Journal of Sports Sciences

Understanding the presence of mental fatigue in English academy soccer players

--Manuscript Draft--

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Manuscript Number:	RJSP-2019-1252
Article Type:	Original Manuscript
Keywords:	Mental fatigue; soccer; academy
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Abstract

Research has demonstrated that induced mental fatigue impairs soccer-specific technical, tactical and physical performance in soccer players. The findings are limited by the lack of elite players and low ecological validity of the tasks used to induce mental fatigue, which do not resemble the cognitive demands of soccer. The current study collected survey data from English academy soccer players (n = 256; age groups - U14 – U23), with questions comprising of five themes (descriptors of physical and mental fatigue, travel, education, match-play and fixture congestion). The survey consisted of multiple choice responses, checkboxes and blinded/unblinded (for duration based questions) 0-100 arbitrary unit (AU) slider scales. Listening to music (81.6% of players), using social media (58.3%) and watching videos (34.3%) were the most common pre-match activities. Pre-match subjective mental fatigue was low (18.7±18.8 AU), and most frequently reported at the end of a match (47±26 AU) and remained elevated 24-hours post-match (36±27 AU). Travel (29±24 AU), fixture congestion (44±25 AU) and education (30±26 AU) demonstrated a low to moderate presence of subjective mental fatigue. These findings provide an overview of activities performed by English academy soccer players pre-match, and demonstrate that mental fatigue is experienced as a result of match-play.

Introduction

In elite academy soccer, physical loading (e.g. total running distance, high intensity running distances, number of sprints) placed on players during match-play incurs physical fatigue [1, 2]. Research investigating fatigue in soccer has predominately been measured from a neuromuscular and metabolic standpoint [3], although a further emerging topic is the role of mental fatigue [4]. Indeed, players frequently make quick and accurate decisions with reference to ball location and the actions of team-mates and opposing players, whilst influenced by physical, technical and tactical factors [5]. These processes require prolonged vigilance, decision making, constantly receiving and processing information, which have been theorised to contribute to mental fatigue during match-play [6]. Subsequent literature [7] proposed that non-soccer-specific factors (travel, screen exposure and lifestyle stressors) provide an increased risk of mental fatigue. However, the presence and impact of mental fatigue in soccer remains unknown for several reasons; 1) a lack of research in the area, 2) a lack of elite players recruited in the literature and 3) the low ecological validity of the tasks used to induce mental fatigue.

In the six original investigative articles assessing the impact of mental fatigue on physical, technical and tactical soccer performance (for a review, please consult Smith et al. 2018 [8]), participants were either recreational or sub-elite youth soccer players, which questions the presence of mental fatigue in highly skilled players. Previous research has demonstrated a difference in resilience to mental fatigue between competitive level. Following a 30-min incongruent Stroop task, elite cyclists displayed greater performance preservation in a 20-min cycling time trial test compared to recreational cyclists [9]. It is therefore possible that highly skilled soccer players are less prone to subjective mental fatigue than lower-skilled counterparts, although this remains unknown. Moreover, the cognitive tasks used to induce mental fatigue in soccer research have been questioned due to low ecological validity [7, 10].

To induce mental fatigue prior to a soccer-specific performance test, participants completed a 30-min computer or paper based version of the modified Stroop task [11-15] or a 20-min whole-body motor coordination task (completing agility ladders whilst juggling a tennis ball) requiring motor coordination, sustained attention, cognitive processing and perceptual skills [16]. Although this research has identified the negative effects of mental fatigue on performance, such generic non-specific tasks fail to reflect the cognitive demands of soccer-specific actions, which consist of greater task complexity and variability under pressure. More specifically, the low contextual interference of the modified Stroop task (i.e. repetitive activity) does not represent the high contextual inference (i.e. unpredictable activity with greater variation in task demand) of soccer [7]. As recently stated by Carling et al [10], it is therefore essential to determine the extent to which mental fatigue occurs in soccer players by developing mentally fatiguing tasks with high ecological validity.

Understanding the real-life cognitive activities performed by highly skilled soccer players and the subjective presence of mental fatigue can aid future research by developing mentally fatiguing protocols with greater ecological validity. This information will also allow practitioners to identify interventions to reduce the impact of mental fatigue on performance. Access to elite soccer environments for research purposes can be challenging due to time, identity exposure and equipment concerns, meaning a more simplistic anonymous approach must be considered. However, the use of online surveys was recently advocated [17] to bridge the gap between research and practice in sport science. Indeed, surveys are quick and easy to administer and can reach a large cohort with anonymity. Therefore, the purpose of this study is to implement an online survey for English academy soccer players which investigates the real-life cognitive activity exposure, and presence of subjective mental fatigue in soccer-specific (i.e. match-play), education, travel and lifestyle scenarios.

Methodology

Participants

The sample consisted of youth soccer players (n = 256) representing Category 1 & 2 (the two highest tiers of English academy soccer) teams in England. The players varied in age (U14 – 38 (14.8%); U15 – 15 (5.9%); U16 – 46 (18%); U17 – 15 (5.9%); U18 – 94 (36.7%); U19 – 14 (5.5%); U20 – 1 (0.4%); U21 – 1 (0.4%); U23 – 32 (12.5%)), position (goalkeeper = 31 (12.1%); full back = 44 (17.2%) central defender = 51 (19.9%); central midfielder = 63 (24.6%); winger = 39 (15.2%); striker = 28 (10.9%)) and period of time contracted to a professional academy system (0 – 3 years = 90 (35.2%); 4 – 6 years = 65 (25.4%); 7 – 9 years = 73 (28.5%); 10 years or more = 28 (10.9%)). Ethical approval was obtained by the host institution under the Declaration of Helsinki.

Procedure

An invitation email was sent to practitioners connected to academy clubs in the English Premier League (n = 20) and Football League (n = 72). Recipients were informed that the survey was investigating the perceived presence of mental fatigue in academy soccer, would take no longer than 10-min to complete, and could be conducted on a laptop, a tablet device or mobile phone. Subsequent reminder emails were sent to practitioners if there was no response to the initial contact after 28 days.

Survey design

An initial survey containing 32 items was created using an online platform (Survey Monkey, California, USA). The initial survey was piloted with 19 elite and 64 regional academy soccer players. Verbal and written feedback was obtained from respondents based on the clarity and relevance of the questions used. Based on this feedback and further discussions with the research team, a revised 29 item survey consisting of five sections was created. Section 1 (“*Participant information and perceptions of mental and physical fatigue”* - 5 items)

collected baseline information related to age category, playing experience and playing position. This section also contained two opinion-based questions which asked players to select from a list of words (e.g. "a difficulty in maintaining performance levels", "reduced reaction times", "reduced motivation") which they would associate with the terms "physical fatigue" and "mental fatigue". In Section 2 ("Travel" - 4 items), the modality, frequency and duration of journeys to training were queried, along with the perceived presence of mental fatigue from the journeys. The education commitments and perceived influence of education on soccer commitments were explored in Section 3 ("Education" - 4 items), whilst Section 4 ("Pre-match activity and match-play" - 12 items) examined activity profiles of players in the final two hours prior to kick off and perceived subjective mental fatigue of travelling to away matches, pre-match team talks and match-play. Section 5 ("Fixture congestion" - 4 items) investigated the frequency of academy match-play and the perceived cognitive demand of playing in congested schedules. The survey consisted of multiple choice responses, checkboxes to select more than one answer where appropriate, blinded (for opinion based questions) and unblinded (for duration based questions) 0-100 arbitrary unit (0-100) slider scales and empty text boxes to provide the opportunity for respondents to provide further information if required.

