Between-Match Variability of Peak Power Output and Creatine Kinase Responses to Soccer Match-Play

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Abstract

Russell, M, Northeast, J, Atkinson, G, Shearer, DA, Sparkes, W, Cook, CJ, and Kilduff, LP. Between-match variability of peak power output and creatine kinase responses to soccer match-play. *J Strength Cond Res* 29(8): 2079–2085, 2015—Postmatch assessments of peak power output (PPO) during countermovement jumps and creatine kinase (CK) concentrations are common markers of recovery status in soccer players. Yet, the impact of soccer match-play on recovery in the 48 hours after competition is unclear, and the between-match variability of these responses has not been examined. Fourteen reserve team players from an English Premier League club were examined over 1–4 matches per player. Creatine kinase and PPO were measured before, 24, and 48 hours after each match. Data were analyzed with within-subjects linear mixed models. Compared with the prematch baseline, PPO was 237 ± 170 W and 98 ± 168 W lower at 24 and 48 hours, respectively ($p \leq 0.005$) and CK was elevated (24 hours: 334.8 ± 107.2 $\mu \cdot L^{-1}$, 48 hours: 156.9 ± 121.0 $\mu \cdot L^{-1}$; both $p \leq 0.001$) after match-play. These responses were consistent across the different matches and playing positions ($p > 0.05$). Within-subject correlations between PPO and CK were significant ($r = -0.558$; $p \leq 0.005$). The between-match variability of PPO was 10.9, 11.0, and 9.9%, respectively at baseline, 24 and 48 hours, whereas for CK, the variability was 41.7, 30.0, and 34.3%, respectively. These findings highlight that more than 48 hours are needed to restore metabolic and performance perturbations after soccer match-play, and that CK demonstrates greater between-match variability than PPO. Such information is likely to be of interest to those responsible for the design of training schedules in the days after a match and sports scientists whose responsibilities include the monitoring of recovery status in soccer players.

Key Words fatigue, football, eccentric, recovery, muscle damage

Introduction

The demands and responses to 90 minutes of soccer match-play have been extensively reported (4,29,31). Players typically cover distances of 9–14 km per match (4,10,29), with the majority of time spent in low-intensity activities, such as jogging and walking (3,31). However, the outcome of a soccer match is heavily influenced by the high-intensity components of play despite the game being primarily aerobic in nature (3). Notably, approximately 300 acceleration and deceleration efforts (when defined as movement changes exceeding 0.5 $m \cdot s^{-2}$) are performed per half (32), and ~18% of the total distance covered during a soccer match is done so while accelerating or decelerating (1). Given the established muscle-damaging effects of high-intensity eccentric exercise (6,11,37), it is not surprising that selected indices of postexercise performance are influenced by soccer match-play (21,25,34).

Participation in a soccer match leads to transient metabolic and physical performance disturbances over the subsequent hours and days of recovery (25). Creatine kinase (CK), an intracellular protein commonly associated with muscle damage, reaches peak concentrations (70 to 250% of baseline) within 24–48 hours of soccer-specific exercise and demonstrates considerable variability in its recovery kinetics. In a review of responses observed after soccer-specific exercise, Nedelec et al. (25) reported that between 24 and 120 hours are required to normalize metabolic disturbances. Similarly, the recovery response of physical performance variables (e.g., countermovement jump; CMJ) has also been shown to vary between studies where a single bout of soccer-specific

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exercise has been examined. For example, Magalhaes et al. (21) reported significant reductions in jump performance for 72 hours after a soccer match, whereas Silva et al. (34) observed restoration of jump performance for 48 hours after a Portuguese League game. Consequently, the effects of soccer match-play upon metabolic and performance responses in the days after a game are unclear. The ability to accurately quantify recovery status in the applied setting is necessary for the effective management of ergogenic strategies and training loads, especially during congested fixture periods. Empirical observations and published studies alike (25) highlight that indices of CMJ performance (e.g., peak power output; PPO) and CK concentrations are common markers used to assess the influence of previous exercise on subsequent performance.

