

1 **Title:** Changes in perceptions of mental fatigue during a season in professional under-23 English
2 Premier League soccer players

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19 **Abstract**

20 The present study assessed changes in academy soccer players' perception of mental fatigue (MF)
21 across a competitive season, investigating the relationship between MF and other subjective measures
22 of wellness. Ten players completed a modified Brief Assessment of Mood (BAM+) questionnaire that
23 included the question: 'How mentally fatigued do you feel'? on match-day (MD) and one (MD+1),
24 two (MD+2) and three (MD+3) days post-match (35 matches). Players reported their MF, along with
25 other subjective measures (sleep, muscle soreness, fatigue and motivation). Results found MF was
26 elevated on MD+1 (43 ± 1 mm) compared to all other days (all $P \leq 0.001$). Players reported lower MF
27 on MD+1 in the late-season phase (34 ± 2 mm) compared to both early- (50 ± 2 mm, $P \leq 0.001$) and mid-
28 season (46 ± 2 mm, $P \leq 0.001$). This coincided with an 80%-win rate in the late-season phase versus the
29 early- (33%) and mid-season (50%). There were very strong repeated-measures correlations between
30 changes in MF and sleep ($r = -0.77$), muscle soreness ($r = 0.94$), fatigue ($r = 0.92$) and motivation ($r =$
31 0.89 ; all $P \leq 0.0005$). In conclusion, MF was closely aligned to match success and other wellness
32 variables. This data suggests a potential lack of sensitivity for identifying MF using a subjective
33 questionnaire. Therefore, researchers and practitioners could work together to identify other ways of
34 practically assessing MF.

35 **Keywords:** football, monitoring, recovery, cognition, affect, visual analogue scale

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40 **Introduction**

41 Soccer match-play is a physically and cognitively demanding activity, requiring players to process
42 information such as the location of the ball, their teammates and opponents, and thus perform
43 appropriate physical movements and skill actions (within the tactical constraints imposed by the
44 coaching staff, field space and opposition; Coutts, 2016; Smith et al., 2018) This may not only lead to
45 physical fatigue, but also mental fatigue. Mental (or cognitive) fatigue is considered a
46 psychobiological state, resulting in a reduced ability to perform cognitive and behavioural tasks, with
47 associated feelings of lethargy and demotivation (Boksem & Tops, 2008; Marcora, Staiano, &
48 Manning, 2009; McMorris, Barwood, Hale, Dicks, & Corbett, 2018).

49 Physical performance in laboratory-controlled conditions may be reduced when mentally
50 fatigued (Marcora et al., 2009; Smith, Coutts, et al., 2016; Smith, Marcora, & Coutts, 2015) (although
51 it may depend on the type and duration of exercise; Duncan, Fowler, George, Joyce, & Hankey, 2015;
52 Martin, Thompson, Keegan, Ball, & Rattray, 2015). Similarly equivocal findings have been reported
53 during soccer small-sided games, with one study observing reduced physical activity profiles
54 (Coutinho et al., 2018), whilst others have observed no differences in running performance despite
55 increased ratings of perceived exertion (Badin, Smith, Conte, & Coutts, 2016; Coutinho et al., 2017).
56 Some aspects of technical (Badin et al., 2016; Smith, Coutts, et al., 2016; Smith, Fransen, Deprez,
57 Lenior, & Coutts, 2017), tactical (Coutinho et al., 2017; Coutinho et al., 2018), and perceptual-
58 cognitive performance (Smith, Zeuwts, et al., 2016) are negatively affected by mental fatigue.
59 However, researchers have experimentally induced mental fatigue through the use of cognitively
60 demanding tasks, such as the Stroop Test, with one previous study utilising an agility-focused motor
61 task (Coutinho et al., 2018). The ecological validity of these types of tasks in an applied soccer setting

62 is questionable, though the neurobiological and physiological response to mental fatigue has been
63 shown not to differ dependent on the source of inducement (i.e. traditional mental fatigue task vs.
64 applied environment). However, there is scope to investigate the impact of normal day-to-day
65 practices of soccer players on mental fatigue.

66 Professional soccer players can play up to 60 matches in a competitive season, including
67 periods of fixture congestion where they may be required to play three matches in seven days (Carling
68 et al., 2015). Changes in performance, injury risk and objective and subjective wellness/recovery have
69 been assessed during a competitive season (Abbott, Brownlee, Harper, Naughton, & Clifford, 2018;
70 Abbott et al., 2019; Slater et al., 2018). However, changes in perceptions of mental fatigue across a
71 season have not been previously investigated, despite anecdotal evidence of players and coaches
72 previously citing the mentally fatiguing nature of professional soccer, particularly towards the end of
73 the season. Furthermore, contextual variables such as match location, strength of opposition and
74 match outcome have been shown to differentially affect subjective measures of wellness and fatigue
75 post-match (Abbott et al., 2018). However, the influence of these factors on mental fatigue has not
76 been investigated. Therefore, the aim of this study was to assess changes in perception of mental
77 fatigue across a competitive season in under-23 professional soccer players. Furthermore, the
78 influence of soccer-specific contextual variables was investigated, as well as the relationship between
79 mental fatigue and other subjective measures of wellness.