Statistical analysis

Survey data were initially screened for missing data and outliers. Univariate skewness and kurtosis were also examined. Each section of the survey was then analysed sequentially. Firstly, words used to describe physical and mental fatigue in section 1 (*Participant information and perceptions of mental and physical fatigue*) were explored relative to demographic information using chi-square. This section also included both nominal and scale variables. Nominal variables were assessed relative to demographic information examining chi-square. Scale variables from section 2 (*Travel*) were examined using a one-way ANOVA

with planned pairwise comparisons for position, age, playing experience, and division. In section 3 (*Education*), ordinal variables were examined using a Kruskal-Wallis test, while scale variables were subjected to a similar one-way ANOVA as described above. Section 4 (*Pre-match activity and match-play*) contained nominal and scale variables. Nominal variables were assessed using chi-square, while scale variables were examined using a one-way ANOVA. As section 5 (*Fixture congestion*) contained only scale variables, ANOVAs with planned pairwise comparisons were conducted.

In total, there were significant multiple comparisons and therefore it was necessary to correct for these to reduce the likelihood of a type one error. To correct for this, we calculated the False Discovery Rate (FDR) recommended by Benjamini and Hochberg [18]. This method requires the calculation of a q value that must be greater than p to not be deemed a false discovery. All analyses were subjected to 2000 bootstrapped samples and the null hypothesis was rejected if and only if $p < q$ and, for scale variables, the 95% confidence interval did not contain zero. Effect sizes were interpreted using Ferguson's recommendations for minimum practical effect [19]. Specifically, strength of association (e.g., Cramer's V for chi-square) indices were practically significant when $V \geq .20$ and group differences (e.g., Cohen's d for pairwise comparisons) were considered to be of practically significant when $d \geq .41$.

Results

Descriptions of physical and mental fatigue

There were clear distinctions in how participants described perceptions of physical fatigue and mental fatigue. The most prominent descriptors of physical fatigue were "Exhausted" (72%), "Reduced energy levels" (62.7%), and "Sluggish" (55.2%). For mental fatigue, the most common descriptors were "A difficulty in maintaining concentration" (55%), "Reduced

motivation" (43.5%), and "Difficulty in reacting to mistakes" (37.3%). Chi-square (χ^2) associations in Table 1 represent the extent to which individuals identify the descriptor as being only related to physical fatigue or mental fatigue. Figure 1 presents the frequency of selection for each descriptor for physical fatigue and mental fatigue. Overall, physical fatigue was largely associated with energy, while mental fatigue was associated with cognition.

insert Table 1 here

insert Figure 1 here

Travel

86% of participants travelled to training by car, primarily as a passenger (59%). While only 22 participants (8.8%) noted that they used public transport to travel to training; they all represented the U15 & U19 squads. This contributed to a significant age group effect on mode of travel ($\chi^2 = 194.15$, $p < .001$, $V = .35$). Unsurprisingly, a significant variation in the frequency of training sessions for different age groups was found ($F(8,259) = 43.65$, $p < q$). As illustrated in Figure 2, U20 to U23 players trained at least five times per week. Three training sessions per week was most common for U14 to U16 players.

insert Figure 2 here

The average length of the journey to training was 32.±18.7-min. Participants rated the subjective mental fatigue related to their average journey to training at 29±25 AU (0 – never, 100 - always). This was not significantly impacted by age group ($F(8,262) = 1.66$, $p = .11$). The correlation between journey length and journey fatigue was small to moderate ($r = .36$, 95% CI = .35, .46, $p < .001$).

Education

All U17 players were in full-time education, and all but two of the 98 U18s were also in education. However, of those in the U19 and U23 age groups, only 36.5% were currently in education. Less than 1 in 10 (7.7%) of participants from age groups U19 and upwards were in higher education. As education is compulsory up to 16, days in education were close to 5 per week for such groups. This was substantively fewer however for U17 ($M_{\text{hours per week}} = 8.6\pm3$), U18 ($M_{\text{hours per week}} = 9.1\pm3.1$), U19 ($M_{\text{hours per week}} = 6\pm4.7$), and U23 players ($M_{\text{hours per week}} = 5.1\pm4.3$). There was a low positive correlation between hours in education and the mental aspects of education (i.e. classroom lessons, coursework, exam preparation) having a perceived negative impact on soccer-specific performance ($r = .27$, $p < .001$, 95% CI = .15, .39). A similar association existed between hours in education and physical aspects of education (i.e. physical education and extracurricular sport) having a perceived negative impact on soccer-specific performance ($r = .24$, $p < .001$, 95% CI = .11, .36). However, the negative perceived impacts were largely contained to U14 players ($M_{\text{mental}} = 49\pm33$ AU, all other ages $M < 33$ AU; $M_{\text{physical}} = 40\pm28$ AU, all other ages $M \leq 21$ AU). Overall, there was a clear trend that the mental aspects of education had a greater negative effect on performance than physical aspects ($M\text{diff} = 8.9$, $t(230) = 5.05$, $p < .001$).

Pre-match activity

Listening to music was the most commonly cited activity players engaged in during the final two hours prior to kick-off on a match day (81.6%). Over half (58.3%) reported using social media in this time. Around one-third (34.3%) of participants indicated that they watched videos, 21.4% slept, 12.6% prayed, 12.2% played mobile app games, 8.5% played video games, 7% played card games/puzzles, and 2.2% of players reported reading before games.

Travelling to away matches

Three modes of transport for away matches were identified by participants; travelling on a team bus (67.9%), passenger in a car (29.4%), and driving (2.7%). There was a significant effect for age ($\chi^2 = 53.72$, $p < .001$, $V = .45$), as younger participants were more reliant upon being driven to away matches. For age groups U19 and above, travel was almost exclusively on the team bus. The majority (79.1%) of participants indicated that they reached the match location between 1-2 hours prior to kick-off. Overall, the journey to an away match (Q18 - "The journey to an away match is mentally fatiguing") was considered somewhat mentally fatiguing (39±24 AU; 0 – never, 100 - always). The age group affected most by travel was the U14s (45±31 AU). Overall, there was a moderately strong positive correlation between the perception of how fatiguing the journey was and that the journey had a negative impact on performance ($r = .64$, $p < .001$, 95% CI = .56, .71).