Although acknowledging the influence of the nature of the protocol used (i.e., contact or noncontact exercise) (24,36), the lack of agreement regarding the duration needed to allow restoration of metabolic and performance disturbances after soccer-specific exercise may be explained by the variability that exists between matches in the reported recovery markers. In global measures of physical soccer performance (e.g., the total distance covered), the between-match variation is typically stable (coefficient of variance [CV]: <5%); however, higher speed activities demonstrate greater variability (CV: ~16–30%) (14,30). As high-intensity actions such as sprinting (26) and those that involve impacts between players (35) correlate to indices of muscle damage, it is plausible that the greater degree of between-match variation that exists in such actions may also impact upon the stability of selected markers of recovery over multiple games. To our knowledge, an examination of the between-match variation in markers of recovery (e.g., PPO and CK concentrations) is lacking.

In summary, information concerning the impact of match-play on performance and metabolic markers in the days after exercise, and the variability of these responses, is unclear. As recommended by Drust et al. (13), the variability in the responses to match-play should be quantified to provide meaningful insight into the sensitivity of tools used to monitor performance. Consequently, such information is likely to provide a deeper insight into the design of applied research studies, the selection of reliable performance measures, and the selection of appropriate recovery interventions. Therefore, the aim of this study was 2-fold: (a) to examine the impact of soccer match-play on markers of postexercise recovery and (b) to investigate the between-match variability in common markers of recovery status over multiple soccer matches.

Methods

Experimental Approach to the Problem

This longitudinal and observational study profiled the impact of professional soccer match-play on metabolic and performance variables assessed before and after competition. The study took place between November and January of the 2013–14 competitive season during which four 90-minute matches were played. The activity in the 48-hour period before each game included a single training session on both days that lasted no longer than 60 minutes and started at approximately 10:30 hours. Specifically, these sessions were characterized as low-volume and low-intensity training that 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. Players were advised to rest in the afternoons after training. In agreement with previous studies, assessments of CK and CMJ performance were assessed to monitor the impact of match-play during the 48 hours after each game (21,34). The test-retest reliability of our variables (measured using coefficient of variation analyses) was 3.0 and 3.2% for CK and PPO, respectively.

Subjects

Data are presented for 14 professional soccer players who play in outfield positions (center back, center midfield, full back, striker, or wing) for a Premier League under-21 soccer team. Because of the observational nature of the study design, no attempts to influence team selection were made over the 4 matches; thus, each player made a varying number of appearances (i.e., 2 ± 1) during the study. Data are only presented for players who completed more than 60 minutes of a match. Altogether, 34 individual observations of match performance were obtained (9 observations for matches 1–3, and 7 observations from match 4). The study conforms to the Code of Ethics of the World Medical Association (approved by the ethics advisory board of Swansea University) and required players to provide informed consent before participation. All players were considered healthy and injury-free at the time of the study and were in full-time training. Players were considered to be in the maintenance phase of their training cycle while undertaking individual resistance training programs and team-based conditioning sessions.

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 hours and 48 hours after each match at a time that was within 60 minutes of the data collection time for the baseline sample.

Countermovement Jump Testing

Using CMJ analyses, PPO was determined using a portable force platform (Type 92866AA, Kistler, Winterthur, Switzerland) according to methods described previously (28,38). The vertical component of the ground reaction force elicited during the CMJ and the participants' body mass was used to determine the instantaneous velocity and displacement of the participant's center of gravity (16). The coefficient of variation for peak force during the CMJ was 3.9%. Instantaneous power output was determined using Equation 1, and the highest value produced was deemed the PPO, a variable, which has been shown to demonstrate greater test-retest reliability than the use of peak force alone (17).

$$\text{Power (W)} = \text{vertical GRF (N)} \times \text{vertical velocity of center of gravity} \left(\text{m}\cdot\text{s}^{-1}\right). \quad (1)$$

Creatine Kinase Measurement

After immersing the hand in warm water, whole blood (120 μL) was sampled from the fingertip and centrifuged (3,000 revolutions per minute for 10 minutes; Labofuge 400R; Kendro Laboratories, Langenselbold, Germany). Plasma samples were then stored at −70° C before subsequently being analyzed for CK concentrations (Cobas Mira; ABX Diagnostics, Northampton, United Kingdom). Samples were measured in duplicate (3% coefficient of variation) and recorded as a mean.

