15-min. The number of high-speed changes of direction was  
226 higher only for 60-75-min relative to 0-15-min values, although more explosive efforts were performed  
227 between 60-75-min and 75-90-min compared with the initial 15-min of match-play. The number of  
228 dives was higher at 30-45-min, 60-75-min, 75-90-min compared with 0-15-min, whilst more medium  
229 jumps were performed between 30-45-min than 0-15-min. The number of low jumps were reduced at  
230 all time-points relative to 0-15-min values.

231 \*\*\*\*\* INSERT TABLE 3 NEAR HERE \*\*\*\*\*

232 \*\*\*\*\* INSERT TABLE 4 NEAR HERE \*\*\*\*\*

233

234

**235 DISCUSSION**

236

237 In agreement with our hypotheses, professional soccer goalkeepers experienced differing physical  
238 demands over the course of one competitive week (i.e., as a function of activity type; part A), and  
239 transient changes throughout 90-min of match-play (i.e., as a function of match duration; part B).  
240 Notably, in part A, exposure to high-intensity actions (such as dives, jumps, high-speed changes of  
241 direction, and explosive efforts) was greatest in goalkeeping and shooting-based training activities, but  
242 lowest in match-related activities such as small-sided games and competitive match-play. In part B,  
243 goalkeepers performed more dives and explosive efforts during the final 15-min (i.e., 75-90-min) of  
244 competitive matches when compared with the opening phase (i.e., 0-15-min) of play. Collectively, this  
245 comprehensive analysis of the physical demands of professional soccer goalkeepers provides novel  
246 information that will be useful to inform practitioners when planning the preparation and periodization  
247 of training and/or recovery strategies for soccer goalkeepers over the course of the competitive week.

248 Whilst match-play may be expected to elicit the greatest movement demands of any activity performed  
249 by soccer players throughout a competitive week, this was not necessarily the case for goalkeepers  
250 when certain position-specific performance metrics (i.e., dives, jumps, changes of direction, and  
251 explosive efforts) were considered. Notably, goalkeepers in the current study performed more dives  
252 (~51 vs ~10), high-speed changes of direction (~34 vs ~8), high (~14 vs ~1) and medium (~19 vs ~7)  
253 jumps, and explosive efforts (~70 vs ~16) during a ~79-min goalkeeping-training session when  
254 compared with 90-min of match-play. In a case study of a single professional goalkeeper, Malone et al.  
255 (13) have previously reported increases in the number of high-intensity (defined as a change in speed  
256  $>3 \text{ m}\cdot\text{s}^{-2}$ ) accelerations and decelerations performed four days prior to a match (i.e., ‘match-day minus  
257 four’) when compared with match-day itself. As a lack of goalkeeper-specific performance variables,  
258 and the omission of information characterizing the type of training performed (other than proximity to  
259 match-day), limits the ability to make direct comparisons between these two studies, such observations  
260 reinforce the notion that the physical demands placed upon soccer goalkeepers appear to differ markedly  
261 dependent upon the specific type of activity being undertaken. Importantly, it remains to be determined

262 whether the same is true with regards to the cognitive loads experience by goalkeepers throughout  
263 training and match-play.

264 Training sessions incorporating small-sided games are often used by practitioners to provide a match-  
265 specific physical conditioning stimulus for outfield players, and have been reported to augment the  
266 development of physiological, psychological, technical, and tactical performance whilst also facilitating  
267 the longitudinal monitoring of neuromuscular fatigue (20). However, consistent with the differences in  
268 positional responsibilities between goalkeepers and outfield players, it is possible that small-sided  
269 games may not promote the development of goalkeeper-specific physical qualities to the same extent.  
270 Indeed, fewer dives (~5 vs ~10 to ~51) and explosive efforts (~8 vs ~16 to ~70) were performed during  
271 small-sided games compared with all other activities (Table 1). That said, small-sided games may  
272 provide other benefits to the goalkeeper such as the development of tactical cues and interpersonal  
273 understanding when working with their defenders, or opportunities to consolidate technical abilities  
274 (such as dives, blocks, spreads) which may initially be practiced during isolated goalkeeping sessions.  
275 Nevertheless, although such observations are limited to one club during a single competitive week-long  
276 microcycle, and aspects relating to cognitive function were not assessed, the movement demands  
277 elicited may call into question the efficacy of small-sided games to challenge the physical development  
278 of soccer goalkeepers.

