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Fatigue experiences in competitive soccer: development during matches and the impact of general performance capacity

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ABSTRACT

Background: Fatigue as a result of prolonged activity may increase injury risk and decrease performance.
Purpose: To provide insight in the development of fatigue experiences during soccer matches and the extent to which general performance capacity (i.e. overall physical fitness, psychological fitness, and recovery) contributes to these fatigue experiences.
Methods: 450 Soccer players from the highest divisions in the Netherlands completed a questionnaire to assess (a) fatigue experiences (feeling tired, physically exhausted, not fit, weak, and mentally exhausted: not at all [1] – very much [7]) during a typical match; and (b) subjective indices of general performance capacity (i.e. general capacity to handle workload).
Results: On average, fatigue levels were reported to be moderate. Fatigue increased primarily during the second half of the match and only a small decrease in fatigue was observed during half time. Generally, higher intensity fatigue experiences were reported by attackers than defenders. Regression analyses showed that players' general performance capacity explained a substantial part of fatigue at the start of a match and also predicted the development of fatigue experiences during a match, with low performance capacity being associated with higher baseline levels of fatigue and a steeper increase in fatigue over time.
Conclusions: The observed association between players' general performance capacity and their fatigue levels during matches suggests that periodic screening of general performance capacity can be informative with regard to the employability of players across different stages of match-play and as such, aid in reducing injury risk and increasing performance.

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Introduction

Fatigue is a common phenomenon resulting from prolonged physical or mental activity and is characterized by feelings of low energy and resistance to further effort [1]. Most

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people occasionally feel fatigued and recognize its effect upon mood and performance in daily life [1]. In sports, fatigue may be even more prominent due to prolonged and/or repeated high-intensity activity. During a soccer match, players perform on average at 85% of their maximal heart rate [2] and run over 10 km [3]. Depending on players' positions, up to 4.5 km may be characterized as high-intensity running [3]. During matches, such activity may lead to the development of fatigue, which may – in turn – increase injury risk and decrease performance [4]. Against this background, it is important to gain insight in the origin and intensity of players' fatigue experiences during matches.

The occurrence of fatigue during a soccer match seems likely as it is a high-intensity game with high aerobic and anaerobic demands [5]. However, soccer players' match-fatigue levels (i.e. the intensity of fatigue experiences during matches) are not often reported. A recent study of a single team showed that the perceived exertion of individual soccer matches was on average rated as being 'very hard' [6] suggesting high levels of fatigue. Similarly, two small-sample studies reported 'hard' to 'very hard' ratings of perceived exertion after single (unofficial) matches [7,8]. Although these studies provide a general indication about the extent to which individual matches result in intense fatigue experiences, several questions remain. That is, it is still unclear how fatigue experiences typically develop within matches, whether fatigue experiences differ depending on player position, and what the origin of these fatigue experiences is.

The effort-recovery model [9] provides a valuable framework for the study of fatigue. According to this model, levels of fatigue depend on the ratio between workload and performance capacity (i.e. an individual's capacity to handle workload). When workload is high, the same individual will become fatigued faster as compared to when workload is low. Similarly, an individual with low performance capacity will become fatigued faster – given the same objective workload – when compared to an individual with high performance capacity. In soccer, workload comprises all physical and mental activities performed during a match. Performance capacity, on the other hand, is an individual's capacity to handle that workload and is comprised of physical fitness, psychological fitness, and the ability to recover from previous exercise [e.g. 10]. Previous research has extensively described workload in soccer based on match analyses, showing differences depending on players' positions (i.e. defenders, midfielders, and attackers) [11] and indicating that a higher workload is generally associated with a more pronounced decrease in soccer-specific activity over the course of a match [11]. While this indicates that workload may induce fatigue, still little is known about the extent to which inter- and intra-individual differences in performance capacity influence this relationship.

