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# Relationships between match activities and peak power output and Creatine Kinase responses to professional reserve team soccer match-play

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ABSTRACT

The specific movement demands of soccer that are linked to post-match recovery and readiness to train are unclear. Therefore, we examined the relationship between Global Positioning System (GPS) variables and the change (Δ; from baseline) in Creatine Kinase (CK) concentrations and peak power output (PPO; during the countermovement jump) at 24 h and 48 h post-match. Fifteen English Premier League reserve team players were examined over 1–4 matches. Measurements of CK and PPO were taken before (24 h prior to match-play) and after (+24 h and +48 h) each game during which movement demands were quantified using 10 Hz GPS data. High intensity distance covered ($r = 0.386$, $p = 0.029$; $r = -0.349$; $p = 0.050$), high intensity distance covered·min$^{-1}$ ($r = 0.365$, $p = 0.040$; $r = -0.364$, $p = 0.040$), high speed running distance ($r = 0.363$, $p = 0.041$; $r = -0.360$, $p = 0.043$) and the number of sprints·min$^{-1}$ ($r = 0.410$, $p = 0.020$; $r = -0.368$, $p = 0.038$) were significantly related to ΔCK and ΔPPO at +24 h post-match, respectively. No relationships were observed between any match variables and ΔCK and ΔPPO after +48 h of recovery. These findings highlight that high intensity match activities are related to ΔCK and ΔPPO in the 24 h, but not 48 h, following soccer match-play. Such information is likely of interest to those responsible for the design of soccer player's training schedules in the days following a match.



## 1. Introduction

Soccer typically requires distances of 9–14 km to be covered per match (Bangsbo, 1994; Carling & Dupont, 2011). While low-intensity activities are dominant (Bangsbo, 1994; Carling & Dupont, 2011), ~300 changes in movement that exceed 0.5 m s$^{-2}$ (and thus are classified as acceleration/deceleration efforts) are performed per half in 90 min of match-play (Russell, Sparkes, Northeast, Cook, et al., in press). Eccentric contributions to these muscle actions (Brancaccio, Lippi, & Maffulli, 2010; Clarkson, Nosaka, & Braun, 1992; Warren, Lowe, & Armstrong, 1999) likely explain the transient metabolic and physical performance disturbances attributed to exercise-induced muscle damage that are observed for up to 120 h

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post-match (Nedelec et al., 2012, 2014). Although unclear (McCall et al., 2015), insufficient recovery time has been associated with injury risk in European club competitions (Dupont et al., 2010) and international tournaments (Carling, Le Gall, & Dupont, 2012). Consequently, the ability to profile and/or predict post-match physiological and performance changes resulting from competitive involvement is desirable.

Indices of CMJ performance (e.g., peak power output; PPO) and Creatine Kinase (CK) concentrations are common markers used to assess the influence of prior exercise on subsequent performance (Nedelec et al., 2012, 2014; Russell, Sparkes, Northeast, & Kilduff, in press; Russell et al., 2015). Indeed, we recently reported that PPO during the CMJ was reduced (+24 h: −237 ± 170 W, +48 h: −98 ± 168 W) whereas CK was elevated (+24 h: +334.8 ± 107.2 μ $L^{-1}$, +48 h: +156.9 ± 121.0 μ $L^{-1}$) after 90 min of soccer match-play (Russell et al., 2015); responses which were consistent across four matches and a variety of playing positions. While such markers have provided worthwhile information regarding the time-course of changes following soccer-specific exercise, the time required for such changes to manifest (e.g., up to 120 h; Nedelec et al., 2012, 2014) likely precludes the sole use of these variables to inform training program design in the days soon after match-play. This problem is likely exacerbated by the between-match variability of CK and PPO responses to soccer match-play (Russell et al., 2015).

Previous authors have reported the use of match-play performance characteristics to predict individualized recovery kinetics in rugby union (Jones et al., 2014; Smart, Gill, Beaven, Cook, & Blazevich, 2008; Takarada, 2003), rugby league (McLellan & Lovell, 2012; McLellan, Lovell, & Gass, 2011) and Australian football (Young, Hepner, & Robbins, 2012) players. In one of the few studies to examine such relationships in soccer, Nedelec et al. (2014) reported significant correlations between the number of short sprints performed and the increase in muscle soreness at 48 and 72 h following competitive soccer match-play. However, an acknowledged limitation of this study was the use of video motion analyses when Global Positioning System (GPS) tracking data can report the intensity of match activities as opposed to just the amount (Nedelec et al., 2014). GPS tracking has demonstrated relationships between high speed running characteristics and changes in CK (Thorpe & Sunderland, 2012) and neuromuscular function (Duffield, Murphy, Snape, Minett, & Skein, 2012; Young et al., 2012) during the post-exercise recovery period.