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83 **Methods**

84 The study conformed with The Code of Ethics of the World Medical Association and received ethical
85 approval from the University of Huddersfield School of Human and Health Sciences ethics
86 committee. All players provided written informed consent prior to data collection.

87 Ten under-23 male soccer players (20 ± 1 years, 180 ± 7 cm, 78.5 ± 8.7 kg, $n = 4$ international
88 level [U19 or above]) participated in this study during the 2017-2018 English Premier League 2
89 Division 2 season. Data was collected from a total of 24 players; however, 14 players' data was not
90 analysed due to playing <50% of matches. This was due to injury, international duty, or loans to other
91 clubs. The players completed a Brief Assessment of Mood (BAM+; Shearer et al., 2017))
92 questionnaire in the morning (~9.30am) on match-day (MD), the day after a match (MD+1), as well
93 two and three days after (MD+2 and MD+3). The BAM+ was adapted to include an eleventh
94 question: 'How mentally fatigued do you feel?' with a 100 mm visual analogue scale anchored with
95 'not at all' and 'extremely'. Players were instructed to draw a line on the scale at the point that best
96 represented how they felt at that time. In order to overcome self-assessment bias and the players'
97 potential lack of metacognition (Thompson et al., 2019), a clear and uniform definition of mental
98 fatigue was provided based on Marcora et al., (2009): 'a reduced ability to perform cognitive and
99 behavioural tasks with feelings of lethargy'. The following variables from the BAM+ were also
100 analysed: sleep (how well do you feel you have slept?), muscle soreness (how sore do your muscles
101 feel?), fatigue (how fatigued do you feel?), and motivation (how motivated to train do you feel?).
102 Players only completed the modified BAM+ if they played >45 minutes in a match. A total of 35
103 matches were included (two matches that required extra-time were excluded from analyses due to the

104 potential influence on recovery (Winder, Russell, Naughton, & Harper, 2018)), resulting in 201 player
105 observations.

106 The following contextual variables were considered in analyses: season-phase (early [first 12
107 matches, August-October], mid [12 matches, November-January] and late [last 11 matches, February-
108 April]), match outcome (win, draw or loss), days off training post-match (one or two), quality of
109 opposition (top- [1st-4th or division above], mid- [5th-8th] and bottom- [9th-12th or division(s) below]
110 table), match location (home or away) and fixture congestion (≤ 3 days or > 3 days between matches).

111 Linear mixed models (LMM) were used to examine the influence of different contextual factors
112 (location, result, level of opposition, phase of the season, fixture congestion, and the number of days
113 off during the weekly microcycle) on the dependent variables (mental fatigue, motivation, sleep, fatigue
114 and muscle soreness) recorded across the different match day codes (MD, MD+1, MD+2, and MD+3).
115 An LMM was utilised to overcome the assumption of independence, and also because of the flexibility
116 that this method has in accounting for the altering sample sizes between groups with repeated measures.
117 Before running the LMM, basic variance components analysis was performed on each dependent
118 variable assess if the random factors of *player* and *match* contributed significant variance. Given the
119 large number of individual match observations, Wald Z statistics were utilised to test the null hypothesis
120 that the population variance is zero, if rejected the proposed random factors were included in subsequent
121 larger models. The covariance structure of the random factors was set to variance components in all
122 models. Model fit was assessed using Akaike's information criterion (AIC). For the dependent variable
123 of mental fatigue, the AIC revealed the model that best fit the data utilising the first order auto-
124 regressive (AR-1) repeated covariance structure for the repeated measures. The fixed effects and their
125 interactions in each model included the contextual factor and match day code. All models estimated

126 parameters using the maximum likelihood method. Where appropriate, LSD adjusted post hoc analyses
127 and the respective 95% confidence intervals (95% CI) of the differences were reported. Unless
128 otherwise stated, data is presented as means and standard error (SE), with mean differences (*Mdiff*)
129 presented as a measure of effect size where appropriate. All statistical procedures were carried out using
130 IBM SPSS Statistics (Version 25, Chicago, IL, USA), with two-tailed significance being accepted at
131 $P < 0.05$. Repeated measures correlations were conducted using *rmcorr* (Bakdash & Marusich, 2017) in
132 R Studio (Version 1.1.463, RStudio Inc., Boston, MA) to investigate relationships between ratings of
133 mental fatigue and other BAM+ variables over time.

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145 **Results**

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147 ***Variance Calculations***

148 The basic variance components analysis for the random factors of *player* and *match* and was used to
149 determine if any contributed significant variance. For the current study, only *match* was included as a
150 random factor for the mental fatigue data. For measures of sleep, motivation, fatigue, and muscle
151 soreness, neither *player* or *match* were included as random factors.