Previous studies showed that reduced physical fitness, reduced psychological fitness, and limited recovery (e.g. sleep restriction) may lead to increased fatigue experiences [7,12,13] and an increased injury risk [14]. For example, it has been shown that lowering psychological fitness by performing a cognitively demanding task leads to increased fatigue levels during subsequent soccer-specific physical exercise [13]. These previous studies focused on single as opposed to combined aspects of performance capacity (i.e. physical and psychological fitness) and have tested momentary (e.g. match-specific) changes in performance capacity rather than investigating the impact of relatively stable (individual) differences in capacity. In competitive soccer, however, the rapid succession of matches may lead to an accumulation of workload and there is often little time for adequate recovery. As a consequence, decreases in momentary performance capacity within matches may develop into more chronic differences in performance capacity over time (i.e. 'general' performance capacity). In addition, general performance capacity is likely to differ between players. Following the effort-recovery theory [9], such differences in general performance capacity may determine fatigue at the start of a match as well as its development over the course of a match, with less fit players becoming fatigued faster with the same workload. So far, it remains unclear to what extent differences in general performance capacity influence fatigue experiences in soccer matches.

The current study aimed to investigate the development of fatigue experiences during subsequent phases of a typical match and to identify differences in fatigue experiences between players' positions. Second, based on the effort-recovery theory [9], the aim was to examine the extent to which general performance capacity contributes to these fatigue experiences. To this end, a large-scale cross-sectional survey was distributed among (sub)elite soccer players. In line with recent literature, which proposes a central role for perceived effort and exertion in explaining the fatigue-performance relation [15,16], our study focused on the subjective experience of fatigue. It was hypothesized that fatigue increased during both halves and decreased during half time. Furthermore, it was expected that lower general performance capacity would predict higher levels of fatigue at the start of a match and a steeper increase of fatigue over the course of a match.

Method

All soccer clubs in the four highest divisions in the Netherlands were invited to take part in our study. One hundred fifty clubs were approached for participation, of which 37 clubs (525 field players) agreed to participate. After excluding players who did not play any matches during the last three months ($N = 34$), players with missing fatigue data ($N = 30$), and players who indicated that they did not understand the questions (e.g. due to poor understanding of the Dutch language; $N = 11$), our final sample consisted of 450 male soccer players. The mean (±SD) age of participants was 23.7 ± 3.8 years, their weight was on average 76.6 ± 6.9 kg, their BMI was 22.9 ± 1.6 kg/m^2 and the majority were Dutch (84.7%). Participants were all (sub)elite soccer players, as their teams competed in the highest four divisions in the Netherlands: first division (2.4%), second division (7.8%), third division (20.4%), and fourth division (69.3%). All participants read a consent statement and ethical approval was granted by the Ethics Committee Faculty of Social Sciences of the Radboud University (ECSW2014-2411-264).

All participating players completed a questionnaire which contained questions about general characteristics (e.g. age, weight), soccer characteristics (e.g. position, number of matches), fatigue experiences during a soccer match, and general performance capacity.

For fatigue experiences during a soccer match, players were asked to rate their fatigue levels during a 'typical' match (i.e. an average match during the last three months). By taking fatigue levels of a typical match rather than a specific single match, the variety in workload and fatigue experiences due to specific match-related factors (e.g. opponent strength and match-specific emotions) was reduced. Although a recall period may sometimes result in overestimations of fatigue [17], similar approaches using average retrospective measurements (i.e. asking for 'typical' experiences) have previously shown that such measurements are reliable and accurately reflect momentary measures of emotion and mood [18–20].