Statistical Analyses

Data are presented as mean ± *SD*. The longitudinal and observational nature of the study yielded an unbalanced number of involvements in each of the 4 matches. Therefore, within-subject mixed linear models were used with both fixed (time: baseline, 24, 48 hours; match: 1–4) and random (participant and position) factors being examined. Where significant interaction effects were observed, match or position was deemed to have influenced the outcome variable. Main effects of factor were examined using least signigficant difference post hoc comparisons and 95% confidence intervals (CI). Within-subject correlations between PPO (dependent variable) and CK (covariate) were examined using a univariate general linear model analysis. Statistical significance was set at $p \leq 0.05$, and all analyses were conducted using SPSS (version 21.0; IBM, Armonk, NY, USA). In agreement with previous studies, the between-match variability was examined using coefficients of variation derived from log-transformed data (18). The *SD* of these data was then multiplied by 100 to give the coefficient of variation.

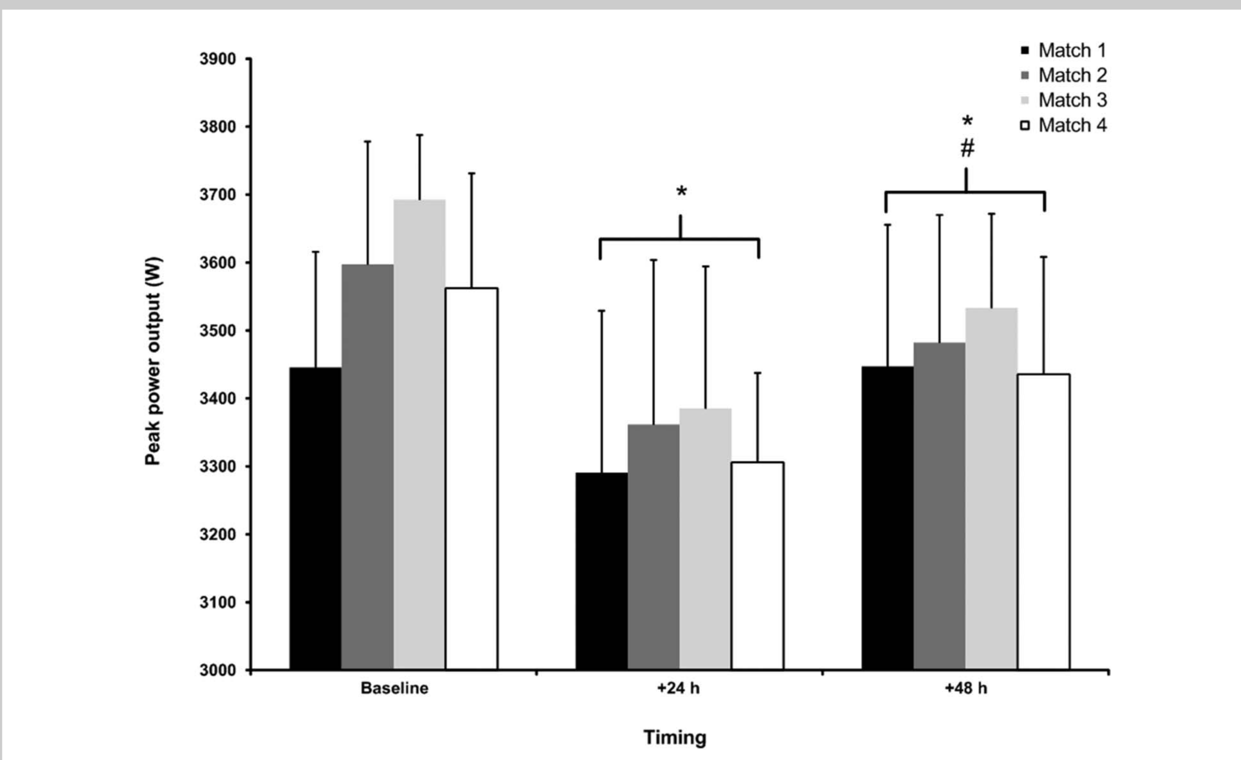

Figure 1. Time-course of peak power output (PPO) response to soccer match-play. *Significant difference from baseline. #Significant difference from 24 hours.