152 When analysing all matches, there was a significant time effect ($P \leq 0.0005$), with mental
153 fatigue elevated on MD+1 (43 ± 1 mm) compared to MD ($P \leq 0.001$; 27 ± 1 mm; $Mdiff = 17$; 95%
154 $CI_{diff} = 14$ to 19), MD+2 ($P \leq 0.001$; 32 ± 1 mm; $Mdiff = 11$; 95% $CI_{diff} = 9$ to 14) and MD+3 ($P \leq 0.001$;
155 29 ± 1 mm; $Mdiff = 14$; 95% $CI_{diff} = 12$ to 16). Mental fatigue was also higher on MD+2 compared to
156 MD ($P \leq 0.001$; $Mdiff = 5$; 95% $CI_{diff} = 3$ to 7) and MD+3 ($P = 0.025$; $Mdiff = 3$; 95% $CI_{diff} = 0$ to 5).
157 Furthermore, mental fatigue was higher on MD+3 than MD ($P = 0.045$; $Mdiff = 3$; 95% $CI_{diff} = 3$ to 5).

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159 ***Influence of Contextual factors***

160 There was a significant phase of the season by MD code interaction ($P \leq 0.001$), with significantly higher
161 values recorded on MD+1 during the early- ($P \leq 0.001$; 50 ± 2 mm; $Mdiff = 16$; 95% $CI_{diff} = 9$ to 23) and
162 mid-season phase ($P \leq 0.001$; 46 ± 2 mm; $Mdiff = 12$; 95% $CI_{diff} = 6$ to 19) compared to the late-season
163 phase (34 ± 2 mm; Table 1). Significantly higher values were also recorded on MD+2 during the early-
164 season phase ($P = 0.023$; 36 ± 2 mm; $Mdiff = 8$; 95% $CI_{diff} = 1$ to 15) when compared to the late-season
165 phase (28 ± 2 mm; Table 1).

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INSERT TABLE 1 HERE

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168 There was a significant match outcome by MD code interaction ($P \leq 0.001$), with significantly higher
169 values recorded on MD+1 following a loss ($P \leq 0.001$; 54 ± 3 mm; $Mdiff = 17$; 95% $CI_{diff} = 10$ to 24) or a
170 draw ($P \leq 0.001$; 48 ± 2 mm; $Mdiff = 11$; 95% $CI_{diff} = 6$ to 17) when compared to a win (37 ± 2 mm; Table
171 1). Significantly higher values were also recorded on MD+2 following a loss (42 ± 3 mm) compared to
172 a win ($P \leq 0.001$; 29 ± 2 mm; $Mdiff = 13$; 95% $CI_{diff} = 7$ to 20) or a draw ($P \leq 0.001$; 30 ± 2 mm; $Mdiff =$
173 12; 95% $CI_{diff} = 5$ to 20; Table 1).

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175 There was a significant opposition level by MD code interaction ($P \leq 0.001$), with significantly higher
176 values recorded on MD+1 ($P \leq 0.001$; $Mdiff = 10$; 95% $CI_{diff} = 4$ to 16) when playing against middle-table
177 opposition (49 ± 3 mm) compared to top-table opposition (39 ± 2 mm; Table 1). The opposite response
178 was observed on MD+3 ($P = 0.003$; $Mdiff = 9$; 95% $CI_{diff} = 3$ to 15), with higher values observed when
179 playing top-table opposition (33 ± 2 mm) when compared to mid-table opposition (23 ± 3 mm; Table
180 1).

181 There was a significant days off by MD code interaction ($P = 0.004$), with significantly ($P = 0.027$; $Mdiff =$
182 6; 95% $CI_{diff} = 1$ to 10) higher values recorded on MD+1 with two days off (46 ± 2 mm) compared to
183 one day off (40 ± 2 mm; Table 1). Furthermore, there was a significant fixture congestion by MD code
184 interaction ($P \leq 0.001$), with significantly ($P = 0.003$; $Mdiff = 8$; 95% $CI_{diff} = 3$ to 13) higher values recorded
185 on MD+1 following a match preceded by more than three days' rest (46 ± 2 mm) when compared to a
186 match preceded by three or less days rest (38 ± 2 mm; Table 1). There was also a significant match

187 location by MD code interaction ($P \leq 0.001$), with significantly ($P = 0.008$; $M_{diff} = 8$; 95% $CI_{diff} = 2$ to 14)
188 higher values recorded on MD+1 following a home match (47 ± 2 mm) when compared to an away
189 match (39 ± 2 mm; Table 1).

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191 When analysing all matches, there was a significant time effect for sleep, muscle soreness,
192 fatigue and motivation (all $P \leq 0.001$; see Table 2 for interaction effects). Subjective ratings of muscle
193 soreness were elevated on MD+1 (58 ± 1 mm) compared to MD ($P \leq 0.001$; 29 ± 1 mm; $M_{diff} = 28$,
194 95% $CI_{diff} = 23$ to 33), MD+2 ($P \leq 0.001$; 40 ± 1 mm; $M_{diff} = 17$, 95% $CI_{diff} = 12$ to 21) and MD+3
195 ($P = 0.014$; 32 ± 1 mm; $M_{diff} = 26$, 95% $CI_{diff} = 20$ to 31). Subjective ratings of fatigue were elevated
196 on MD+1 (58 ± 2 mm) compared to MD ($P \leq 0.001$; 27 ± 1 mm; $M_{diff} = 31$, 95% $CI_{diff} = 26$ to 36) and
197 MD+2 ($P \leq 0.001$; 41 ± 2 mm; $M_{diff} = 18$, 95% $CI_{diff} = 14$ to 21), with no differences at MD+3 (30 ± 1
198 mm, $P = 0.434$).