Players' ratings of fatigue were assessed for the first ten minutes of the first half (T1), the last ten minutes of the first half (T2), the first ten minutes of the second half (T3), and the last ten minutes of the second half (T4). For each time-point, four items of the subscale 'subjective feelings of fatigue' of the Checklist Individual Strength [21] were presented. These items included feeling 'tired', 'physically exhausted', 'fit' (reversed), and 'weak'. In addition, an item on mental exhaustion was added, thereby ensuring that our measurement of fatigue asked for feelings of general fatigue (e.g. feeling tired) as well as physical and mental components of fatigue (e.g. physical exhaustion, mental exhaustion). All items were answered on a 7-point scale that ranged from 'not at all' (1) to 'very much' (7) and did not contain any other descriptive adjectives (e.g. 'please indicate how [physically exhausted] you typically feel during the [last 10 minutes of a match]'). For statistical analyses, overall fatigue scores at T1–T4 were calculated by averaging scores across items. Internal consistency of the fatigue scale was good, with Cronbach's alphas of .83–.86 across T1–T4.

To assess general performance capacity, specific indices of physical fitness, psychological fitness, and recovery were selected. Physical fitness was assessed using the 4-item *low fitness/injury* subscale of the Dutch version of the REST-Q [10,22]. An example item is: 'I felt vulnerable to injuries'. Cronbach's alpha was .77 in our study. Psychological fitness was assessed using a 6-item scale of *affective well-being*, which was adapted from previous studies and showed to possess a good reliability [23,24]. Items included feeling 'irritated' (reversed), 'happy', 'stressed' (reversed item), 'relaxed', 'enthusiastic', and 'satisfied'. Cronbach's alpha was .80 in our study. Recovery was assessed using the 4-item Jenkins Sleep Questionnaire, which measures *sleep problems* [25]. An example item is 'I had trouble falling asleep'. Cronbach's alpha was .65 in our study. For the purpose of the current study, all 14 items on general performance capacity (physical fitness, psychological fitness, and recovery) were answered on a 7-point scale (score 0–6; never, seldom, sometimes, regularly, often, very often, and always [as in the RESTQ-Sport; 10,22]) and reflected the last three months (e.g. during the last three months, how often did you [feel vulnerable to injuries]?). Sleep problems and low fitness/injury were framed negatively (i.e. higher scores indicate lower performance capacity). Affective well-being was framed positively (i.e. higher scores indicate higher performance capacity).

Data analysis

To get insight in the development of fatigue experiences during a typical match and differences between positions, differences in fatigue scores as a function of time (T1–T4) and player position (defender, midfielder, attacker) were analyzed using a 4×3 Repeated Measures (RM) ANOVA. Significant effects were followed up using paired *t*-tests or Gabriel's post-hoc tests [26]. Effect sizes (η^2 for ANOVAs, Cohen's *d* for *t*-tests and post-hoc tests) were calculated for all analyses. To get insight in the contribution of general performance capacity on match fatigue (i.e. fatigue experiences during matches), mean values for each general-performance-capacity subscale (i.e. low injury/fitness, affective well-being, and sleep problems) were calculated. Furthermore, Pearson correlations were computed between each general-performance-capacity subscale and fatigue scores at T1–T4.

Additionally, regression analyses were performed to examine our three general-performance-capacity indicators as statistical predictors of fatigue at the start of a match and the development of fatigue over time. To predict fatigue at the start of a match, a linear regression analysis was conducted with the general-performance-capacity indicators as predictors of fatigue at T1. To predict changes in fatigue during the first half, half-time, and the second half, stepwise linear regressions were used with the general-performance-capacity indicators as predictors. Thereby, fatigue at T2, T3, and T4 were dependent variables and we controlled for fatigue at T1, T2, and T3, respectively.

Before conducting the statistical analyses, assumptions of normality, homoscedasticity, linearity, and sphericity were tested for the independent variables in this study. Assumptions of linearity and homoscedasticy were always met. For most variables, data were normality distributed. When slight deviations from normality were found, data were also analyzed using transformations and using non-parametric tests. However, because these tests showed similar results and did not alter the conclusions, only the original analyses are reported. When the assumption of sphericity was not met, we used Greenhouse-Geisser correction. All analyses were performed in SPSS 21.0 and a $p < 0.05$ was considered as statistically significant.