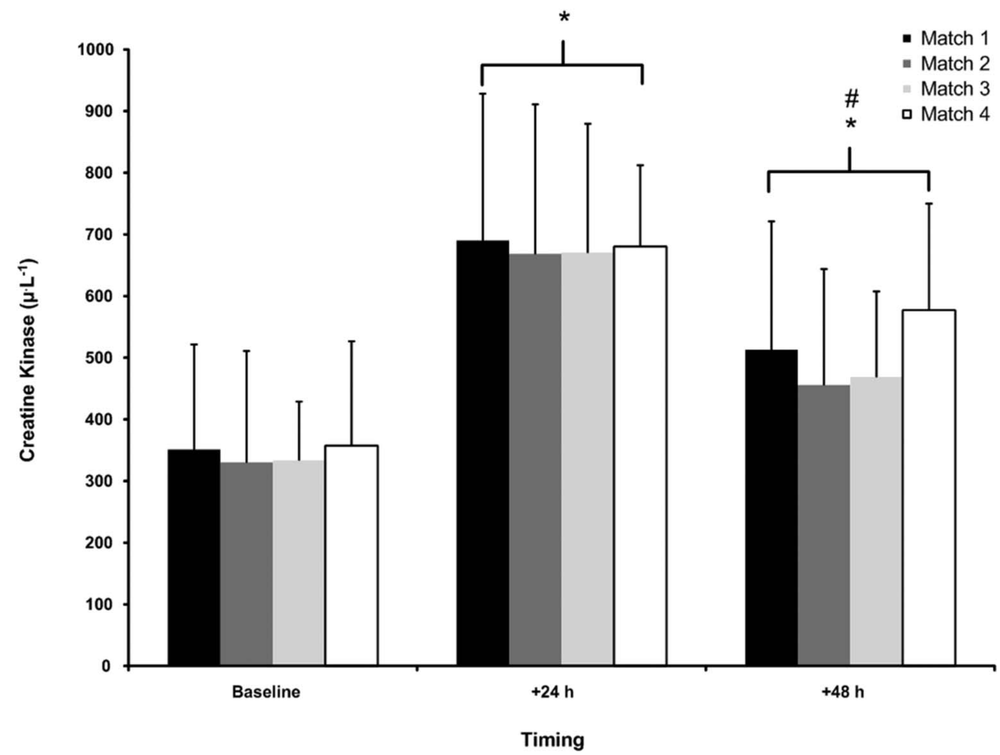

Figure 2. Time-course of creatine kinase (CK) response to soccer match-play. *Significant difference from baseline. #Significant difference from 24 hours.

Results

Impact of Match-Play on Recovery Markers

Match (match × time interaction: $F = 0.646$, $p = 0.693$) or position (position × time interaction: $F = 0.639$, $p = 0.742$) did not influence PPO. However, PPO throughout the recovery period changed according to time (time effect: $F = 16.892$, $p \leq 0.001$; Figure 1). Specifically, performance at both 24 hours (−237 ± 170 W; 95% CI: −313 to −153 W; −6.6 ± 5.2%; $p \leq 0.001$) and 48 hours (−98 ± 168 W; 95% CI: −195 to −35 W; −2.8 ± 5.3%; $p = 0.005$) was reduced when compared with baseline (3,575 ± 392 W). Notably, PPO at 48 hours (3,477 ± 347 W) was 4.2 ± 3.1% greater than 24 hours ($p = 0.005$; 95% CI: 38–198 W; Figure 1).