199 Subjective ratings of sleep were lower on MD+1 (46 ± 1 mm) compared to MD ($P \leq 0.001$; 59
200 ± 2 mm; 95% $M_{diff} = 13$, 95% $CI_{diff} = 8$ to 18) and compared to MD+3 ($P \leq 0.001$; 55 ± 1 mm; $M_{diff} =$
201 9 , 95% $CI_{diff} = 2$ to 15), with no difference on MD+2 (59 ± 1 mm, $P = 1.000$). Motivation to train was
202 lower on MD+1 (36 ± 2 mm) compared to MD ($P \leq 0.001$; 53 ± 1 mm; $M_{diff} = 16$, 95% $CI_{diff} = 9$ to
203 23), but no differences were observed on MD+2 (48 ± 1 mm, $P = 0.060$) or MD+3 (51 ± 2 mm,
204 $P = 1.000$). Irrespective of the contextual variables, there was a significant repeated-measures
205 correlation between mental fatigue and: sleep ($r = -0.77$; $P \leq 0.001$), muscle soreness ($r = 0.94$;
206 $P \leq 0.001$), fatigue ($r = 0.92$; $P \leq 0.001$), and motivation ($r = -0.89$; $P \leq 0.001$).

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208 **Discussion**

209 This is the first study to measure perceptions of mental fatigue across a competitive season in
210 professional soccer academy players. The main findings are: 1) mental fatigue is elevated for two
211 days following a match, 2) a number of contextual variables influence this response, in particular,
212 match outcome, 3) subjective ratings of mental fatigue are closely related to other subjective measures
213 of wellness.

214 In this study the players reported lower sensations of mental fatigue on MD in the late-season
215 phase compared to both the early- and mid-season phase. Whilst this is the first study to track changes
216 in mental fatigue during a season and so comparisons to other published research is not possible,
217 players and coaches have been cited in the media highlighting increased mental fatigue towards the
218 end of the season (albeit anecdotal evidence). Moreover, elite Australian athletes have cited a
219 cumulative effect of mental fatigue across the course of a season . However, the club involved in this
220 present study won 80% (9 out of 11) of matches in the final third of the season, putting themselves in
221 the playoff stage and winning promotion from the league. In comparison, in the early- and mid-season
222 phases, the club won 33% and 50% of matches, respectively. More acutely, players reported higher
223 mental fatigue on MD+1 following a loss or draw versus a win (Table 1), which persisted at MD+2
224 following a loss. Combined, these findings would suggest that match outcome greatly impacts
225 players' perception of mental fatigue, regardless of season phase.

226 Although there were very strong correlations between mental fatigue and the other subjective
227 measures irrespective of contextual variables, some did not follow a similar pattern based on match
228 outcome. Both sleep and motivation to train were not acutely affected by losing and were actually

229 higher in the early-season phase compared to the mid- and late-season phases (Table 2). Nevertheless,
230 muscle soreness was higher on MD+2 following a loss, and fatigue was higher on both MD+1 and
231 MD+2 after losing. Interestingly, players reported lower fatigue and muscle soreness in the late-
232 season phase on MD+1 and MD+2 compared to the early-season phase (and on MD+1 vs. mid-season
233 phase) which is contrary to previous investigations , who, similar to the present study, identified
234 impaired subjective wellness following a loss compared to a win, but no differences in muscle
235 soreness or fatigue (Abbott et al., 2018). One explanation may be the players completing the BAM+
236 in a ‘socially desirable’ manner during the late-season phase, when the club was winning matches and
237 in a position to try and gain promotion . The players may have potentially rated themselves less
238 fatigued and sore to demonstrate they were coping well and would not reduce their chances of being
239 selected in the starting eleven . Perhaps, the most simple explanation is that a winning environment
240 creates a positive environment for players, which may ‘override’ any feeling of mental fatigue.

241 Players reported higher perceptions of mental fatigue, muscle soreness and fatigue on MD+1
242 following matches against mid-table opposition compared to top-table opposition, as well as greater
243 feelings of mental fatigue on MD+1 following home matches compared to away matches (Table 1).
244 These findings are contradictory to previous research that has shown that playing against stronger or
245 equal opponents is both more physically and technically difficult than playing against lower-level
246 opposition, and leads to impaired subjective wellness (Abbott et al., 2018). Again, match outcome
247 may go some way in explaining these results, with the club winning 67% of matches versus top-table
248 opposition compared to 38% when playing mid-table opposition. Furthermore, the club had a higher
249 win percentage when playing away (68%) compared to at home (40%).

250 Previous research has suggested that there is individual heterogeneity with regards to athlete
251 susceptibility to mental fatigue. This may be due to differences in intellect, with athletes who have a
252 higher intellect more likely to suffer from greater mental fatigue (through overthinking). Furthermore,
253 athletes who are more experienced are less likely to suffer from sensations of mental fatigue. As the
254 present study had participants with an average age of 20 ± 1 years, mental fatigue may have been
255 more apparent due to their relative lack of experience playing at a professional level. Practitioners
256 and coaches should be cognisant of which athletes may be most vulnerable to the effects of mental
257 fatigue and plan their training accordingly, particularly sessions that are likely to impose a large
258 cognitive demand, such as reviewing of video footage and tactical drills.