Results

As appears from Figure 1, overall fatigue scores across general match play ranged between 2.2 and 3.6 (7-point scale). Statistical analysis of fatigue scores showed a main effect of time (F (2.57, 1101.20) = 319.48, $p < 0.001$, $\eta^2 = .427$) and position (F (2, 428) = 3.20, $p = 0.04$, $\eta^2 = .015$), but no time × position interaction (F (5.15, 1101.20) = 1.52, $p = 0.18$, $\eta^2 = .007$). Paired t-tests on the main effect of time showed that fatigue increased during the first half, from 2.2 ± 1.0 on T1 to 2.5 ± 0.9 on T2 (t (430) = 7.32, $p < 0.001$, $d = 0.40$). During half time, fatigue was slightly decreased to 2.4 ± 0.9 on T3 (t (430) = −2.67, $p < 0.01$, $d = -0.12$), which was still higher than fatigue on T1 (t (430) = 5.74, $p < 0.001$, $d = 0.28$). During the second half, fatigue increased to 3.6 ± 1.1 on T4 (t (430) = 22.57, $p < 0.001$, $d = 1.09$). Fatigue scores for the different player positions are shown in Table 1. Post-hoc tests on the main effect of position indicated that attackers scored on average 0.23 higher than defenders ($p = 0.03$, $d = 0.30$). No other differences were found (defenders vs. midfielders: $p = 0.65$, $d = 0.12$; midfielders vs. attackers: $p = 0.37$, $d = 0.18$). The separate fatigue items (i.e. tired, physically exhausted, not fit, weak, and mentally exhausted) generally showed a similar pattern over time and similar effects of position compared with overall fatigue scores.

Descriptive analyses of general performance capacity showed that players seldom to sometimes felt physically unfit (low fitness/injury: 1.8 ± 0.9), often felt psychologically fit (affective well-being: 3.9 ± 0.7), and seldom to sometimes reported problems sleeping (sleep problems: 1.5 ± 0.9). Although these numbers are an indicative of a generally healthy population with reasonable performance capacity, 8.4% of the players felt regularly or often unfit, 10.3% did not regularly feel psychologically fit, and 9.1% reported to experience sleep problems regularly or often.

Correlations between low fitness/injury and affective well-being, low fitness/injury and sleep problems, and affective well-being and sleep problems were all significant and in the expected directions (r's = −0.351, 0.374, −0.323, p's < 0.001). Furthermore, at all four time points, higher levels of fatigue were related to lower fitness/injury (r's = 0.322–0.385, p's < 0.001), lower affective well-being (r's = −0.246 to −0.406, p's < 0.001), and more sleep

