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

Abstract

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

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

Introduction

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

Physical performance in laboratory-controlled conditions may be reduced when mentally fatigued (Marcora et al., 2009; Smith, Coutts, et al., 2016; Smith, Marcora, & Coutts, 2015) (although it may depend on the type and duration of exercise; Duncan, Fowler, George, Joyce, & Hankey, 2015; Martin, Thompson, Keegan, Ball, & Rattray, 2015). Similarly equivocal findings have been reported during soccer small-sided games, with one study observing reduced physical activity profiles (Coutinho et al., 2018), whilst others have observed no differences in running performance despite increased ratings of perceived exertion (Badin, Smith, Conte, & Coutts, 2016; Coutinho et al., 2017). Some aspects of technical (Badin et al., 2016; Smith, Coutts, et al., 2016; Smith, Fransen, Deprez, Lenior, & Coutts, 2017), tactical (Coutinho et al., 2017; Coutinho et al., 2018), and perceptual-cognitive performance (Smith, Zeuwts, et al., 2016) are negatively affected by mental fatigue. However, researchers have experimentally induced mental fatigue through the use of cognitively demanding tasks, such as the Stroop Test, with one previous study utilising an agility-focused motor task (Coutinho et al., 2018). The ecological validity of these types of tasks in an applied soccer setting is questionable, though the neurobiological and physiological response to mental fatigue has been shown not to differ dependent on the source of inducement (i.e. traditional mental fatigue task vs. applied environment). However, there is scope to investigate the impact of normal day-to-day practices of soccer players on mental fatigue.

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

Methods

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

Ten under-23 male soccer players (20 ± 1 years, 180 ± 7 cm, 78.5 ± 8.7 kg, n = 4 international level [U19 or above]) participated in this study during the 2017-2018 English Premier League 2 Division 2 season. Data was collected from a total of 24 players; however, 14 players' data was not analysed due to playing <50% of matches. This was due to injury, international duty, or loans to other clubs. The players completed a Brief Assessment of Mood (BAM+; Shearer et al., 2017)) questionnaire in the morning (~9.30am) on match-day (MD), the day after a match (MD+1), as well two and three days after (MD+2 and MD+3). The BAM+ was adapted to include an eleventh question: 'How mentally fatigued do you feel?' with a 100 mm visual analogue scale anchored with 'not at all' and 'extremely'. Players were instructed to draw a line on the scale at the point that best represented how they felt at that time. In order to overcome self-assessment bias and the players' potential lack of metacognition (Thompson et al., 2019), a clear and uniform definition of mental fatigue was provided based on Marcora et al., (2009): 'a reduced ability to perform cognitive and behavioural tasks with feelings of lethargy'. The following variables from the BAM+ were also analysed: sleep (how well do you feel you have slept?), muscle soreness (how sore do your muscles feel?), fatigue (how fatigued do you feel?), and motivation (how motivated to train do you feel?). Players only completed the modified BAM+ if they played >45 minutes in a match. A total of 35 matches were included (two matches that required extra-time were excluded from analyses due to the potential influence on recovery (Winder, Russell, Naughton, & Harper, 2018)), resulting in 201 player observations.

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

Linear mixed models (LMM) were used to examine the influence of different contextual factors (location, result, level of opposition, phase of the season, fixture congestion, and the number of days off during the weekly microcycle) on the dependent variables (mental fatigue, motivation, sleep, fatigue and muscle soreness) recorded across the different match day codes (MD, MD+1, MD+2, and MD+3). An LMM was utilised to overcome the assumption of independence, and also because of the flexibility that this method has in accounting for the altering sample sizes between groups with repeated measures. Before running the LMM, basic variance components analysis was performed on each dependent variable assess if the random factors of *player* and *match* contributed significant variance. Given the large number of individual match observations, Wald Z statistics were utilised to test the null hypothesis that the population variance is zero, if rejected the proposed random factors were included in subsequent larger models. The covariance structure of the random factors was set to variance components in all models. Model fit was assessed using Akaike's information criterion (AIC). For the dependent variable of mental fatigue, the AIC revealed the model that best fit the data utilising the first order auto-regressive (AR-1) repeated covariance structure for the repeated measures. The fixed effects and their interactions in each model included the contextual factor and match day code. All models estimated parameters using the maximum likelihood method. Where appropriate, LSD adjusted post hoc analyses and the respective 95% confidence intervals (95% CI) of the differences were reported. Unless otherwise stated, data is presented as means and standard error (SE), with mean differences (*Mdiff*) presented as a measure of effect size where appropriate. All statistical procedures were carried out using IBM SPSS Statistics (Version 25, Chicago, IL, USA), with two-tailed significance being accepted at $P<0.05$. Repeated measures correlations were conducted using *rmcorr* (Bakdash & Marusich, 2017) in R Studio (Version 1.1.463, RStudio Inc., Boston, MA) to investigate relationships between ratings of mental fatigue and other BAM+ variables over time.