259 There were very strong correlations between mental fatigue and other subjective measures,
260 including motivation. Mental fatigue and motivation have been previously shown to be linked
261 (Boksem, Meijman, & Lorist, 2006), with the present findings providing a further example of this. As
262 such, coaches and practitioners should be conscious of the stimuli that players/athletes are exposed to,
263 ensuring training tasks are sufficiently varied and stimulating, whilst avoiding cognitive overload.
264 Furthermore, future research could assess other subjective measures that may be of relevance to
265 mental fatigue, including enthusiasm, (dis)engagement, and concentration .

266 There were some limitations with this study. A clear definition of mental fatigue is not readily
267 available and whilst we did provide a definition to the players, it is difficult to completely distinguish
268 mental fatigue from other BAM+ variables (lethargy is also related to fatigue and motivation).
269 Therefore, future research may benefit from comparing objective measures of mental fatigue with
270 self-reported measures in the same participants, however what these objective measures might look
271 like is subject to future research. Furthermore, whilst the visual analogue scale we used to assess the

272 players' perception of mental fatigue has been used in previous research (Smith, Coutts et al., 2016;
273 Smith, Zeuwts et al., 2016) it has not been fully validated and as such there is scope for a validation
274 study of this measure. The English Premier League 2 Division 2 club that participated in this study
275 competed in 37 matches over the course of the season. This is considerably lower than what some
276 other clubs, particularly at the adult professional level, would compete in during a season (potentially
277 up to 60 matches; Carling et al., 2015). This is not including matches that players may participate in
278 for their national team. Therefore, assessing whether a greater number of matches across a season
279 contributes to increased sensations of mental fatigue remains to be investigated.

280 It should be noted, somewhat ironically, that as mental fatigue is characterised by a decrement
281 in the ability to perform cognitive tasks, the players' ability to accurately complete the BAM+ may
282 have been compromised and as such there may have been some self-assessment bias (Thompson et
283 al., 2019). This may be particularly apparent when players report poorer sleep, as there is a synergistic
284 effect between mental fatigue and sleepiness (Smith et al., 2018). Finally, the findings may only be
285 representative of this particular group of players, the practices of the club and the way the season
286 developed. Indeed, as academy players, they may experience different work and life stressors to
287 senior players; however, further research is required (Thompson et al., 2019).

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293 **Practical Applications**

- 294 • Changes in perceptions of mental fatigue seem to be closely associated with match success
295 (i.e., lower ratings of mental fatigue following a win compared to a loss or draw), so
296 practitioners and coaches should be cognisant of this when prescribing training with complex
297 information in the days following a draw or a loss.
- 298 • A subjective measure of mental fatigue is closely correlated with other subjective measures
299 including sleep, muscle soreness, fatigue and motivation to train, as such, more sensitive
300 measures of measuring mental fatigue may be required.
- 301 • If deemed necessary, practitioners and researchers should work together to identify a sensitive
302 and ecologically valid tool to measure mental fatigue, as well as potential interventions that
303 improve perceptions of fatigue.
- 304 • Subjective measures of wellness can be used in decision-making regarding training
305 prescription.
- 306 • The findings may only be representative of this group of players and the methods employed at
307 the club; therefore, future research may benefit from a multi-club approach and as such, we
308 encourage practitioners to engage with researchers and colleagues to facilitate this.

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315 **Conclusion**

316 Whilst acknowledging that the findings may only be representative of this group of players in this
317 particular season, perception of mental fatigue acutely increases following matches, and is linked to
318 match outcome. Subjective measures of wellness can be used effectively to identify when players may
319 need an extra day off training. If deemed necessary, researchers should work with practitioners to
320 identify sensitive measures of mental fatigue that can be used effectively in the field. Occam's Razor
321 may not exist in relation to mental fatigue, and more sophisticated objective measures with high
322 sensitivity may be required. However, a cost-benefit analysis and an assessment of the practical
323 application of such measures is required.