Match-play

Perceptions of mental fatigue on match day are presented in Table 2. The average length of a pre-match team talk was 10±4.8-min and occurred, on average, 32±17.3-min prior to kick off. Listening to a team-talk had a low perceived subjective impact on mental fatigue (11±18 AU). Five minutes prior to kick off, subjective mental fatigue was greater, though still not substantial (19±19 AU). Subjective mental fatigue at half-time was greater still (32±20 AU), but peaked immediately after the match (47±26 AU). This was affected by age ($F(6,249) =$

4.21, $p < q$), where it was significantly higher in the U19s than the U15s and U16s, and significantly higher in the U18s than in the U16s. Subjective perceptions of mental fatigue reduced only moderately 24 hours post-match (36±27 AU), and was unaffected by age group.

insert Table 2 here

Match congestion

36.2% of participants played soccer in addition to their academy club commitments. This was significantly affected by age group ($\chi^2 = 70.99$, $p < .001$, $V = .51$). The proportion who played away from the academy by age was 48.7% (U14s), 73.33% (U15s), 76% (U16s), 12.5% (U17s), 16.2% (U18s), 20% (U19s), and 24.3% (U23s). Age groups up to and including U16s were typically also involved in school soccer (66.4%). Participation in other additional soccer activities was minimal. Three players indicated that they played Sunday League soccer (1.1%), four (1.5%) played 5-a-side, nine (3.3%) played county soccer, and nine (3.3%) played internationally.

On average, participants played 1.5±0.8 matches per week. This varied significantly by age group ($F(6,249) = 2.57$, $p < q$). While there was a general trend that the younger participants played more frequently, post-hoc analyses corrected for multiple corrections did not specify any statistically significant comparisons. The frequency of matches was not related to responses for the item "It is mentally fatiguing to frequently play in competitive soccer matches" ($r = -.00$, $p = .99$, 95% CI = -.12, .12). The response to this item was 44±25 AU on the 0-100 scale (0 – strongly disagree, 100 – strongly agree) and was not significantly affected by age group ($F(6,249) = 1.70$, $p > q$). The frequency of competitive matches was also not significantly related to perceptions of boredom ($r = .06$, $p = .35$, 95% CI = -.07, .18). In response to the item "I become bored of frequently playing competitive soccer matches", players typically scored this very low (i.e., strongly disagree; 11±17 AU). This did depend

somewhat on age group ($F(6,249) = 3.16$, $p < q$), as U14s players scored statistically significantly higher than those in the U18s age group ($M_{diff} = 13.45$, $SE = 3.18$, $p < q$, 95% CI = 3.69, 23.21). Indeed, the U14s scored higher on perceived boredom than all groups, though these were not statistically significant after correcting for multiple comparisons. There was a small positive relationship between mental fatigue from frequency of competitive matches and boredom ($r = .23$, $p < .001$, 95% CI = .11, .34).

Discussion

The present study aimed to identify the real-life cognitive demands experienced by English academy soccer players in non-soccer specific activities (travel, education), pre-match activities (player activity, team talks), and the presence of mental fatigue throughout match-play, post-match and during congested fixture periods. The results showed that tasks performed by English academy soccer players (both pre-match and during a regular training week) do not elicit the cognitive engagement/complexity demonstrated (predominantly via the modified Stroop task) in previous literature [11-16]. These findings determine that players do not enter matches mentally fatigued, but subjective perceptions of mental fatigue increase throughout match-play and remains elevated 24-hours post-match. Other factors (travel, education, intake of tactical information) generally did not incur subjective mental fatigue. Whilst the current findings demonstrate that the presence of mental fatigue in soccer has been overestimated in previous literature [6], differences are likely to occur in other elite settings (i.e. adult elite players), who face different commitments and pressures to win.

The first section of the survey determined the association English academy soccer players made with the terms “physical fatigue” and “mental fatigue”. Indeed, mental fatigue is a novel and complex phenomenon, and participants may be unable to accurately define the meaning of the term [7]. In the current study, players selected phrases (“a difficulty in

maintaining concentration", "reduced motivation", and "difficulty in reacting to mistakes") which resonated with the impact of induced mental fatigue reported in the literature. More specifically, mental fatigue impairs attention [20], reaction times [21], performance monitoring and slower adjustments in performance after errors [22]. In recent research [23], focus groups with 32 athletes and coaches in professional sport identified several descriptors of mental fatigue (disengagement, decreased motivation and enthusiasm, increased displays of emotion and withdrawal, changes in concentration, decreased discipline and attention to detail) similar to the findings of the current study. These findings show that athletes can distinguish between physical fatigue and mental fatigue, demonstrating a competency in the understanding of mental fatigue. The ability for players to define mental fatigue could aid practitioners in detecting fluctuations in mental fatigue and identifying interventions to reduce its impact.

One of the other main objectives of the current study was to establish common activities performed in the two hour period of preparation before a match. Understanding this time window is important due to the present use of tasks with low ecological validity to induce mental fatigue in soccer research [7]. The results showed that screen-based activities (using social media, watching videos (e.g. YouTube/Netflix), playing mobile app games and playing video games) were prevalent before a match. Previous research investigating screen based activities have provided contrasting results. Firstly, a 30-min smartphone puzzle application ("Brain it on") impaired Yo-Yo Intermittent Recovery Test level 1 and Loughborough Soccer Passing Test performance in academy soccer players (compared to a resting control group) [24]. Whilst an improvement in ecological validity compared to previous research, the nature of the task (complex puzzles) likely provides a greater cognitive demand than the more prevalent use of social media, videos and games in the current cohort. Conversely, in a university student population, mental fatigue (measured by pre to post change in

mathematical task performance) was unaffected by video game participation (FIFA 15, Electronic Arts) [25]. This study was limited by a failure to include a control group or report the number of games played/duration of games. Along with screen based activities, listening to music proved to be a popular choice of activity pre-match. Music has proven effective in increasing motor task performance, emotional regulation and arousal for sport-specific physical and cognitive activities [26-27]. Based on the low perceived subjective feeling of mental fatigue 5-min before kick-off, music likely has a positive impact on arousal and motivation, and despite the prevalent use of screen time activity, it did not provide a cognitive demand great enough to induce mental fatigue. Contrary to previous research which induced mental fatigue before a soccer-specific activity [11-16] the pre-match time period does not appear to be a prevalent time-point for the occurrence of mental fatigue in English academy soccer players.

Following the limited presence of subjective mental fatigue following pre-match activity, it is necessary to discuss other time periods which may induce mental fatigue. English academy soccer players in the current study are exposed to frequent travel commitments (i.e. travel to training and matches) and intake of tactical information (i.e. team talks) from coaching staff. However, these activities were not perceived to induce mental fatigue. This may be explained by their duration (10-min) and complexity of information received. Previous literature [28] has demonstrated that prolonged auditory processing (50-min auditory processing task) impaired cognitive task performance, decreased arousal and motivation, and increased mental fatigue. Exposure to cognitively demanding speech- picture verification tasks of contrasting difficulty levels in different signal- to- noise ratios (SNRs) has also been shown to increase pupil diameter, denoting a reduction in physiological arousal [29]. However in real-life soccer scenarios, a pre-match team talk likely contains a summary of themes previously discussed and prepared for in training, providing little novel complex information and

therefore minimal cognitive demand. A low perceived presence of mental fatigue from travel to training may be explained by a shorter mean duration of travel time (32-min) compared to previous studies (90-120-min) which have demonstrated mental fatigue through monotonous simulated road travel [30-31]. Travel duration to away matches proved difficult to implement in the pilot survey due to such a high variation in journeys throughout a season and difficulty in recalling the information, meaning it was removed from the final survey. Therefore despite a minimal presence of mental fatigue when travelling to away matches, this perception is likely open to fluctuation based on the location of the club and frequency of long travel durations. Future research could monitor travel fatigue experienced on long monotonous coach journeys to understand the impact of varying travel distances.