279 Total distance (~5100 to ~5500 m) covered was greatest in match-play versus other activity types, and  
280 the absolute values observed reflect those previously reported in relation to professional goalkeepers  
281 (6, 12, 26). However the ~100 to ~120 m of high-speed distance covered during match-play represents  
282 nearly double the values published previously (6), findings which likely reflect the differing thresholds  
283 of high-speed running categorization (i.e.,  $>5.5 \text{ m}\cdot\text{s}^{-1}$  vs  $>4.17 \text{ m}\cdot\text{s}^{-1}$  in the current study). It should be  
284 noted that as part of their distributional role, goalkeepers may also perform a number high-velocity  
285 kicking actions which may substantially add to overall physical loading; particularly on match-day. In  
286 support, data from Australian Football players has reported significant reductions in the eccentric  
287 strength of the hamstring musculature following performance of 100 drop kicks (8). Unfortunately, the  
288 absence of physiological measurements in the current study, and in the goalkeeper-specific literature

289 published to date, means the physiological and fatigue responses to goalkeeper-specific activities  
290 remain to be determined.

291 Di Salvo et al. (6) used a multi-camera tracking system to monitor total distance covered by 62 English  
292 Premier League goalkeepers, and reported no significant differences between the first and second halves  
293 of match-play. In contrast, as has been established in relation to outfield players (15, 16, 23),  
294 goalkeepers in the current study covered less total distance (2887 m vs 2663 m) during the second half,  
295 when compared with the opening 45-min. However, whilst outfield players experience between-half  
296 decrements in a number of other physical (e.g., high-speed distance, number of  
297 accelerations/decelerations etc.) and technical (e.g., passing speed and success) key performance  
298 indicators (16, 19, 21), this was not the case for goalkeepers. Indeed, high-speed distance and the  
299 number of dives performed remained similar between halves, whilst goalkeepers performed more  
300 explosive efforts (7.4 vs 6.4) and high-speed changes of direction (4.0 vs 3.3) from 45-90-min,  
301 compared with before half-time. Whilst the reasons for such responses remain to be determined, these  
302 observations further emphasize the unique physical and technical demands associated with soccer  
303 goalkeepers, and thus highlight the need for individualized consideration of preparatory and recovery  
304 practices for this bespoke population of player.

305 In addition to between-half differences, for certain metrics (i.e., the number of dives, high-speed  
306 changes of direction, and explosive efforts), goalkeepers appeared to experience greater physical  
307 demands during the final 30-min (i.e., 60-75 and 75-90-min epochs) of a match, when compared with  
308 the opening 15-min. In addition to the potential influence of tactical changes and other contextual  
309 variables, such observations may plausibly reflect the performance fluctuations experienced by outfield  
310 players. Speculatively, the progressive fatigue experienced by outfield players during a 90-min match  
311 (1, 2, 15) may compromise a team's defensive structure and promote an increase in the number of  
312 scoring opportunities (e.g., shots taken and crosses played into the goalkeeping area) towards the end  
313 of a match (6, 17). If true, these changes would likely influence the physical demands experienced by  
314 goalkeepers, who may be required to respond in order to protect their goal and/or quickly re-distribute  
315 the ball to team-mates.