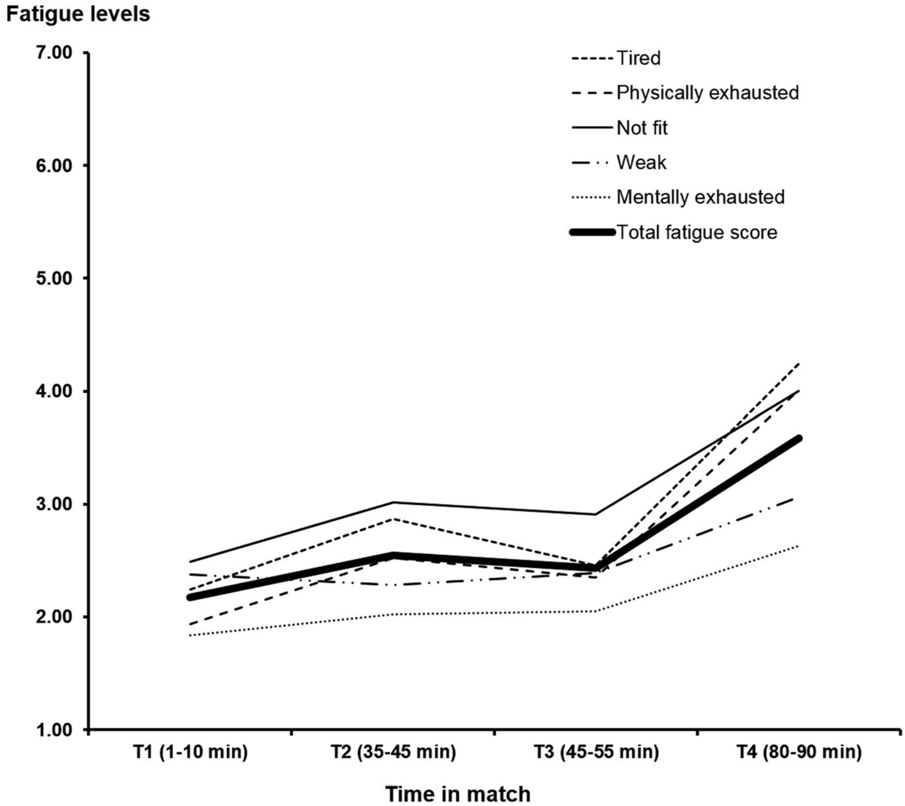

Figure 1. Mean fatigue score and fatigue-item scores across match play. RM ANOVAs for each fatigue item (not reported in the main text) showed: for feeling '*tired*', a main effect of time ($p < 0.001$, $\eta^2 = .377$) and position ($p = 0.01$, $\eta^2 = .020$), but no time × position interaction ($p = 0.60$, $\eta^2 = .003$); for feeling '*physically exhausted*', a main effect of time ($p < 0.001$, $\eta^2 = .434$) and position ($p = 0.05$, $\eta^2 = .014$), but no time × position interaction ($p = 0.32$, $\eta^2 = .005$); for feeling '*not fit*', a main effect of time ($p < 0.001$, $\eta^2 = .290$) and position ($p = 0.01$, $\eta^2 = .021$), but no time × position interaction ($p = 0.99$, $\eta^2 = .004$); for feeling '*weak*', a main effect of time ($p < 0.001$, $\eta^2 = .123$), no main effect of position ($p = 0.67$, $\eta^2 = .002$), and a time × position interaction ($p = 0.05$, $\eta^2 = .010$); and for feeling '*mentally exhausted*', a main effect of time ($p < 0.001$, $\eta^2 = .152$), but no main effect of position ($p = 0.38$, $\eta^2 = .005$) or a time × position interaction ($p = 0.22$, $\eta^2 = .006$).

Table 1. Mean (SD) fatigue scores (scale 1–7) per position.

Position	*N*	Fatigue T1 (min 1–10)	Fatigue T2 (min 35–45)	Fatigue T3 (min 45–55)	Fatigue T4 (min 80–90)
Total Defenders	162	2.1 (1.0)	2.4 (0.9)	2.3 (0.9)	3.4 (1.1)
Central defender	78	2.2 (0.8)	2.4 (0.8)	2.3 (0.8)	3.5 (0.9)
Full back	78	2.1 (1.0)	2.4 (1.0)	2.3 (0.9)	3.4 (1.2)
Total Midfielders	143	2.2 (1.0)	2.6 (0.9)	2.5 (1.0)	3.5 (1.2)
Defensive midfielder	38	2.2 (0.9)	2.3 (0.8)	2.3 (0.9)	3.4 (1.3)
Midfielder	60	2.0 (0.9)	2.5 (0.9)	2.4 (0.9)	3.4 (1.0)
Attacking midfielder	40	2.3 (1.0)	2.8 (0.9)	2.7 (1.1)	3.9 (1.3)
Total Attackers	126	2.2 (1.0)	2.7 (1.0)	2.5 (1.0)	3.8 (1.2)
Winger	69	2.2 (1.0)	2.6 (0.9)	2.5 (1.0)	3.9 (1.1)
Striker	53	2.2 (1.1)	2.7 (1.0)	2.4 (1.0)	3.8 (1.2)
Overall	431	2.2 (1.0)	2.5 (0.9)	2.4 (0.9)	3.6 (1.1)

Note: 15 players could be identified as a defender, midfielder, or attacker, but their position could not be further specified (e.g. central defender or full back).