The current study also demonstrated a minimal impact of fixture congestion on perceived mental fatigue. This is the first known study to investigate this, as previous fixture congestion research has focused on physical performance decrements [32-35]. These findings may be explained by the lack of exposure to congested fixture periods (mean number of games per week = 1.5±0.8). The low prevalence of congested periods at academy level may provide a difficulty in players providing an educated and experienced response to such questions, in comparison to senior elite players who can be exposed to more than sixty games per season [36]. Education commitments (physical and mental) were also shown to have minimal perceived impact on soccer-specific performance. Combining education and sport can be challenging, as shown by research which cited schedule clashes and fatigue as limiting factors to sporting performance [37] and a perceived cause of mental fatigue [23]. The contrast in findings can be explained for several reasons. Firstly, elite academy soccer players may be given a clear distinction between time committed to soccer and education, with special dispensation for exam and coursework deadlines based on soccer commitments, therefore minimising the stress of education. Conversely, the current survey may have lacked

enough depth in questioning to elucidate the impact of education on performance. The timing of questioning can also have an impact on response. The survey was completed between July – December, a time traditionally free of exams and demanding coursework deadlines in the UK. It is recommended that future research frequently administers a survey throughout a season to understand fluctuations in responses.

Conclusion

This study provides novel findings which demonstrates English academy soccer players' understanding of mental fatigue and perceptions of mental fatigue when exposed to tasks cited as potentially detrimental to performance in previous work (Thompson et al. 2018; Coutts, 2016). The results show that mental fatigue is not prevalent at pre-match, nor in several other soccer-specific scenarios, but is subjectively present post-match and 24-hours post-match. These findings provide a reference point for subsequent research which incorporates ecologically valid protocols in mental fatigue studies. Such studies could include the impact of relevant screen time exposure (social media/watching videos) on soccer-specific performance, or the impact of music on the alleviation of mental fatigue. Travel is potentially more problematic for players based on team location, and future surveys could factor for this by splitting cohorts into geographical regions of the country. Additionally, the timing of future surveys must also be considered. Indeed, certain themes in the survey are likely to fluctuate in the season, such as the impact of education on soccer-specific performance (during exam periods) or fixture congestion (during a tournament phase), and future survey designs must be conducted frequently with comparisons made to early, mid and late phases of the season.

Disclosure of interest

The authors report no conflict of interest.

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Table 1.

Physical fatigue and mental fatigue descriptors indicated by participants with chi-square values.

Descriptor	Physical (%)	Mental (%)	χ^2	*p*	Cramer's *V*
"Difficulty in reacting to mistakes"	18.5	37.3	.59	.444	.05
"Reduced motivation"	21	43.5	3.45	.063	.11
"Tense"	13.3	16.2	1.09	.296	.06
"Exhausted"	72	30.3	3.12	.078	.11
"Angry"	10.3	30.7	12.11	.001*	.21
"A difficulty in maintaining concentration"	25.1	55	12.62	<.001*	.22
"Reduced reaction times"	32.8	34.7	3.75	.053	.12
"Feeling sleepy/drowsy"	38	32.8	16.35	<.001*	.25
"Reduced arousal"	6.3	15.5	9.13	.003*	.18
"On edge"	5.2	18.1	15.21	<.001*	.24
"Sluggish"	55.4	21.8	.90	.32	.06
"Pain soreness"	51.3	5.2	.01	.921	.01
"Reduced energy levels"	62.7	21.4	.62	.423	.05
"Confusion"	6.6	32.5	10.28	.001*	.20
"Weak"	39.1	14	13.21	<.001*	.22
"Panicky"	3.3	25.1	13.75	<.001*	.23
"A difficulty in maintaining performance levels"	32.1	21.4	15.42	<.001*	.24

*$p < q$

Table 2. Mean and SD (0-100 AU) of mental fatigue indicators on match day by age group.

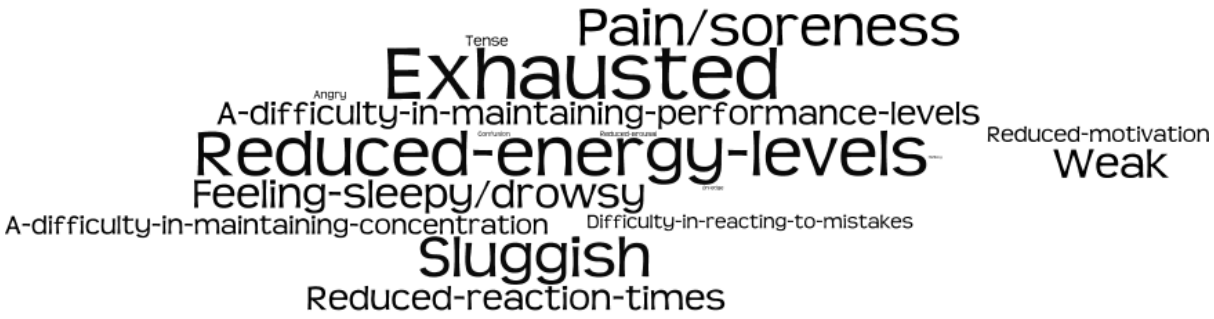
[a]Statistically significantly different (p < q) from under 14s, [b]under 15s, [c]under 16s.

Mental fatigue indicator	Under 14s (*n* = 38)	Under 15s (*n* = 15)	Under 16s (*n* = 48)	Under 17s (*n* = 15)	Under 18s (*n* = 96)	Under 19s (*n* = 15)	Under 23s (*n* = 36)
Journey to away match	49±28	31±21	32±20[a]	36±20	38±25	37±13	43±20
From team talk	30±32	6±7[a]	5±8[a]	5±8[a]	9±14[a]	6±6[a]	8±10[a]
5-min before kick-off	28±26	9±13[a]	15±17[a]	12±16	20±19	14±10	20±16
At half-time	33±25	17±16	27±20	38±18	32±19	35±16	38±15[b]
Immediately after match	43±29	31±25	37±27	55±25	53±25[c]	61±27[b,c]	51±20
24 hours after match	37±35	31±23	29±25	30±22	36±26	44±29	43±27

Figure 1.

Selected descriptors of physical fatigue (a) and mental fatigue (b) with size representative of frequency.