In seven semi-professional soccer players, and using GPS analysis, significant correlations between indices of high intensity running (i.e., sprint number, sprint distance and high intensity distance covered) and immediate post-match increases in CK concentrations are reported (Thorpe & Sunderland, 2012). However, while acknowledging the small sample size used in this study, correlations between movement characteristics and physiological variables assessed immediately post-match may not reflect relationships between these indices after more prolonged durations of recovery (e.g., +24 and +48 h); especially, given the time-course of recovery of selected physiological variables and the fact that the days following match-play likely elicit reductions in a player's training volume. Typically, players will have a rest day or a recovery day in the 24 h following a match.

In summary, there is a paucity of literature that has examined the impact of soccer playing actions on post-match markers of recovery status. Such information would likely be of benefit to applied practitioners seeking methods of informing the modulation of training program design in the days following competitive encounters. Therefore, the aim of this study was to examine relationships between the movement demands of professional reserve team soccer match-play (determined by GPS) and post-match changes (from baseline) in CK concentrations and CMJ performance. We hypothesized that soccer-specific playing actions performed during match-play would be associated with changes in CK and PPO post-match.

## 2. Methods

### *2.1. Experimental design*

This longitudinal and observational study investigated relationships between GPS variables collected during match-play and changes in CK concentrations and CMJ performance in the 48 h following soccer-specific exercise. The study presents data from a three month period whereby five consecutive matches were played during the 2013/2014 competitive season. The activity in the 48 h period before each game included a single training session on both days that lasted no longer than 60 min and started at ~10:30 h. These sessions typically required a channel warm-up (including dynamic stretches and short sprints), box drills (e.g., static keep ball, 6 vs 2) and tactical practices to be performed and were characterized by coaching staff as low volume and low intensity. Players were advised to rest in the afternoons following training. In agreement with previous studies, assessments of CK concentrations and CMJ performance were measured to monitor the impact of match-play during the 48 h following each game (Russell, Sparkes, Northeast, et al., in press; Russell et al., 2015) and GPS variables were collected during competitive encounters (Russell, Sparkes, Northeast, Cook, et al., in press; Russell, Sparkes, Northeast, et al., in press). The test–retest reliability of our variables (measured using coefficient of variation analyses) was 3.0% and 3.2% for CK and PPO, respectively.

### *2.2. Participants*

Data are presented for 15 professional soccer players (age: 20 ± 1 years; stature: 1.80 ± 0.04 m; mass: 70.4 ± 5.4 kg) who play in outfield positions (centre back, centre midfield, full back, striker or wing) for a Premier League under-21 soccer team.

Due to the observational nature of the study design, team selection was not influenced throughout the study period; thus each player made a varying number of appearances (i.e., 2 ± 1). Data are only presented for players who completed between 60 and 90 min of a match. Altogether, 32 individual observations of match performance were obtained. The study required players to provide informed consent prior to participation and conforms to the Code of Ethics of the World Medical Association (approved by the ethics advisory board of Swansea University). All players were considered healthy and injury-free at the time of the study and were in the maintenance phase of their full time training cycle which included individual resistance training programs as well as team-based conditioning sessions.

### 2.3. Procedures

Baseline samples of whole blood and measurements of CMJ performance (which were preceded by a standardized dynamic warm-up), were obtained on the morning of the day before matches. Additional whole blood analyses and CMJ tests were performed at +24 h and +48 h after each match at a time that was within 60 min of the data collection time for the baseline sample. Each player performed independent baseline and post-match assessments on the day of each match. All matches were played on outdoor natural grass pitches in accordance with English Football Association rules. All players performed standardized preparations before each match in agreement with the performance strategy of the club involved. Match activities were recorded using GPS.