316 When interpreting the current findings, a number of limitations should be considered. It is prudent to  
317 note that although all goalkeepers were over the age of 16 years at the time of data-collection, these  
318 data do not distinguish between age-groups within the sampled population. Due to the sample of  
319 professional players used in this study, negligible statistical power would have been yielded if such an  
320 approach had been adopted. Nonetheless, novel findings have been presented, which support and extend  
321 the limited body of research documenting the physical demands of professional soccer goalkeepers.  
322 Similarly, whilst the current study used MEMS devices to quantify the physical demands faced by  
323 professional goalkeepers during a competitive week, future research should aim to highlight the  
324 cognitive, technical and physical demands that MEMS devices cannot quantify. In particular, given  
325 empirical observations that goalkeepers may experience substantial mental fatigue as a result of match-  
326 play, profiling the cognitive and/or psychological responses to different goalkeeper-specific activities  
327 would allow practitioners to better understand the total load experienced by goalkeepers and thus help  
328 to elucidate the potential mechanisms underpinning any periods of reduced physical or technical  
329 performance. Such holistic research could implement differential rating of perceived exertion (dRPE)  
330 metrics which quantify self-perceived breathlessness, leg and upper body exertion, as well as cognitive  
331 and technical demands (14).

332 In conclusion, soccer goalkeepers occupy a unique tactical role, yet the physical demands experienced  
333 during position-specific training and match-play activities are not well understood. The current study  
334 presents novel physical data which provide insight into the training and competitive demands of  
335 professional soccer goalkeepers, and thus may aid practitioners when seeking to devise training and  
336 recovery practices. Indeed, knowledge of the demands elicited by different activities is likely beneficial  
337 when looking to develop periodization strategies which appropriately balance stimulus and recovery  
338 across a micro, meso, and/or macrocycle. For example, the apparent lesser degree of physical loading  
339 elicited by small-sided games when compared with other activities such as goalkeeping, may suggest  
340 that small-sided games represent an appropriate activity when reductions in physical loading are desired  
341 (e.g., de-load periods or when development of other technical skills is the priority), or that small-sided  
342 games may need to be supplemented with other activities in order to ‘top-up’ the physical, and in turn



343 technical, stimuli provided on any given day. Goalkeepers also experienced transient changes in  
344 physical demands throughout 90-min of match-play; responses which may be attributable to changes in  
345 tactics in conjunction with the progressive fatigue of outfield players towards the end of a match.  
346 Observed increases in certain position-specific movements towards the end of match-play, highlight a  
347 potential role for ergogenic interventions at specific time-points during a match, and/or requirements  
348 for goalkeeper training to ensure that players are equipped to respond to such heightened demands.

349

350

351 **DECLARATION OF INTEREST STATEMENT**

352 No external financial support was received and there are no conflicts of interest to declare. Authors AW  
353 and CR had their salaries paid by AFC Bournemouth at the time of submission but this organisation  
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355 manuscript preparation.

356

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428 **LEGENDS**

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430 **Table 1:** Mean (standard deviation) movement demands elicited throughout goalkeeper-specific  
431 activities performed during a competitive week

432 **Table 2:** Mean (standard deviation) physical performance variables in the first and second halves of  
433 match-play

434 **Table 3:** Mean (standard deviation) physical performance variables per 15-min of match-play

435 **Table 4:** Effect estimates showing changes from the reference value in physical performance variables  
436 per 15-min of match-play

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**Table 1:** Mean (standard deviation) movement demands elicited throughout goalkeeper-specific activities performed during a competitive week