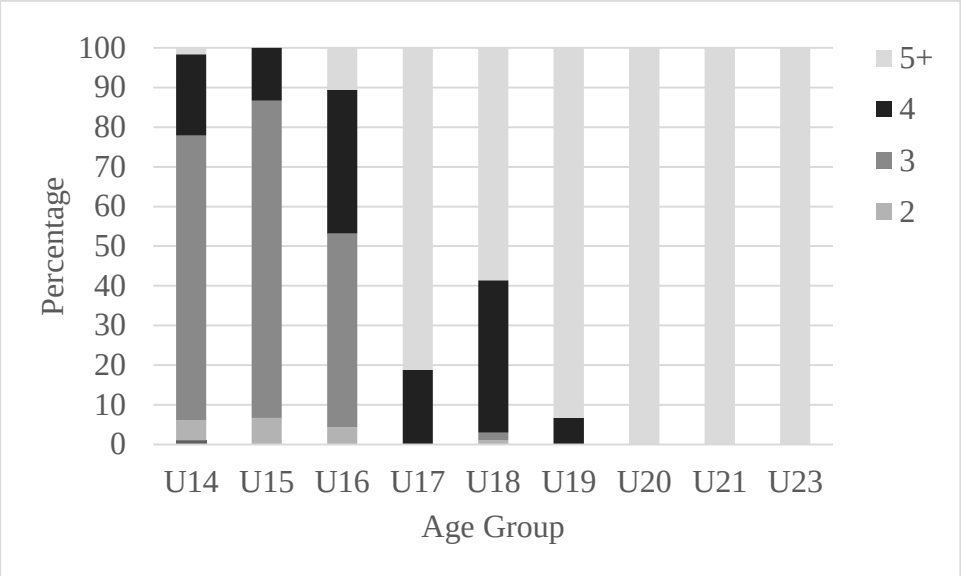
(a) Physical fatigue



(b) Mental fatigue

Figure 2.

Self-report frequency of training per week by age group.



Understanding the presence of mental fatigue in English academy soccer players.

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Word count – 4402.

Abstract

Research has demonstrated that induced mental fatigue impairs soccer-specific technical, tactical and physical performance in soccer players. The findings are limited by the lack of elite players and low ecological validity of the tasks used to induce mental fatigue, which do not resemble the cognitive demands of soccer. The current study collected survey data from English academy soccer players (n = 256; age groups - U14 – U23), with questions comprising of five themes (descriptors of physical and mental fatigue, travel, education, match-play and fixture congestion). The survey consisted of multiple choice responses, checkboxes and blinded/unblinded (for duration based questions) 0-100 arbitrary unit (AU) slider scales. Listening to music (81.6% of players), using social media (58.3%) and watching videos (34.3%) were the most common pre-match activities. Pre-match subjective mental fatigue was low (18.7±18.8 AU), and most frequently reported at the end of a match (47±26 AU) and remained elevated 24-hours post-match (36±27 AU). Travel (29±24 AU), fixture congestion (44±25 AU) and education (30±26 AU) demonstrated a low to moderate presence of subjective mental fatigue. These findings provide an overview of activities performed by English academy soccer players pre-match, and demonstrate that mental fatigue is experienced as a result of match-play.

Introduction

In elite academy soccer, physical loading (e.g. total running distance, high intensity running distances, number of sprints) placed on players during match-play incurs physical fatigue [1, 2]. Research investigating fatigue in soccer has predominately been measured from a neuromuscular and metabolic standpoint [3], although a further emerging topic is the role of mental fatigue [4]. Indeed, players frequently make quick and accurate decisions with reference to ball location and the actions of team-mates and opposing players, whilst influenced by physical, technical and tactical factors [5]. These processes require prolonged vigilance, decision making, constantly receiving and processing information, which have been theorised to contribute to mental fatigue during match-play [6]. Subsequent literature [7] proposed that non-soccer-specific factors (travel, screen exposure and lifestyle stressors) provide an increased risk of mental fatigue. However, the presence and impact of mental fatigue in soccer remains unknown for several reasons; 1) a lack of research in the area, 2) a lack of elite players recruited in the literature and 3) the low ecological validity of the tasks used to induce mental fatigue.

In the six original investigative articles assessing the impact of mental fatigue on physical, technical and tactical soccer performance (for a review, please consult Smith et al. 2018 [8]), participants were either recreational or sub-elite youth soccer players, which questions the presence of mental fatigue in highly skilled players. Previous research has demonstrated a difference in resilience to mental fatigue between competitive level. Following a 30-min incongruent Stroop task, elite cyclists displayed greater performance preservation in a 20-min cycling time trial test compared to recreational cyclists [9]. It is therefore possible that highly skilled soccer players are less prone to subjective mental fatigue than lower-skilled counterparts, although this remains unknown. Moreover, the cognitive tasks used to induce mental fatigue in soccer research have been questioned due to low ecological validity [7, 10]. To induce mental fatigue prior to a soccer-specific performance test, participants completed a

30-min computer or paper based version of the modified Stroop task [11-15] or a 20-min whole-body motor coordination task (completing agility ladders whilst juggling a tennis ball) requiring motor coordination, sustained attention, cognitive processing and perceptual skills [16]. Although this research has identified the negative effects of mental fatigue on performance, such generic non-specific tasks fail to reflect the cognitive demands of soccer-specific actions, which consist of greater task complexity and variability under pressure. More specifically, the low contextual interference of the modified Stroop task (i.e. repetitive activity) does not represent the high contextual inference (i.e. unpredictable activity with greater variation in task demand) of soccer [7]. As recently stated by Carling et al [10], it is therefore essential to determine the extent to which mental fatigue occurs in soccer players by developing mentally fatiguing tasks with high ecological validity.

Understanding the real-life cognitive activities performed by highly skilled soccer players and the subjective presence of mental fatigue can aid future research by developing mentally fatiguing protocols with greater ecological validity. This information will also allow practitioners to identify interventions to reduce the impact of mental fatigue on performance. Access to elite soccer environments for research purposes can be challenging due to time, identity exposure and equipment concerns, meaning a more simplistic anonymous approach must be considered. However, the use of online surveys was recently advocated [17] to bridge the gap between research and practice in sport science. Indeed, surveys are quick and easy to administer and can reach a large cohort with anonymity. Therefore, the purpose of this study is to implement an online survey for English academy soccer players which investigates the real-life cognitive activity exposure, and presence of subjective mental fatigue in soccer-specific (i.e. match-play), education, travel and lifestyle scenarios.

Methodology

Participants

The sample consisted of youth soccer players (n = 256) representing Category 1 & 2 (the two highest tiers of English academy soccer) teams in England. The players varied in age (U14 – 38 (14.8%); U15 – 15 (5.9%); U16 – 46 (18%); U17 – 15 (5.9%); U18 – 94 (36.7%); U19 – 14 (5.5%); U20 – 1 (0.4%); U21 – 1 (0.4%); U23 – 32 (12.5%)), position (goalkeeper = 31 (12.1%); full back = 44 (17.2%) central defender = 51 (19.9%); central midfielder = 63 (24.6%); winger = 39 (15.2%); striker = 28 (10.9%)) and period of time contracted to a professional academy system (0 – 3 years = 90 (35.2%); 4 – 6 years = 65 (25.4%); 7 – 9 years = 73 (28.5%); 10 years or more = 28 (10.9%)). Ethical approval was obtained by the host institution under the Declaration of Helsinki.

Procedure

An invitation email was sent to practitioners connected to academy clubs in the English Premier League (n = 20) and Football League (n = 72). Recipients were informed that the survey was investigating the perceived presence of mental fatigue in academy soccer, would take no longer than 10-min to complete, and could be conducted on a laptop, a tablet device or mobile phone. Subsequent reminder emails were sent to practitioners if there was no response to the initial contact after 28 days.