#### 2.3.1. Global Positioning System (GPS) analysis

Throughout soccer match-play, players wore 10 Hz GPS units (Viper pod, STATSports, Belfast, UK) positioned on the upper torso via a specifically designed vest garment to reduce movement artefacts (Harley et al., 2010). Units were activated according to the manufacturer's guidelines immediately prior to the pre-match warm-up (~40 min before kick-off) and to avoid inter-unit variation players wore the same GPS device for each match. Data relating to the GPS signal strength was unavailable. After each match, the raw data files were analyzed and 19 indices of physical performance were derived automatically (Viper PSA software, STATSports, Belfast, UK). Operational definitions for these variables are as per Russell et al. (in press) and the manufacturer's website (http://statsports.com/technology/viper-software/); briefly, the variables presented relate to coverage of total, high intensity, sprint and high speed running distance and the number of sprints, accelerations (total and high intensity), decelerations (total and high intensity) and impacts (total and high intensity).

#### 2.3.2. Creatine Kinase measurement

Whole blood (120 μL) was sampled from the fingertip and centrifuged (3000 revolutions·min$^{-1}$ for 10 min; Labofuge 400R, Kendro Laboratories, Germany). Plasma samples were then stored at −70 °C before subsequently being analyzed for CK concentrations (Cobas Mira; ABX Diagnostics, Northampton, UK). Samples were measured in duplicate (3% coefficient of variation) and recorded as a mean.

#### 2.3.3. Countermovement jump testing

Using a portable force platform (Type 92866AA, Kistler, Germany) and CMJ analyses, PPO was determined according to methods described previously (Owen, Watkins, Kilduff, Bevan, & Bennett, 2014; West et al., 2011). The vertical component of the ground reaction force during the CMJ and the participants' body mass was used to determine instantaneous velocity and displacement of the participant's centre of gravity (Hatze, 1998). Instantaneous power output was determined using Eq. (1) and the highest value produced was deemed the PPO.

$$\text{Power (W)} = \text{vertical GRF (N)} \times \text{Vertical velocity of centre of gravity } (\text{m s}^{-1}) \tag{1}$$

### 2.4. Statistical analysis

Data are presented as mean ± standard deviation (SD). Statistical significance was set at an alpha level of $p \leqslant 0.05$ and all analyses were conducted using SPSS Version 21.0 (IBM, Armonk, NY, USA). In agreement with the hypotheses of the study, relationships between GPS variables and the change (relative to baseline; Δ) in physiological and performance measures at 24 and 48 h post-match were investigated using Pearson's product moment correlation coefficients on data collapsed across all matches. Effect sizes are deemed small ($r$ = 0.1), moderate ($r$ = 0.3) and strong ($r$ = 0.5) according to Cohen (1988).

## 3. Results

Baseline CK and PPO values were 334 ± 127 μ L$^{-1}$ and 3628 ± 415 W respectively. Table 1 presents the correlation coefficients between match activities and ΔCK and ΔPPO at +24 h (+337 ± 102 μ L$^{-1}$, −269 ± 165 W, respectively) and +48 h (+133 ± 86 μ L$^{-1}$, −110 ± 151 W, respectively) following match-play.

**Table 1**
Pearson's product moment correlation coefficients between match activities and changes (Δ) in peak power output (PPO; during countermovement jumps) and Creatine Kinase (CK) concentrations at 24 and 48 h following soccer match-play.

| Match performance variable | ΔPPO (W) | | ΔCK (μ L$^{-1}$) | |
|---|---|---|---|---|
| | +24 h | +48 h | +24 h | +48 h |
| Total distance covered | 0.128 | 0.229 | 0.265 | 0.121 |
| Distance covered per min | −0.006 | 0.114 | 0.292 | 0.000 |
| High intensity distance covered | −0.349* | −0.239 | 0.386* | 0.134 |
| High intensity distance covered per min | −0.364* | −0.260 | 0.365* | 0.100 |
| Sprint distance | −0.349* | −0.319 | 0.253 | 0.159 |
| Sprint distance per min | −0.355* | −0.321 | 0.233 | 0.122 |
| High speed running distance | −0.360* | −0.268 | 0.363* | 0.145 |
| High speed running distance per min | −0.372* | −0.284 | 0.340 | 0.109 |
| Total number of sprints | −0.347 | −0.227 | 0.433* | 0.181 |
| Total number of sprints per min | −0.368* | −0.256 | 0.410* | 0.147 |
| Total number of accelerations | 0.205 | 0.302 | 0.037 | 0.120 |
| Total number of high intensity accelerations | −0.390* | −0.220 | 0.312 | 0.156 |
| Total number of high intensity accelerations per min | −0.390* | −0.233 | 0.249 | 0.099 |
| Total number of decelerations | 0.235 | 0.320 | −0.003 | 0.119 |
| Total number of high intensity decelerations | −0.314 | −0.103 | 0.404* | 0.174 |
| Total number of high intensity decelerations per min | −0.337 | −0.140 | 0.371* | 0.140 |
| Total number of impacts | 0.272 | 0.302 | 0.005 | −0.013 |
| Total number of high intensity impacts | −0.188 | −0.091 | 0.078 | −0.003 |
| Total number of high intensity impacts per min | −0.227 | −0.121 | 0.068 | −0.036 |