| Variable                              | Activity type |                          |                          |                          |                          |                            |                        |
|---------------------------------------|---------------|--------------------------|--------------------------|--------------------------|--------------------------|----------------------------|------------------------|
|                                       | Match (a)     | Goalkeeping-training (b) | Shooting-training (c)    | Small-sided games (d)    | Pre-match shooting (e)   | Pre-match warm-up (f)      |                        |
| Duration (min)                        | 91 (4)        | 79 (19)                  | 29 (9) <sup>ab</sup>     | 14 (4) <sup>abc</sup>    | 12 (2) <sup>abc</sup>    | 35 (9) <sup>abde</sup>     |                        |
| Dives (No.)                           | 10 (1)        | 51 (11) <sup>a</sup>     | 39 (13) <sup>a</sup>     | 5 (3) <sup>abc</sup>     | 36 (6) <sup>abd</sup>    | 20 (3) <sup>abcde</sup>    |                        |
| Total distance (m)                    | 5169 (705)    | 3154 (1182) <sup>a</sup> | 1400 (606) <sup>ab</sup> | 687 (194) <sup>abc</sup> | 869 (154) <sup>abc</sup> | 1658 (288) <sup>abde</sup> |                        |
| High-speed distance (m)               | 103 (72)      | 88 (99)                  | 6 (9) <sup>a</sup>       | 3 (6) <sup>ab</sup>      | 5 (9) <sup>ab</sup>      | 8 (8) <sup>ab</sup>        |                        |
| Jumps (No.)                           | High          | 1 (1)                    | 14 (10) <sup>a</sup>     | 3 (5) <sup>b</sup>       | 0 (0) <sup>bc</sup>      | 1 (1) <sup>bd</sup>        | 5 (3) <sup>ade</sup>   |
|                                       | Medium        | 7 (4)                    | 19 (3) <sup>a</sup>      | 7 (3) <sup>b</sup>       | 3 (5) <sup>b</sup>       | 7 (3)                      | 13 (4) <sup>acde</sup> |
|                                       | Low           | 7 (5)                    | 10 (2)                   | 7 (7)                    | 6 (4) <sup>b</sup>       | 8 (4)                      | 4 (3) <sup>ab</sup>    |
| High-speed changes of direction (No.) | 8 (3)         | 34 (12) <sup>a</sup>     | 23 (9) <sup>a</sup>      | 5 (2) <sup>abc</sup>     | 24 (5) <sup>abd</sup>    | 15 (3) <sup>abcde</sup>    |                        |
| Explosive efforts (No.)               | 16 (3)        | 70 (18) <sup>a</sup>     | 39 (18) <sup>ab</sup>    | 8 (3) <sup>abc</sup>     | 40 (7) <sup>abd</sup>    | 24 (4) <sup>abcde</sup>    |                        |

<sup>a</sup> represents significant within-variable difference relative to match, <sup>b</sup> represents significant within-variable difference relative to goalkeeping, <sup>c</sup> represents significant within-variable difference relative to shooting, <sup>d</sup> represents significant within-variable difference relative to small-sided games, <sup>e</sup> represents significant within-variable difference relative to pre-match shooting

**Table 2:** Mean (standard deviation) physical performance variables in the first and second halves of match-play

| <b>Variable</b>                       | <b>Overall</b> | <b>First half</b> | <b>Second half</b> |
|---------------------------------------|----------------|-------------------|--------------------|
| Dives (No.)                           | 7 (4)          | 3 (3)             | 4 (2)              |
| High jumps (No.)                      | 1 (1)          | 1 (1)             | 1 (1)              |
| Medium jumps (No.)                    | 8 (5)          | 4 (3)             | 4 (3)              |
| Low jumps (No.)                       | 11 (8)         | 6 (4)             | 6 (5)              |
| Total distance (m)                    | 5549 (750)     | 2887 (384)        | 2663 (409) **      |
| High-speed distance (m)               | 117 (60)       | 63 (36)           | 54 (42)            |
| High-speed changes of direction (No.) | 7 (4)          | 3 (2)             | 4 (3) *            |
| Explosive efforts (No.)               | 17 (7)         | 6 (4)             | 7 (4) *            |

\* difference at  $p < 0.05$  level relative to first half values, \*\* difference at  $p < 0.001$  level relative to first half values

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**Table 3:** Mean (standard deviation) physical performance variables per 15-min of match-play