Table 2. Results of regression analyses to predict fatigue levels during a match.

	Fatigue scores during a match							
	Fatigue T1 (start 1st half)		Fatigue T2 (end 1st half)		Fatigue T3 (start 2nd half)		Fatigue T4 (end 2nd half)	
Predictor	ΔR^2	β	ΔR^2	β	ΔR^2	β	ΔR^2	β
Step 1	n/a		.19***		.36***		.25***	
Fatigue at previous time point[a]				.32***		.53***		.42***
Step 2	.24***		.04***		.04***		.05***	
Low fitness/injury		.25***		.15**		.08		.22***
Affective well-being		−.29***		−.10*		−.11*		−.04
Sleep problems		.09		.05		.08*		−.00

[a]For fatigue at T2, there was controlled for fatigue at T1. For fatigue at T3, there was controlled for fatigue at T2. For fatigue at T4, there was controlled for fatigue at T3.

$^*p < .05$, $^{**}p < .01$, $^{***}p < .001$.

problems (r's = 0.199–0.277, p's < 0.001). Also, the experiences of fatigue at T1–T4 were positively correlated to each other (r's = 0.299–0.607, p's < 0.001).

Table 2 shows the results of the regression analyses to predict fatigue levels based on our indices of general performance capacity. At the start of a match, fatigue was strongly and significantly predicted by low fitness/injury and affective well-being, but not by sleep problems ($R^2 = 0.24$, $p < 0.001$). With respect to fatigue during later phases of a match, the control variables (i.e. fatigue at the previous time point) appeared strong and significant predictors (R^2's = 0.19–0.36, p's < 0.001). Still, at each time point, percentage of explained variance within the respective regression models was further improved by adding general performance capacity as a predictor. In predicting changes in fatigue during the first half (i.e. T1–T2) low fitness/injury and affective well-being were significant predictors ($\Delta R^2 = 0.04$, $p < 0.001$); in predicting changes in fatigue during half time (i.e. T2–T3; recovery) affective well-being and sleep problems were significant predictors ($\Delta R^2 = 0.04$, $p < 0.001$); and in predicting changes in fatigue during the second half (i.e. T3–T4) low fitness/injury was again a significant predictor ($\Delta R^2 = 0.05$, $p < 0.001$).

Discussion

Using a large sample of (sub)elite soccer players, this study investigated experiences of fatigue in competitive soccer matches. Fatigue experiences play an important role in performance decrements under highly demanding circumstances [15,16] and could indicate higher injury risks [27,28]. The current study aimed to provide insight in general experiences of match fatigue, to identify potential differences in fatigue between players' positions, and – based on effort-recovery theory [9] – to identify the contribution of general performance capacity to these fatigue experiences. Findings showed that fatigue levels increased during match play, that attackers typically report slightly higher levels of fatigue than defenders, and – in line with effort-recovery theory – that general performance capacity predicts baseline levels of fatigue as well the rate of increase in fatigue across match play.

Fatigue increased during a typical match and was most prevalent towards the end of the second half of match play. Interestingly, only a minor decrease of fatigue was found during half-time and the second half made a relatively large contribution to the final fatigue scores. A possible cause for the limited recovery during half time is that half time is simply too short to completely restore players' resources. The large increase in fatigue during the second half concurs well with performance decrements that are observed in the second halves of matches [11,29,30], and can most likely be explained by decrements in momentary performance capacity that result from an accumulation of workload during a match. Against expectations, even at the end of a match, in absolute terms, on average only moderate fatigue scores were observed.