Survey design

An initial survey containing 32 items was created using an online platform (Survey Monkey, California, USA). The initial survey was piloted with 19 elite and 64 regional academy soccer players. Verbal and written feedback was obtained from respondents based on the clarity and relevance of the questions used. Based on this feedback and further discussions with the research team, a revised 29 item survey consisting of five sections was created. Section 1 (“*Participant information and perceptions of mental and physical fatigue”* - 5 items)

collected baseline information related to age category, playing experience and playing position. This section also contained two opinion-based questions which asked players to select from a list of words (e.g. "a difficulty in maintaining performance levels", "reduced reaction times", "reduced motivation") which they would associate with the terms "physical fatigue" and "mental fatigue". In Section 2 ("Travel" - 4 items), the modality, frequency and duration of journeys to training were queried, along with the perceived presence of mental fatigue from the journeys. The education commitments and perceived influence of education on soccer commitments were explored in Section 3 ("Education" - 4 items), whilst Section 4 ("Pre-match activity and match-play" - 12 items) examined activity profiles of players in the final two hours prior to kick off and perceived subjective mental fatigue of travelling to away matches, pre-match team talks and match-play. Section 5 ("Fixture congestion" - 4 items) investigated the frequency of academy match-play and the perceived cognitive demand of playing in congested schedules. The survey consisted of multiple choice responses, checkboxes to select more than one answer where appropriate, blinded (for opinion based questions) and unblinded (for duration based questions) 0-100 arbitrary unit (0-100) slider scales and empty text boxes to provide the opportunity for respondents to provide further information if required.

Statistical analysis

Survey data were initially screened for missing data and outliers. Univariate skewness and kurtosis were also examined. Each section of the survey was then analysed sequentially. Firstly, words used to describe physical and mental fatigue in section 1 (*Participant information and perceptions of mental and physical fatigue*) were explored relative to demographic information using chi-square. This section also included both nominal and scale variables. Nominal variables were assessed relative to demographic information examining chi-square. Scale variables from section 2 (*Travel*) were examined using a one-way ANOVA

with planned pairwise comparisons for position, age, playing experience, and division. In section 3 (*Education*), ordinal variables were examined using a Kruskal-Wallis test, while scale variables were subjected to a similar one-way ANOVA as described above. Section 4 (*Pre-match activity and match-play*) contained nominal and scale variables. Nominal variables were assessed using chi-square, while scale variables were examined using a one-way ANOVA. As section 5 (*Fixture congestion*) contained only scale variables, ANOVAs with planned pairwise comparisons were conducted.

In total, there were significant multiple comparisons and therefore it was necessary to correct for these to reduce the likelihood of a type one error. To correct for this, we calculated the False Discovery Rate (FDR) recommended by Benjamini and Hochberg [18]. This method requires the calculation of a q value that must be greater than p to not be deemed a false discovery. All analyses were subjected to 2000 bootstrapped samples and the null hypothesis was rejected if and only if $p < q$ and, for scale variables, the 95% confidence interval did not contain zero. Effect sizes were interpreted using Ferguson's recommendations for minimum practical effect [19]. Specifically, strength of association (e.g., Cramer's V for chi-square) indices were practically significant when $V \geq .20$ and group differences (e.g., Cohen's d for pairwise comparisons) were considered to be of practically significant when $d \geq .41$.

Results

Descriptions of physical and mental fatigue

There were clear distinctions in how participants described perceptions of physical fatigue and mental fatigue. The most prominent descriptors of physical fatigue were "Exhausted" (72%), "Reduced energy levels" (62.7%), and "Sluggish" (55.2%). For mental fatigue, the most common descriptors were "A difficulty in maintaining concentration" (55%), "Reduced

motivation" (43.5%), and "Difficulty in reacting to mistakes" (37.3%). Chi-square (χ^2) associations in Table 1 represent the extent to which individuals identify the descriptor as being only related to physical fatigue or mental fatigue. Figure 1 presents the frequency of selection for each descriptor for physical fatigue and mental fatigue. Overall, physical fatigue was largely associated with energy, while mental fatigue was associated with cognition.

insert Table 1 here

insert Figure 1 here

Travel

86% of participants travelled to training by car, primarily as a passenger (59%). While only 22 participants (8.8%) noted that they used public transport to travel to training; they all represented the U15 & U19 squads. This contributed to a significant age group effect on mode of travel ($\chi^2 = 194.15$, $p < .001$, $V = .35$). Unsurprisingly, a significant variation in the frequency of training sessions for different age groups was found ($F(8,259) = 43.65$, $p < q$). As illustrated in Figure 2, U20 to U23 players trained at least five times per week. Three training sessions per week was most common for U14 to U16 players.

insert Figure 2 here

The average length of the journey to training was 32.±18.7-min. Participants rated the subjective mental fatigue related to their average journey to training at 29±25 AU (0 – never, 100 - always). This was not significantly impacted by age group ($F(8,262) = 1.66$, $p = .11$). The correlation between journey length and journey fatigue was small to moderate ($r = .36$, 95% CI = .35, .46, $p < .001$).

Education

All U17 players were in full-time education, and all but two of the 98 U18s were also in education. However, of those in the U19 and U23 age groups, only 36.5% were currently in education. Less than 1 in 10 (7.7%) of participants from age groups U19 and upwards were in higher education. As education is compulsory up to 16, days in education were close to 5 per week for such groups. This was substantively fewer however for U17 ($M_{\text{hours per week}} = 8.6\pm3$), U18 ($M_{\text{hours per week}} = 9.1\pm3.1$), U19 ($M_{\text{hours per week}} = 6\pm4.7$), and U23 players ($M_{\text{hours per week}} = 5.1\pm4.3$). There was a low positive correlation between hours in education and the mental aspects of education (i.e. classroom lessons, coursework, exam preparation) having a perceived negative impact on soccer-specific performance ($r = .27$, $p < .001$, 95% CI = .15, .39). A similar association existed between hours in education and physical aspects of education (i.e. physical education and extracurricular sport) having a perceived negative impact on soccer-specific performance ($r = .24$, $p < .001$, 95% CI = .11, .36). However, the negative perceived impacts were largely contained to U14 players ($M_{\text{mental}} = 49\pm33$ AU, all other ages $M < 33$ AU; $M_{\text{physical}} = 40\pm28$ AU, all other ages $M \leq 21$ AU). Overall, there was a clear trend that the mental aspects of education had a greater negative effect on performance than physical aspects ($M\text{diff} = 8.9$, $t(230) = 5.05$, $p < .001$).

Pre-match activity

Listening to music was the most commonly cited activity players engaged in during the final two hours prior to kick-off on a match day (81.6%). Over half (58.3%) reported using social media in this time. Around one-third (34.3%) of participants indicated that they watched videos, 21.4% slept, 12.6% prayed, 12.2% played mobile app games, 8.5% played video games, 7% played card games/puzzles, and 2.2% of players reported reading before games.

Travelling to away matches

Three modes of transport for away matches were identified by participants; travelling on a team bus (67.9%), passenger in a car (29.4%), and driving (2.7%). There was a significant effect for age ($\chi^2 = 53.72$, $p < .001$, $V = .45$), as younger participants were more reliant upon being driven to away matches. For age groups U19 and above, travel was almost exclusively on the team bus. The majority (79.1%) of participants indicated that they reached the match location between 1-2 hours prior to kick-off. Overall, the journey to an away match (Q18 - "The journey to an away match is mentally fatiguing") was considered somewhat mentally fatiguing (39±24 AU; 0 – never, 100 - always). The age group affected most by travel was the U14s (45±31 AU). Overall, there was a moderately strong positive correlation between the perception of how fatiguing the journey was and that the journey had a negative impact on performance ($r = .64$, $p < .001$, 95% CI = .56, .71).