| Variable                              | Timing     |           |           |           |           |           |
|---------------------------------------|------------|-----------|-----------|-----------|-----------|-----------|
|                                       | 0-15 min   | 15-30 min | 30-45 min | 45-60 min | 60-75 min | 75-90 min |
| Dives (No.)                           | 1 (1)      | 1 (1)     | 1 (1)     | 1 (1)     | 2 (1)     | 1 (1)     |
| High jumps (No.)                      | 0.2 (0.5)  | 0.2 (0.5) | 0.2 (0.4) | 0.2 (0.4) | 0.2 (0.5) | 0.2 (0.5) |
| Medium jumps (No.)                    | 1.3 (1.4)  | 1.1 (1.3) | 1.3 (1.5) | 1.8 (1.8) | 1.3 (1.5) | 1.0 (1.3) |
| Low jumps (No.)                       | 2.4 (2.1)  | 1.8 (1.5) | 1.7 (1.9) | 2.1 (2.5) | 1.8 (2.1) | 1.6 (1.8) |
| Total distance (m)                    | 1005 (135) | 950 (135) | 931 (160) | 917 (152) | 867 (151) | 878 (163) |
| High-speed distance (m)               | 26 (21)    | 19 (15)   | 18 (18)   | 16 (16)   | 18 (17)   | 20 (25)   |
| High-speed changes of direction (No.) | 1.1 (1.1)  | 1.2 (1.4) | 1.0 (1.2) | 1.3 (1.4) | 1.5 (1.3) | 1.3 (1.5) |
| Explosive efforts (No.)               | 2.0 (1.8)  | 2.2 (2.0) | 2.2 (2.1) | 2.2 (2.0) | 2.8 (2.0) | 2.5 (2.4) |



**Table 4:** Effect estimates showing changes from the reference value in physical performance variables per 15-min of match-play

| Variable                              | 0-15 min | 15-30 min                  | 30-45 min                   | 45-60 min                  | 60-75 min                     | 75-90 min                    |
|---------------------------------------|----------|----------------------------|-----------------------------|----------------------------|-------------------------------|------------------------------|
| Dives (No.)                           | REF      | 1.13<br>[0.86,1.48]        | 1.32<br>[1.02,1.71]*        | 1.06<br>[0.81,1.40]        | 1.56<br>[1.21,2.00]***        | 1.31<br>[1.01,1.71]*         |
| High jumps (No.)                      | REF      | 1.00<br>[0.54,1.83]        | 0.81<br>[0.42,1.53]         | 0.86<br>[0.46,1.61]        | 1.14<br>[0.64,2.05]           | 1.14<br>[0.64,2.05]          |
| Medium jumps (No.)                    | REF      | 0.86<br>[0.67,1.12]        | 1.05<br>[0.82,1.33]         | 1.40<br>[1.12,1.76]***     | 1.04<br>[0.81,1.33]           | 0.79<br>[0.61,1.03]          |
| Low jumps (No.)                       | REF      | 0.74<br>[0.61,0.91]***     | 0.74<br>[0.61,0.90]***      | 0.90<br>[0.75,1.08]        | 0.77<br>[0.64,0.94]*          | 0.67<br>[0.55,0.82]***       |
| Total distance (m)                    | REF      | -54.72<br>[-82.63,-26.81]* | -73.66<br>[-101.58,-45.75]* | -87.91<br>[-115.82,59.99]* | -138.15<br>[-166.07,-110.24]* | -126.73<br>[-154.67,-98.82]* |
| High speed distance (m)               | REF      | -6.82<br>[-11.78,-1.86]**  | -8.00<br>[-12.96,-3.04]**   | -9.35<br>[-14.31,-4.39]*** | -8.11<br>[-13.07,-3.15]**     | -5.72<br>[-10.69, -0.76]*    |
| High speed changes of direction (No.) | REF      | 1.08<br>[0.84, 1.40]       | 0.91<br>[0.70,1.19]         | 1.13<br>[0.87,1.46]        | 1.32<br>[1.02,1.68]*          | 1.17<br>[0.91, 1.51]         |
| Explosive efforts (No.)               | REF      | 1.07<br>[0.88, 1.29]       | 1.08<br>[0.89,1.30]         | 1.08<br>[0.89,1.30]        | 1.35<br>[1.13,1.62]***        | 1.21<br>[1.01, 1.45]*        |

Data are reported as incidence risk ratios (RR) other than for total distance and high speed distance which is b [95% CI].  
 p<0.05 \*; p<0.01 \*\*; p<0.001 \*\*\*. Reference value REF.

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