These fatigue levels do not correspond to previous studies that – based on rates of perceived exertion – appear to suggest higher levels of fatigue upon completing a match [6,7,8]. Surely, one explanation for this discrepancy may be the different means of assessment (i.e. our five-item fatigue scale vs. a one-item rating of perceived exertion) and, potentially, also differences in the recall period between the actual experience of fatigue and the time of measurement (i.e. multiple days vs. a few minutes). However, given that with large recall periods individuals appear to overestimate rather than underestimate their fatigue experiences, [17,31], this latter explanation does not appear to be likely. Instead, it is important to note that in the current study, players reported fatigue experiences regarding their perception of a 'typical' match rather than during a particularly easy or more difficult match, in which workload and, hence, fatigue levels may arguable be lower or higher, respectively. Similarly, more extreme fatigue levels (or less extreme fatigue levels) may be more prevalent for specific players. By showing that attackers reported higher fatigue scores than defenders, this study indicates that fatigue experiences may differ depending on player position. Future research should investigate the development of fatigue during individual matches, examine variation between these matches (e.g. easy and difficult matches), and thereby take specific player positions into account.

Regarding general performance capacity (i.e. physical fitness, psychological fitness, and recovery), players with a lower general performance capacity reported both higher fatigue levels at the start of a match and larger increases in fatigue levels during a match. While previous studies focused on the effect of momentary changes in performance capacity on fatigue [e.g. 7,12,13], our study thus shows that relatively stable (individual) differences in performance capacity also contribute to players' fatigue experiences. The contribution of general performance capacity to fatigue at the beginning of a match was substantial. Although average fatigue levels at the start of a match were low, higher fatigue levels for players with a lower general performance capacity may still result in decreased performance and an increased injury risk, especially because fatigue during later phases of a match was strongly related to fatigue in earlier phases. The contribution of general performance capacity to the development of fatigue during a match was small but significant. This indicates that despite immediate effects of acute workload (i.e. soccer-specific activity performed during a match), also general differences in performance capacity may contribute to the rate with which players become fatigued (and recover) during matches. These findings support the notion that both workload and performance capacity contribute to fatigue [9] and further stress the importance of considering both workload and performance capacity when analyzing fatigue in soccer.

Our findings regarding the impact of general performance capacity on match fatigue hold a number of practical implications. First, monitoring physical fitness, psychological fitness, and recovery may provide insight in the degree to which players can resist the strain of upcoming matches and can effectively be called upon or should be given more time to recover. Second, our results suggest that increasing general performance capacity in players might reduce experiences of match fatigue and, hence, improve performance and reduce injury risk. On a practical note this means that coaches should balance training load, match load, and recovery in order to obtain high levels of general performance capacity. This implies that during periods of congested matches improved recovery strategies [32] or player rotation may be needed, whereas during more quiet match periods, physical conditioning may be intensified. In all cases it is valuable to also consider individual differences.

In interpreting the current findings it is important to acknowledge that our results are based on retrospective assessments and target general rather than match-specific levels of fatigue and performance capacity. Although data collection was anonymous, we cannot rule out the possibility that a socially desirable answering tendency may have led to an underestimation of fatigue experiences. While these subjective assessments allowed us to effectively test our hypotheses in a large group of high-level soccer players and provided insight in the level and origin of fatigue experiences in soccer, match-specific analyses and objective measurements of performance capacity are needed to confirm the current findings.

In conclusion, the current study showed that in (sub)elite soccer experiences of fatigue increase during matches but generally do not reach extreme values. Fatigue experiences differ depending on player position, with attackers reporting higher levels of fatigue than defenders. Importantly, differences in general performance capacity (physical fitness, psychological fitness, and recovery) were shown to affect players' fatigue levels at the start of a match and contributed to the rate of increase in fatigue during matches. These results suggest that monitoring players' general performance capacity could provide important information on the employability of players, while improving players' general performance capacity may decrease match fatigue and, thereby, enhance performance and reduce injury risk.

Disclosure statement

No potential conflict of interest was reported by the authors.

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