Concentrations of CK were not influenced by match (match × time interaction: $F = 0.368$, $p = 0.897$) or position (position × time interaction: $F = 0.613$, $p = 0.764$); however, a main effect of time was observed ($F = 48.497$, $p \leq 0.001$; Figure 2). Compared with baseline (343 ± 150 $\mu \cdot L^{-1}$), CK was elevated at 24 hours (334.8 ± 107.2 $\mu \cdot L^{-1}$, 95% CI: 264.5–398.8 $\mu \cdot L^{-1}$, 97.8 ± 51.5%; $p \leq 0.001$) and 48 hours (156.9 ± 121.0 $\mu \cdot L^{-1}$; 95% CI: 102.8–237.2 $\mu \cdot L^{-1}$; 45.8 ± 56.4%; $p \leq 0.001$) after match. At 48 hours, CK (499.4 ± 176.8 $\mu \cdot L^{-1}$) was still elevated compared with baseline; however, values were 26.3 ± 20.0% lower than observed at 24 hours ($p \leq 0.001$; 95% CI: −228.8 to −94.5 $\mu \cdot L^{-1}$; Figure 2). Within-subject correlations between PPO and CK were significant ($r = -0.558$; $p \leq 0.005$).

Between-Match Variability of Recovery Markers

Over the 4 matches examined, the variability of PPO values at baseline, 24 and 48 hours was 10.9, 11.0, and 9.9% respectively. The variability of CK was 41.7, 30.0, and 34.3% at baseline, 24 and 48 hours.

Discussion

In professional Premier League reserve team soccer players, this study investigated the impact of soccer match-play on markers of recovery status after competition and also profiled the between-match variability of these responses. Our findings indicate that professional soccer match-play influences lower body PPO and CK concentrations for at least 48 hours after a game. Additionally, correlations existed between CK and PPO, and we also provided evidence that the between-match variability in PPO is less than that observed in CK. Such data are likely to be of interest to both strength and conditioning coaches responsible for the design of training schedules and sports scientists whose responsibilities include the monitoring of recovery status of soccer players.

We provide further evidence that soccer match-play induces elevations in CK which, in the case of the time points examined in this study, peaked at 24 hours and remained elevated at 48 hours when compared with baseline. Although we are unable to localize the source (e.g., cardiac muscle, skeletal muscle, or brain tissue) of the increase in CK concentrations in this study, we propose that the observed response is likely attributed to the high-intensity components of match-play and rapid decelerations, which are characterized by repeated eccentric contractions of the lower body (23). Unfortunately, movement data are not available to support this premise; however, the number of acceleration and deceleration efforts performed during soccer match-play has been quantified (32), and correlations exist between high-intensity activities and CK (26). Eccentric muscle actions often result in perforations in the sarcolemma and damage to sarcomeres (12). Rises in circulating CK can occur when the sarcolemma and Z-disks are damaged (6–8), and the increased membrane permeability allows CK to leak into interstitial fluid, where it then enters circulation through the lymphatic system (5). Our data therefore suggest that more than 48 hours are required to normalize perturbations observed in CK after soccer match-play.

Our study highlighted a baseline value of 343 ± 150 $\mu \cdot L^{-1}$ for CK, which is greater than that observed by Magalhaes et al. (21) in the second and third division Portuguese League players (~175 $\mu \cdot L^{-1}$). Given the professional standard of players used in this study, it was not possible to enforce a period of abstinence from physical activity before each match. Although the 2 morning training sessions performed in the 48-hour period preceding match-play were characterized as low intensity, we acknowledge that baseline CK values may have been influenced by these activities. That said, professional soccer players participating in daily training have been reported to demonstrate persistent high-resting CK values (25), and thus differences in the level of player are likely to explain the discrepancy when compared with Magalhaes et al. (21). Notably, the pattern of response of CK postmatch (Figure 2) is consistent with other studies examining the responses of soccer players (25).

An impaired function of the stretch-shortening cycle has been strongly associated with fatigue (27), and because of the frequency of stretch-shortening cycle actions involved in soccer match-play, CMJ performance is often reported as a marker of recovery status (25). Although the most appropriate variable to analyze and interpret during CMJ performance remains unclear (39), we observed a reduction in PPO at 24 and 48 hours of recovery, which was consistent with observations from professional female (2) and male (21) soccer players. This transient reduction is likely because of an impairment of excitation-contraction coupling as a consequence of low-frequency fatigue (9,20,22). The reduction in PPO could also be justified by changes in joint sequencing related to a change in motor pattern used for performance and/or by muscle damage induced by high-intensity sprinting (23) that potentially induces some selective damage of type 2 muscle fibers (9). In support of this, we observed significant inverse within-subject correlations between CK concentrations and PPO ($r = -0.558$; $p \leq 0.005$).