Results

Variance Calculations

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

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

Influence of Contextual factors

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

INSERT TABLE 1 HERE

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

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

There was a significant days off by MD code interaction (P=0.004), with significantly (P=0.027; *Mdiff*= 6; 95% CI_{diff}= 1 to 10) higher values recorded on MD+1 with two days off (46 ± 2 mm) compared to one day off (40 ± 2 mm; Table 1). Furthermore, there was a significant fixture congestion by MD code interaction (P≤0.001), with significantly (P=0.003; *Mdiff*= 8; 95% CI_{diff}= 3 to 13) higher values recorded on MD+1 following a match preceded by more than three days' rest (46 ± 2 mm) when compared to a match preceded by three or less days rest (38 ± 2 mm; Table 1). There was also a significant match location by MD code interaction (P≤0.001), with significantly (P=0.008; *Mdiff*= 8; 95% CI_{diff}= 2 to 14) higher values recorded on MD+1 following a home match (47 ± 2 mm) when compared to an away match (39 ± 2 mm; Table 1).

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

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

INSERT TABLE 2 HERE

Discussion

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

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

Although there were very strong correlations between mental fatigue and the other subjective measures irrespective of contextual variables, some did not follow a similar pattern based on match outcome. Both sleep and motivation to train were not acutely affected by losing and were actually higher in the early-season phase compared to the mid- and late-season phases (Table 2). Nevertheless, muscle soreness was higher on MD+2 following a loss, and fatigue was higher on both MD+1 and MD+2 after losing. Interestingly, players reported lower fatigue and muscle soreness in the late-season phase on MD+1 and MD+2 compared to the early-season phase (and on MD+1 vs. mid-season phase) which is contrary to previous investigations , who, similar to the present study, identified impaired subjective wellness following a loss compared to a win, but no differences in muscle soreness or fatigue (Abbott et al., 2018). One explanation may be the players completing the BAM+ in a 'socially desirable' manner during the late-season phase, when the club was winning matches and in a position to try and gain promotion . The players may have potentially rated themselves less fatigued and sore to demonstrate they were coping well and would not reduce their chances of being selected in the starting eleven . Perhaps, the most simple explanation is that a winning environment creates a positive environment for players, which may 'override' any feeling of mental fatigue.

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

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

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

There were some limitations with this study. A clear definition of mental fatigue is not readily available and whilst we did provide a definition to the players, it is difficult to completely distinguish mental fatigue from other BAM+ variables (lethargy is also related to fatigue and motivation). Therefore, future research may benefit from comparing objective measures of mental fatigue with self-reported measures in the same participants, however what these objective measures might look like is subject to future research. Furthermore, whilst the visual analogue scale we used to assess the players' perception of mental fatigue has been used in previous research (Smith, Coutts et al., 2016; Smith, Zeuwts et al., 2016) it has not been fully validated and as such there is scope for a validation study of this measure. The English Premier League 2 Division 2 club that participated in this study competed in 37 matches over the course of the season. This is considerably lower than what some other clubs, particularly at the adult professional level, would compete in during a season (potentially up to 60 matches; Carling et al., 2015). This is not including matches that players may participate in for their national team. Therefore, assessing whether a greater number of matches across a season contributes to increased sensations of mental fatigue remains to be investigated.

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

Practical Applications

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

Conclusion

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

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