* Indicates significant correlation at $p < 0.05$ level.

### 3.1. Creatine Kinase (CK) concentrations

High intensity distance covered ($p = 0.029$), high intensity distance covered per min ($p = 0.040$), high speed running distance ($p = 0.041$), the number of sprints ($p = 0.013$), the number of sprints per min ($p = 0.020$), the number of hard decelerations ($p = 0.022$) and the number of hard decelerations per min ($p = 0.036$) correlated with ΔCK at +24 h. No further match performance variables correlated to ΔCK at +24 h (Table 1). No significant correlations existed between any GPS variables and ΔCK at +48 h (Table 1).

### 3.2. Peak power output (PPO)

High intensity distance covered ($p = 0.050$), high intensity distance covered per min ($p = 0.040$), sprint distance ($p = 0.050$), sprint distance per min ($p = 0.046$), high speed running distance ($p = 0.043$), high speed running distance per min ($p = 0.036$), the number of sprints per min ($p = 0.038$), the number of hard accelerations ($p = 0.027$) and the number of hard accelerations per min ($p = 0.027$) correlated with ΔPPO at +24 h. No further match performance variables correlated to ΔPPO at +24 h (Table 1). At +48 h, no significant correlations were observed between any GPS variables and ΔPPO (Table 1).

## 4. Discussion

The aim of this study was to examine relationships between the key movement demands of professional reserve team soccer match-play and post-match changes in physiological and performance indices associated with recovery. Here we report for the first time that markers of high intensity running performance and selected acceleration and deceleration variables correlate to post-match disturbances in CK concentrations and PPO (during CMJs) when assessed at 24 h, but not 48 h, after soccer match-play. These findings highlight that monitoring selected match activities could contribute to the management of player training loads on the first day after soccer match-play has taken place but caution should be applied if such markers are to be used to inform training performed thereafter.

We have previously reported elevations in CK concentrations which peaked at 24 h and remained above baseline values in the 48 h following professional soccer match-play (Russell, Sparkes, Northeast, et al. in press; Russell et al., 2015). Although we were unable to localize the source of these increased CK concentrations (e.g., originating from cardiac or skeletal muscle or brain tissue), we proposed that the responses observed likely reflected the high intensity components of a game. The significant correlations, with moderate effect sizes (i.e., $r$ = >0.3 to <0.5), seen in this study between high intensity match activities and ΔCK at +24 h (Table 1) support this hypothesis. Eccentric muscle actions (such as those involved in actions like sprinting, turning, stopping and cruising) often result in perforations in the sarcolemma and damage to sarcomeres (Clarkson & Sayers, 1999). Rises in circulating CK can occur when the sarcolemma and Z-disks are damaged (Brancaccio, Maffulli, Buonauro, & Limongelli, 2008; Brancaccio, Maffulli, & Limongelli, 2007; Brancaccio et al., 2010) and the increased membrane permeability allows CK to leak into interstitial fluid, where it then enters circulation via the lymphatic system.