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334 **References**

- 335 Abbott, W., Brownlee, T. E., Harper, L. D., Naughton, R. J., & Clifford, T. (2018). The independent
 336 effects of match location, match result and the quality of opposition on subjective wellbeing
 337 in under 23 soccer players: a case study. *Res Sports Med*, 26(3), 262-275.
 338 doi:10.1080/15438627.2018.1447476
- 339 Abbott, W., Brownlee, T. E., Harper, L. D., Naughton, R. J., Richardson, A., & Clifford, T. (2019). A
 340 season long investigation into the effects of injury, match selection and training load on
 341 mental wellbeing in professional under 23 soccer players: A team case study. *Eur J Sport Sci*,
 342 1-7. doi:10.1080/17461391.2019.1600586
- 343 Badin, O. O., Smith, M. R., Conte, D., & Coutts, A. J. (2016). Mental Fatigue: Impairment of
 344 Technical Performance in Small-Sided Soccer Games. *Int J Sports Physiol Perform*, 11(8),
 345 1100-1105. doi:10.1123/ijsp.2015-0710
- 346 Bakdash, J. Z., & Marusich, L. R. (2017). Repeated Measures Correlation. *Front Psychol*, 8, 456.
 347 doi:10.3389/fpsyg.2017.00456
- 348 Boksem, M. A., Meijman, T. F., & Lorist, M. M. (2006). Mental fatigue, motivation and action
 349 monitoring. *Biol Psychol*, 72(2), 123-132. doi:10.1016/j.biopsycho.2005.08.007
- 350 Boksem, M. A., & Tops, M. (2008). Mental fatigue: costs and benefits. *Brain Res Rev*, 59(1), 125-
 351 139. doi:10.1016/j.brainresrev.2008.07.001
- 352 Carling, C., Gregson, W., McCall, A., Moreira, A., Wong del, P., & Bradley, P. S. (2015). Match
 353 running performance during fixture congestion in elite soccer: research issues and future
 354 directions. *Sports Med*, 45(5), 605-613. doi:10.1007/s40279-015-0313-z
- 355 Coutinho, D., Goncalves, B., Travassos, B., Wong, D. P., Coutts, A. J., & Sampaio, J. E. (2017).
 356 Mental Fatigue and Spatial References Impair Soccer Players' Physical and Tactical
 357 Performances. *Front Psychol*, 8, 1645. doi:10.3389/fpsyg.2017.01645
- 358 Coutinho, D., Goncalves, B., Wong, D. P., Travassos, B., Coutts, A. J., & Sampaio, J. (2018).
 359 Exploring the effects of mental and muscular fatigue in soccer players' performance. *Hum*
 360 *Mov Sci*, 58, 287-296. doi:10.1016/j.humov.2018.03.004
- 361 Coutts, A. J. (2016). Fatigue in football: it's not a brainless task! *J Sports Sci*, 34(14), 1296.
 362 doi:10.1080/02640414.2016.1170475
- 363 Duncan, M. J., Fowler, N., George, O., Joyce, S., & Hankey, J. (2015). Mental fatigue negatively
 364 influences manual dexterity and anticipation timing but not repeated high-intensity exercise
 365 performance in trained adults. *Res Sports Med*, 23(1), 1-13.
 366 doi:10.1080/15438627.2014.975811
- 367 Fessi, M. S., & Moalla, W. (2018). Postmatch Perceived Exertion, Feeling, and Wellness in
 368 Professional Soccer Players. *Int J Sports Physiol Perform*, 13(5), 631-637.
 369 doi:10.1123/ijsp.2017-0725
- 370 Lago, C., Casais, L., E., D., & Sampaio, J. (2010). The effects of situational variables on distance
 371 covered at various speeds in elite soccer. *Eur J Sport Sci*, 10(2), 103-109.
- 372 Marcora, S. M., Staiano, W., & Manning, V. (2009). Mental fatigue impairs physical performance in
 373 humans. *J Appl Physiol (1985)*, 106(3), 857-864. doi:10.1152/jappphysiol.91324.2008
- 374 Martin, K., Thompson, K. G., Keegan, R., Ball, N., & Rattray, B. (2015). Mental fatigue does not
 375 affect maximal anaerobic exercise performance. *Eur J Appl Physiol*, 115(4), 715-725.
 376 doi:10.1007/s00421-014-3052-1
- 377 McMorris, T., Barwood, M., Hale, B. J., Dicks, M., & Corbett, J. (2018). Cognitive fatigue effects on
 378 physical performance: A systematic review and meta-analysis. *Physiol Behav*, 188, 103-107.
 379 doi:10.1016/j.physbeh.2018.01.029
- 380 Rago, V., Silva, J., Mohr, M., Randers, M., Barreira, D., Krstrup, P., Rebelo, A. (2018). Influence of
 381 opponent standard on activity profile and fatigue development during preseasonal friendly
 382 soccer matches: a team study. *Res Sports Med*, 26, 413-424.
- 383 Russell, S., Jenkins, D., Rynne, S., Halson, S. L., & Kelly, V. (2019). What is mental fatigue in elite
 384 sport? Perceptions from athletes and staff. *Eur J Sport Sci*, 1-10.
 385 doi:10.1080/17461391.2019.1618397