Match-play

Perceptions of mental fatigue on match day are presented in Table 2. The average length of a pre-match team talk was 10±4.8-min and occurred, on average, 32±17.3-min prior to kick off. Listening to a team-talk had a low perceived subjective impact on mental fatigue (11±18 AU). Five minutes prior to kick off, subjective mental fatigue was greater, though still not substantial (19±19 AU). Subjective mental fatigue at half-time was greater still (32±20 AU), but peaked immediately after the match (47±26 AU). This was affected by age ($F(6,249) =$

4.21, $p < q$), where it was significantly higher in the U19s than the U15s and U16s, and significantly higher in the U18s than in the U16s. Subjective perceptions of mental fatigue reduced only moderately 24 hours post-match (36±27 AU), and was unaffected by age group.

insert Table 2 here

Match congestion

36.2% of participants played soccer in addition to their academy club commitments. This was significantly affected by age group ($\chi^2 = 70.99$, $p < .001$, $V = .51$). The proportion who played away from the academy by age was 48.7% (U14s), 73.33% (U15s), 76% (U16s), 12.5% (U17s), 16.2% (U18s), 20% (U19s), and 24.3% (U23s). Age groups up to and including U16s were typically also involved in school soccer (66.4%). Participation in other additional soccer activities was minimal. Three players indicated that they played Sunday League soccer (1.1%), four (1.5%) played 5-a-side, nine (3.3%) played county soccer, and nine (3.3%) played internationally.

On average, participants played 1.5±0.8 matches per week. This varied significantly by age group ($F(6,249) = 2.57$, $p < q$). While there was a general trend that the younger participants played more frequently, post-hoc analyses corrected for multiple corrections did not specify any statistically significant comparisons. The frequency of matches was not related to responses for the item "It is mentally fatiguing to frequently play in competitive soccer matches" ($r = -.00$, $p = .99$, 95% CI = -.12, .12). The response to this item was 44±25 AU on the 0-100 scale (0 – strongly disagree, 100 – strongly agree) and was not significantly affected by age group ($F(6,249) = 1.70$, $p > q$). The frequency of competitive matches was also not significantly related to perceptions of boredom ($r = .06$, $p = .35$, 95% CI = -.07, .18). In response to the item "I become bored of frequently playing competitive soccer matches", players typically scored this very low (i.e., strongly disagree; 11±17 AU). This did depend

somewhat on age group ($F(6,249) = 3.16$, $p < q$), as U14s players scored statistically significantly higher than those in the U18s age group ($M_{diff} = 13.45$, $SE = 3.18$, $p < q$, 95% CI = 3.69, 23.21). Indeed, the U14s scored higher on perceived boredom than all groups, though these were not statistically significant after correcting for multiple comparisons. There was a small positive relationship between mental fatigue from frequency of competitive matches and boredom ($r = .23$, $p < .001$, 95% CI = .11, .34).

Discussion

The present study aimed to identify the real-life cognitive demands experienced by English academy soccer players in non-soccer specific activities (travel, education), pre-match activities (player activity, team talks), and the presence of mental fatigue throughout match-play, post-match and during congested fixture periods. The results showed that tasks performed by English academy soccer players (both pre-match and during a regular training week) do not elicit the cognitive engagement/complexity demonstrated (predominantly via the modified Stroop task) in previous literature [11-16]. These findings determine that players do not enter matches mentally fatigued, but subjective perceptions of mental fatigue increase throughout match-play and remains elevated 24-hours post-match. Other factors (travel, education, intake of tactical information) generally did not incur subjective mental fatigue. Whilst the current findings demonstrate that the presence of mental fatigue in soccer has been overestimated in previous literature [6], differences are likely to occur in other elite settings (i.e. adult elite players), who face different commitments and pressures to win.

The first section of the survey determined the association English academy soccer players made with the terms “physical fatigue” and “mental fatigue”. Indeed, mental fatigue is a novel and complex phenomenon, and participants may be unable to accurately define the meaning of the term [7]. In the current study, players selected phrases (“a difficulty in

maintaining concentration", "reduced motivation", and "difficulty in reacting to mistakes") which resonated with the impact of induced mental fatigue reported in the literature. More specifically, mental fatigue impairs attention [20], reaction times [21], performance monitoring and slower adjustments in performance after errors [22]. In recent research [23], focus groups with 32 athletes and coaches in professional sport identified several descriptors of mental fatigue (disengagement, decreased motivation and enthusiasm, increased displays of emotion and withdrawal, changes in concentration, decreased discipline and attention to detail) similar to the findings of the current study. These findings show that athletes can distinguish between physical fatigue and mental fatigue, demonstrating a competency in the understanding of mental fatigue. The ability for players to define mental fatigue could aid practitioners in detecting fluctuations in mental fatigue and identifying interventions to reduce its impact.

One of the other main objectives of the current study was to establish common activities performed in the two hour period of preparation before a match. Understanding this time window is important due to the present use of tasks with low ecological validity to induce mental fatigue in soccer research [7]. The results showed that screen-based activities (using social media, watching videos (e.g. YouTube/Netflix), playing mobile app games and playing video games) were prevalent before a match. Previous research investigating screen based activities have provided contrasting results. Firstly, a 30-min smartphone puzzle application ("Brain it on") impaired Yo-Yo Intermittent Recovery Test level 1 and Loughborough Soccer Passing Test performance in academy soccer players (compared to a resting control group) [24]. Whilst an improvement in ecological validity compared to previous research, the nature of the task (complex puzzles) likely provides a greater cognitive demand than the more prevalent use of social media, videos and games in the current cohort. Conversely, in a university student population, mental fatigue (measured by pre to post change in

mathematical task performance) was unaffected by video game participation (FIFA 15, Electronic Arts) [25]. This study was limited by a failure to include a control group or report the number of games played/duration of games. Along with screen based activities, listening to music proved to be a popular choice of activity pre-match. Music has proven effective in increasing motor task performance, emotional regulation and arousal for sport-specific physical and cognitive activities [26-27]. Based on the low perceived subjective feeling of mental fatigue 5-min before kick-off, music likely has a positive impact on arousal and motivation, and despite the prevalent use of screen time activity, it did not provide a cognitive demand great enough to induce mental fatigue. Contrary to previous research which induced mental fatigue before a soccer-specific activity [11-16] the pre-match time period does not appear to be a prevalent time-point for the occurrence of mental fatigue in English academy soccer players.