Although the CK and PPO responses to an isolated soccer simulation or an actual match have previously been reported (2,21,34), we are not aware of any studies that have examined the between-match variability of these markers of recovery status; quantification of which has previously been recommended when seeking to appraise the use of performance-monitoring tools (13). The PPO response demonstrated variation of ~11% between the 4 matches examined, whereas the CK response was higher (i.e., 30–40%). Although movement data were unavailable for this study, the magnitude of variation of CK is similar to the between-match variability of high speed (CV: ~16–30%) (14), but not global (e.g., total distance covered; CV: <5%) (30), markers of physical performance. Speculatively, because CK and PPO were correlated, the variability of the changes over the postmatch period might indicate an ability of PPO to be used as a surrogate marker of the muscle damage response. We believe that the differing variability of the CK and PPO responses can be explained by an interaction of the differences in the magnitude of postexercise changes, the reliability of the variable, and the between-match stability of the measures correlated to the muscle damage response (e.g., total vs. high-intensity distance covered).

The greater degree of variation observed in high speed on-field actions (14), combined with the correlations between such actions and metabolic indices of recovery status (26), speculatively suggests that CK is sensitive enough to detect changes induced by the high-intensity components of match-play. In support of this, despite the magnitude of variability observed, transient changes in CK over the 48-hour period after each match were detectable and reached statistical significance (Figure 2), possibly as a consequence of the greater magnitude of the postexercise CK response (25). Therefore, CK seems to demonstrate sensitivity to post-match changes despite being more variable than PPO and as such may have application as part of a battery of tests used to monitor player's responses to multiple and single soccer matches.

It is important to note that the matches played in this study were all of 90-minute duration. Involvement in extratime has been found to influence selected indices of soccer performance (15). Speculatively, greater perturbations in PPO and CK compared with those reported here may occur after a 120-minute soccer match (33). Given the correlations that exist between the number of playing actions performed and changes in recovery markers after exercise (26), it is plausible that involvement in extratime requires a longer recovery period to normalize metabolic and performance changes induced by match-play. Consequently, modification of the recovery strategies used after a 90-minute match may be required after matches that have required extratime to be played; especially, if such matches are played within 72 hours of each other. However, a direct comparison between the recovery kinetics observed after 120 vs. 90 minutes of match-play remains to be investigated.

Data used in this study were drawn from 1 team over 4 matches within a single season, and as such, we acknowledge that the results obtained may only reflect this playing group. As previous research has shown that larger samples tend to reduce the variability in physical performance parameters (14), it is plausible that the comparatively small sample size presents a further limitation, and future studies with significantly larger data sets are required to provide further information concerning the estimates of the true variability of the recovery response to professional soccer match-play. Finally, as match-specific factors such as game context (e.g., score line, venue, team/opposition quality, etc.) have been found to influence soccer performance (19), we acknowledge that such factors should be considered when contextualizing our findings.

Practical Applications

This study presents novel findings concerning the responses to professional soccer match-play. In addition to profiling the impact of soccer-specific exercise on markers of recovery in the 48 hours after competition, we also demonstrated that the between-match variability in PPO is less than that observed in CK. Speculatively, because CK and PPO were correlated, the variability of the changes over the postmatch period might indicate that PPO be used as a surrogate marker of muscle damage and therefore offers a cost-efficient alternative to more invasive blood measurements. However, we also speculate that the between-match variability of the CK response may indicate greater sensitivity to changes in high-intensity performances. Although we acknowledge that our findings may reflect the characteristics of the particular squad involved in the study, this is the first time that the between-match variability of markers of recovery status have been presented in professional soccer players. Therefore, our findings are likely to be of interest to strength and conditioning coaches responsible for the design of training schedules and sports scientists whose responsibilities include the monitoring of recovery status in soccer players.

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