- 386 Saw, A. E., Main, L. C., & Gastin, P. B. (2015). Monitoring athletes through self-report: factors
387 influencing implementation. *J Sports Sci Med*, *14*(1), 137-146.
- 388 Shearer, D. A., Sparkes, W., Northeast, J., Cunningham, D. J., Cook, C. J., & Kilduff, L. P. (2017).
389 Measuring recovery: An adapted Brief Assessment of Mood (BAM+) compared to
390 biochemical and power output alterations. *J Sci Med Sport*, *20*(5), 512-517.
391 doi:10.1016/j.jsams.2016.09.012
- 392 Slater, L. V., Baker, R., Weltman, A. L., Hertel, J., Saliba, S. A., & Hart, J. M. (2018). Activity
393 monitoring in men's college soccer: a single season longitudinal study. *Res Sports Med*, *26*(2),
394 178-190. doi:10.1080/15438627.2018.1431535
- 395 Smith, M. R., Coutts, A. J., Merlini, M., Deprez, D., Lenoir, M., & Marcora, S. M. (2016). Mental
396 Fatigue Impairs Soccer-Specific Physical and Technical Performance. *Med Sci Sports Exerc*,
397 *48*(2), 267-276. doi:10.1249/MSS.0000000000000762
- 398 Smith, M. R., Fransen, J., Deprez, D., Lenior, M., & Coutts, A. J. (2017). Impact of mental fatigue on
399 speed and accuracy components of soccer-specific skills. *Science and Medicine in Football*,
400 *1*(1), 48-52.
- 401 Smith, M. R., Marcora, S. M., & Coutts, A. J. (2015). Mental Fatigue Impairs Intermittent Running
402 Performance. *Med Sci Sports Exerc*, *47*(8), 1682-1690. doi:10.1249/MSS.0000000000000592
- 403 Smith, M. R., Thompson, C., Marcora, S. M., Skorski, S., Meyer, T., & Coutts, A. J. (2018). Mental
404 Fatigue and Soccer: Current Knowledge and Future Directions. *Sports Med*, *48*(7), 1525-
405 1532. doi:10.1007/s40279-018-0908-2
- 406 Smith, M. R., Zeuwts, L., Lenoir, M., Hens, N., De Jong, L. M., & Coutts, A. J. (2016). Mental
407 fatigue impairs soccer-specific decision-making skill. *J Sports Sci*, *34*(14), 1297-1304.
408 doi:10.1080/02640414.2016.1156241
- 409 Thompson, C. J., Fransen, J., Skorski, S., Smith, M. R., Meyer, T., Barrett, S., & Coutts, A. J. (2019).
410 Mental Fatigue in Football: Is it Time to Shift the Goalposts? An Evaluation of the Current
411 Methodology. *Sports Med*, *49*(2), 177-183. doi:10.1007/s40279-018-1016-z
- 412 Varley, M. C., Gregson, W., McMillan, K., Bonanno, D., Stafford, K., Modonutti, M., & Di Salvo, V.
413 (2017). Physical and technical performance of elite youth soccer players during international
414 tournaments: influence of playing position and team success and opponent quality. *Science
415 and Medicine in Football*, *1*(1), 18=29.
- 416 Winder, N., Russell, M., Naughton, R. J., & Harper, L. D. (2018). The Impact of 120 Minutes of
417 Match-Play on Recovery and Subsequent Match Performance: A Case Report in Professional
418 Soccer Players. *Sports (Basel)*, *6*(1). doi:10.3390/sports6010022

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426 **Table 1** Mental fatigue responses (mm) over time, relative to different contextual variables.

	MD	MD+1	MD+2	MD+3
THREE OR LESS (n = 15)	29 ± 2	38 ± 2 ^a	32 ± 2	30 ± 2
MORE THAN THREE (n = 20)	26 ± 2	46 ± 2	32 ± 2	29 ± 2
ONE DAY OFF (n = 17)	26 ± 2	40 ± 2 ^b	33 ± 2	29 ± 2
TWO DAYS OFF (n = 18)	22 ± 2	46 ± 2	30 ± 2	29 ± 2
HOME (n = 17)	25 ± 2	47 ± 2 ^c	32 ± 2	29 ± 2
AWAY (n = 18)	28 ± 2	39 ± 2	31 ± 2	30 ± 2
TOP (n = 9)	25 ± 2	39 ± 2 ^d	34 ± 2	33 ± 2 ^d
MIDDLE (n = 8)	25 ± 3	49 ± 3	30 ± 3	24 ± 3
BOTTOM (n = 18)	28 ± 2	43 ± 2	31 ± 2	30 ± 2
WIN (n = 20)	27 ± 2	37 ± 2 ^e	29 ± 2 ^e	28 ± 2
LOSS (n = 8)	27 ± 3	54 ± 3	42 ± 3	31 ± 3
DRAW (n = 7)	25 ± 2	48 ± 2 ^e	30 ± 2 ^e	29 ± 2
EARLY (n = 12)	28 ± 2	50 ± 2 ^f	36 ± 2 ^f	29 ± 2
MID (n = 12)	27 ± 2	46 ± 2 ^f	32 ± 2	29 ± 2
LATE (n = 11)	25 ± 2	34 ± 2	28 ± 2	29 ± 2

427 MD = match-day. Early, mid and late = early-, mid- and late-season phase. Top, middle and bottom
428 refer to level of opposition (top-table, mid-table and bottom-table). One and two days off refer to days
429 off training following a match. Three or less = three or less days recovery between matches. More
430 than three = more than three days recovery between matches. a = difference from more than three
431 days rest, b = difference from two days off, c = difference from away matches, d = difference from
432 mid-table opposition, e = difference from a loss, f = difference from late-season phase (all $P < 0.05$).