The recruitment of the stretch shortening cycle has previously been implicated with exercise fatigue (Nicol, Avela, & Komi, 2006). As such, CMJ performance has been suggested as a useful recovery marker (Nedelec et al., 2012, 2014). Indeed, using a similar cohort to that reported in this study, we have reported fatigue-related changes in indices of CMJ performance following soccer match-play (Russell, Sparkes, Northeast, et al., in press; Russell et al., 2015). The significant correlations observed between ΔPPO and numerous high intensity running variables (Table 1) support those of Nedelec et al. (2014) who reported that the decrement in CMJ performance at 24 h post match-play was related to the number of hard changes in direction performed during games. It therefore appears that knowledge of the demands of a match, which are likely to be available to coaching and support staff sooner than peak changes in CK and PPO take to manifest, offer an alternative approach to tailoring the design of the training programs of soccer players who are recovering from a prior game; however, the application of such information is likely limited to the first 24 h after match-play given the absence of any statistically significant correlations between match activities and changes in CK and PPO observed at +48 h.

Physical contacts are known to predict post-match CK concentrations in rugby union (Jones et al., 2014; Smart et al., 2008; Takarada, 2003) and neuromuscular recovery in rugby league (McLellan & Lovell, 2012). Previous authors have subsequently suggested that recovery may be determined by the extent of mechanical damage induced through contact during performance in both rugby codes (Jones et al., 2014). However, in soccer, the degree of contact experienced is considerably less than rugby and likely explains the lack of any impact variables to correlate with either ΔCK or ΔPPO in the 48 h post-match period examined here. Instead, absolute and relative indices of high intensity distance covered and acceleration and deceleration parameters appear more important indicators of the CK and PPO disturbances experienced post-match; especially, in the first 24 h. Such findings agree with those of Thorpe and Sunderland (2012) who found that ΔCK was related to the total number of sprints performed and sprint distance during a professional soccer match.

Notably, none of the match performance indices correlated with changes in the physiological or performance variables assessed at +48 h. In relation to CMJ performance, these findings corroborate those of Nedelec et al. (2014) who proposed that the influence of playing actions on neuromuscular responses may be short lasting and observed only in the first hours of recovery rather than being persistent throughout the entire recovery period (Nedelec et al., 2014). However, the use of video motion analyses was an acknowledged limitation of this work as the intensity of playing actions performed during the match was not reported (Nedelec et al., 2014). Further research opportunities exist to identify additional variables which are likely to inform post-match responses.

From an applied perspective, the day following a match typically requires very low intensities of structured exercise or is a scheduled rest day. In both cases, information concerning the performance of specific match activities (i.e., indices of high intensity distance covered and parameters associated with acceleration and deceleration), could be used as a method of individualising the acute recovery practices of soccer players in the 24 h following a game. Conversely, caution is advised if specific match activities are currently used to inform training program design in sessions performed >24 h post-match. As we did not observe any statistically significant correlations between match activities and ΔPPO or ΔCK values at +48 h, it therefore appears that the effects of soccer match-play remain unclear over longer periods of recovery and thus warrant further investigation.

When interpreting the current findings, a number of limitations should be considered. Information relating to the signal strength of the GPS devices was unavailable throughout the duration of the study. It is therefore possible that the resolution of the data collected could be improved in future research. It is also prudent to note that this data does not distinguish between playing positions which in the case of other team sports has been found to influence the effects of exercise (Jones et al., 2014). Due to the sample of professional players used in this study, data with negligible statistical power would have been yielded if a position-specific approach had been adopted. While acknowledging this limitation, we believe that we present novel findings which support, and extend, previously published data, especially in relation to the time-course of the relationships examined (Thorpe & Sunderland, 2012). Moreover, this study was a descriptive study; therefore, it was not possible to determine the cause of the changes in the performance but we acknowledge the potential role of player-specific (e.g., muscular force production capabilities) and match-specific (e.g., score line, venue, team/opposition quality etc.) factors (Mackenzie & Cushion, 2013; Owen et al., 2015).

## 5. Conclusions

Within the confines of the limitations reported, our data highlights that high intensity components of match-play, such as absolute and relative indices of high intensity distance covered and acceleration and deceleration parameters, are related to post-match changes in CK and PPO that occur in the 24 h, but not 48 h, following competition. Such data highlights a potential role for match activities to predict the acute response to soccer match-play. Consequently, knowledge of the demands of a match, information which is more likely to be available to coaching and support staff sooner that peak changes in CK and PPO take to manifest, offer an additional method of informing the design of training programs and recovery practices for soccer players who have competed 24 h earlier. Furthermore, our data also highlights that caution should be applied to the use of match activities as a modulator of training when said training is performed >24 h following a match.

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