Following the limited presence of subjective mental fatigue following pre-match activity, it is necessary to discuss other time periods which may induce mental fatigue. English academy soccer players in the current study are exposed to frequent travel commitments (i.e. travel to training and matches) and intake of tactical information (i.e. team talks) from coaching staff. However, these activities were not perceived to induce mental fatigue. This may be explained by their duration (10-min) and complexity of information received. Previous literature [28] has demonstrated that prolonged auditory processing (50-min auditory processing task) impaired cognitive task performance, decreased arousal and motivation, and increased mental fatigue. Exposure to cognitively demanding speech- picture verification tasks of contrasting difficulty levels in different signal- to- noise ratios (SNRs) has also been shown to increase pupil diameter, denoting a reduction in physiological arousal [29]. However in real-life soccer scenarios, a pre-match team talk likely contains a summary of themes previously discussed and prepared for in training, providing little novel complex information and

therefore minimal cognitive demand. A low perceived presence of mental fatigue from travel to training may be explained by a shorter mean duration of travel time (32-min) compared to previous studies (90-120-min) which have demonstrated mental fatigue through monotonous simulated road travel [30-31]. Travel duration to away matches proved difficult to implement in the pilot survey due to such a high variation in journeys throughout a season and difficulty in recalling the information, meaning it was removed from the final survey. Therefore despite a minimal presence of mental fatigue when travelling to away matches, this perception is likely open to fluctuation based on the location of the club and frequency of long travel durations. Future research could monitor travel fatigue experienced on long monotonous coach journeys to understand the impact of varying travel distances.

The current study also demonstrated a minimal impact of fixture congestion on perceived mental fatigue. This is the first known study to investigate this, as previous fixture congestion research has focused on physical performance decrements [32-35]. These findings may be explained by the lack of exposure to congested fixture periods (mean number of games per week = 1.5±0.8). The low prevalence of congested periods at academy level may provide a difficulty in players providing an educated and experienced response to such questions, in comparison to senior elite players who can be exposed to more than sixty games per season [36]. Education commitments (physical and mental) were also shown to have minimal perceived impact on soccer-specific performance. Combining education and sport can be challenging, as shown by research which cited schedule clashes and fatigue as limiting factors to sporting performance [37] and a perceived cause of mental fatigue [23]. The contrast in findings can be explained for several reasons. Firstly, elite academy soccer players may be given a clear distinction between time committed to soccer and education, with special dispensation for exam and coursework deadlines based on soccer commitments, therefore minimising the stress of education. Conversely, the current survey may have lacked

enough depth in questioning to elucidate the impact of education on performance. The timing of questioning can also have an impact on response. The survey was completed between July – December, a time traditionally free of exams and demanding coursework deadlines in the UK. It is recommended that future research frequently administers a survey throughout a season to understand fluctuations in responses.

Conclusion

This study provides novel findings which demonstrates English academy soccer players' understanding of mental fatigue and perceptions of mental fatigue when exposed to tasks cited as potentially detrimental to performance in previous work (Thompson et al. 2018; Coutts, 2016). The results show that mental fatigue is not prevalent at pre-match, nor in several other soccer-specific scenarios, but is subjectively present post-match and 24-hours post-match. These findings provide a reference point for subsequent research which incorporates ecologically valid protocols in mental fatigue studies. Such studies could include the impact of relevant screen time exposure (social media/watching videos) on soccer-specific performance, or the impact of music on the alleviation of mental fatigue. Travel is potentially more problematic for players based on team location, and future surveys could factor for this by splitting cohorts into geographical regions of the country. Additionally, the timing of future surveys must also be considered. Indeed, certain themes in the survey are likely to fluctuate in the season, such as the impact of education on soccer-specific performance (during exam periods) or fixture congestion (during a tournament phase), and future survey designs must be conducted frequently with comparisons made to early, mid and late phases of the season.

Disclosure of interest

The authors report no conflict of interest.

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Table 1.

Physical fatigue and mental fatigue descriptors indicated by participants with chi-square values.

Descriptor	Physical (%)	Mental (%)	χ^2	*p*	Cramer's *V*
"Difficulty in reacting to mistakes"	18.5	37.3	.59	.444	.05
"Reduced motivation"	21	43.5	3.45	.063	.11
"Tense"	13.3	16.2	1.09	.296	.06
"Exhausted"	72	30.3	3.12	.078	.11
"Angry"	10.3	30.7	12.11	.001*	.21
"A difficulty in maintaining concentration"	25.1	55	12.62	<.001*	.22
"Reduced reaction times"	32.8	34.7	3.75	.053	.12
"Feeling sleepy/drowsy"	38	32.8	16.35	<.001*	.25
"Reduced arousal"	6.3	15.5	9.13	.003*	.18
"On edge"	5.2	18.1	15.21	<.001*	.24
"Sluggish"	55.4	21.8	.90	.32	.06
"Pain soreness"	51.3	5.2	.01	.921	.01
"Reduced energy levels"	62.7	21.4	.62	.423	.05
"Confusion"	6.6	32.5	10.28	.001*	.20
"Weak"	39.1	14	13.21	<.001*	.22
"Panicky"	3.3	25.1	13.75	<.001*	.23
"A difficulty in maintaining performance levels"	32.1	21.4	15.42	<.001*	.24

*$p < q$

Table 2. Mean and SD (0-100 AU) of mental fatigue indicators on match day by age group.

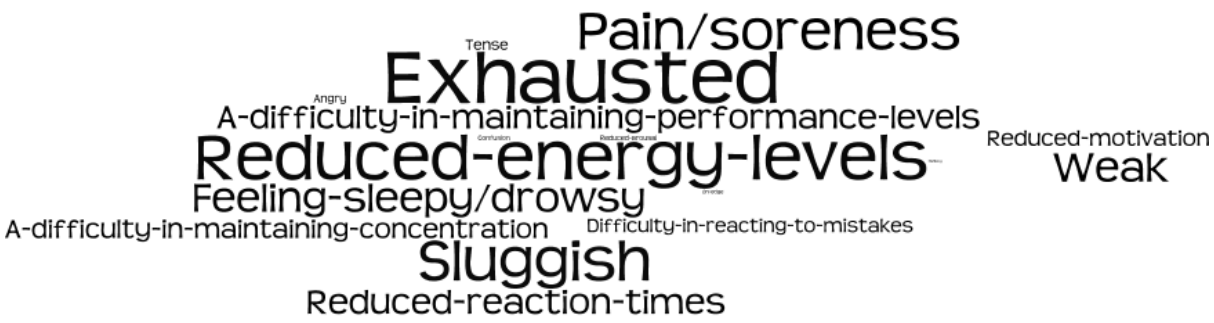
[a]Statistically significantly different (p < q) from under 14s, [b]under 15s, [c]under 16s.

Mental fatigue indicator	Under 14s (*n* = 38)	Under 15s (*n* = 15)	Under 16s (*n* = 48)	Under 17s (*n* = 15)	Under 18s (*n* = 96)	Under 19s (*n* = 15)	Under 23s (*n* = 36)
Journey to away match	49±28	31±21	32±20[a]	36±20	38±25	37±13	43±20
From team talk	30±32	6±7[a]	5±8[a]	5±8[a]	9±14[a]	6±6[a]	8±10[a]
5-min before kick-off	28±26	9±13[a]	15±17[a]	12±16	20±19	14±10	20±16
At half-time	33±25	17±16	27±20	38±18	32±19	35±16	38±15[b]
Immediately after match	43±29	31±25	37±27	55±25	53±25[c]	61±27[b,c]	51±20
24 hours after match	37±35	31±23	29±25	30±22	36±26	44±29	43±27

Figure 1.

Selected descriptors of physical fatigue (a) and mental fatigue (b) with size representative of frequency.

(a) Physical fatigue



(b) Mental fatigue

Figure 2.

Self-report frequency of training per week by age group.