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	EARLY (n = 12)	MID (n = 12)	LATE (n = 11)	WIN (n = 20)	LOSS (n = 8)	DRAW (n = 7)	TOP (n = 9)	MIDDLE (n = 8)	BOTTOM (n = 18)	ONE DAY OFF (n = 17)	TWO DAYS OFF (n = 18)	THREE OR LESS (n = 15)	MORE THAN THREE (n = 20)	HOME (n = 17)	AWAY (n = 18)
Sleep (mm)															
MD	60 ± 2	58 ± 2	61 ± 2	59 ± 1	60 ± 2	62 ± 3	59 ± 2	61 ± 2	59 ± 1	60 ± 1	59 ± 1	60 ± 1	60 ± 1	60 ± 1	59 ± 1
MD+1	53 ± 2	43 ± 1 ^a	45 ± 2	46 ± 1	47 ± 2	49 ± 2	52 ± 2	47 ± 2 ^b	44 ± 1 ^b	46 ± 1	48 ± 1	47 ± 1	46 ± 1	46 ± 1	47 ± 1
MD+2	63 ± 2	58 ± 2	60 ± 2	63 ± 1	56 ± 2	57 ± 2	59 ± 2	62 ± 2	60 ± 1	58 ± 1	62 ± 1	59 ± 1	60 ± 1	59 ± 1	61 ± 1
MD+3	55 ± 2	57 ± 2	53 ± 2	55 ± 1	54 ± 2	55 ± 2	56 ± 2	53 ± 2	56 ± 1 ^c	56 ± 1	54 ± 1	54 ± 1	56 ± 1	55 ± 1	55 ± 1
Muscle Soreness (mm)															
MD	27 ± 1	29 ± 1	31 ± 1	29 ± 1	28 ± 1	31 ± 2	29 ± 1	28 ± 1	30 ± 1	29 ± 1	29 ± 1	30 ± 1	29 ± 1	29 ± 1	29 ± 1
MD+1	65 ± 1	58 ± 1 ^a	48 ± 1 ^{ac}	54 ± 1	63 ± 1	58 ± 2 ^d	53 ± 1 ^c	64 ± 1	56 ± 1 ^c	57 ± 1	57 ± 1	57 ± 1	57 ± 1	56 ± 1	58 ± 1
MD+2	43 ± 1	41 ± 1	37 ± 1 ^a	38 ± 1	42 ± 1 ^d	43 ± 2	39 ± 1	43 ± 1	39 ± 1	41 ± 1	39 ± 1	39 ± 1	41 ± 1	41 ± 1	40 ± 1
MD+3	30 ± 1	31 ± 1	33 ± 1	31 ± 1	31 ± 1	33 ± 2	32 ± 1	33 ± 1	30 ± 1	31 ± 1	32 ± 1	31 ± 1	32 ± 1	32 ± 1	31 ± 1
Fatigue (mm)															
MD	26 ± 1	27 ± 1	27 ± 1	27 ± 1	24 ± 1	29 ± 2	25 ± 1	27 ± 1	28 ± 1	26 ± 1	28 ± 1	26 ± 1	27 ± 1	27 ± 1	27 ± 1
MD+1	65 ± 1	59 ± 1 ^a	49 ± 1 ^{ac}	55 ± 1	62 ± 1 ^d	60 ± 2	55 ± 1	63 ± 1 ^b	57 ± 1	58 ± 1	57 ± 1	58 ± 1	58 ± 1	56 ± 1	59 ± 1
MD+2	44 ± 1	41 ± 1	35 ± 1 ^a	38 ± 1	43 ± 1 ^d	42 ± 2 ^d	40 ± 1	44 ± 1	38 ± 1	41 ± 1	39 ± 1	38 ± 1	42 ± 1	40 ± 1	40 ± 1
MD+3	30 ± 1	28 ± 1	30 ± 1	29 ± 1	32 ± 1	32 ± 2	30 ± 1	33 ± 1	28 ± 1	29 ± 1	30 ± 1	30 ± 1	29 ± 1	31 ± 1	29 ± 1
Motivation (mm)															
MD	58 ± 1	50 ± 1 ^a	50 ± 2 ^a	52 ± 1	54 ± 2	52 ± 2	53 ± 2	55 ± 2	51 ± 1	53 ± 1	52 ± 1	53 ± 1	52 ± 1	52 ± 1	53 ± 1
MD+1	38 ± 2	32 ± 1	40 ± 2 ^c	38 ± 1	34 ± 2	35 ± 2	40 ± 2	35 ± 2	35 ± 1	35 ± 1	384 ± 1	33 ± 1	398 ± 1	36 ± 1	36 ± 1
MD+2	51 ± 2	47 ± 1	49 ± 2	51 ± 1	48 ± 2	46 ± 2	50 ± 2	48 ± 2	50 ± 1	48 ± 1	50 ± 1	50 ± 1	48 ± 1	48 ± 1	50 ± 1
MD+3	56 ± 2	51 ± 1 ^a	47 ± 1 ^a	52 ± 3	53 ± 2	49 ± 2	53 ± 2	52 ± 2	50 ± 1	52 ± 5	51 ± 3	52 ± 1	51 ± 1	49 ± 1	54 ± 1

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452 **Table 2** Subjective sleep, muscle soreness, fatigue and motivation responses over time, relative to different contextual variables.

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454 Data shown as mean \pm standard error. MD = match-day. Early, mid and late = early-, mid- and late-season phase. Top, middle and bottom refer to level of
455 opposition (top-table, mid-table and bottom-table). One and two days off refer to days off training following a match. Three or less = three or less days recovery
456 between matches. More than three = more than three days recovery between matches. a = difference from early-season phase, b = difference from top-table, c
457 = difference from mid-table, d = difference from win and e = difference from mid-season (all $p < 0.05$).

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