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Reference values for the creatine kinase response to professional Australian football match-play

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ABSTRACT

Objectives: Due to the importance of monitoring markers of muscle damage in high-level sport from a medical and athlete recovery perspective, this study aimed to determine the upper limits of normal (ULN) for post-match plasma creatine kinase (CK) in professional Australian footballers. Raw CK values were considered, along with intra-individual deviations from the season-mean.
Design: Case series.
Methods: CK was collected between 36–48 h following professional Australian football match-play. A total of 1565 samples from 62 players were assessed over three consecutive seasons. The ULN were determined for raw scores and as a percentage of each player's season-mean response.
Results: The ULN for raw CK, as determined by the 97.5th, 95th and 90th percentiles were 1715 (90%CI: 1605–1890), 1380 (90%CI: 1325–1475) and 1110 (90%CI: 1050–1170) U L^{-1} respectively. The ULN intra-individual response (97.5th percentile) was defined as a player's score being greater than 94% (90%CI: 84–102%) above their season-mean.
Conclusions: Professional Australian football elicits a profound effect on the CK response. The values provide a reference tool for athletes competing at this level of competition. The novel method of representing the CK response as a percentage difference from an individuals' season-mean enables a superior comparative ability between CK responses and reduces the high CK responder bias that occurs when using raw scores alone. The data will assist medical and conditioning staff in excluding medical emergencies and also aid in individualising the prescription of training loads and recovery to optimise athlete performance and minimise further muscle damage.

1. Introduction

Australian football (AF) is a high intensity football code with the largest audience base of any professional sport in Australia.[1] The demands of the sport have been presented elsewhere, with the professional Australian Football League (AFL) posing significant physiological demands on players as a result of the high running volumes and contact nature of the sport.[2] Intense exercise of this nature elicits a prolonged state of muscle fatigue and muscle damage that can last up to 72 h following an AFL match.[3] This exercise induced muscle damage increases the permeability of the cell membrane that allows muscle enzymes, including creatine kinase (CK), and other intracellular contents to 'leak' from the muscle cell.[4] Accordingly, the assessment of serum CK concentration has been used in team sport settings as a biomarker of exercise induced muscle damage.[5,6] There is some conjecture about the relationship between CK concentration and measures of muscle fatigue, strength and power.[7,8] Some authors have reported that CK concentration is proportional to the extent of muscle damage[9] while others indicate discrepancies in the time course of responses between CK and other markers of muscle damage.[8] Regardless, following repeated bouts of intense activity, muscle damage is cumulative and CK values remain elevated.[4] These values typically return to baseline levels but require a period of adequate rest. Although most CK elevation following AF match-play is cleared within 2–3 days, recovery duration is proportional to the magnitude of CK rise, reducing with a half life of approximately 49 h.[4,10] CK measurement is further utilised in a clinical setting for

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the diagnosis of significant muscle damage due to myopathy and rhabdomyolysis.[11]

There remains controversy regarding the use of CK measurement in athletes.[12] This arises from the difficulty in the interpretation of CK concentrations due to the significant variation between individuals in the amount of CK that is released for an equivalent bout of exercise. Factors known to contribute to this inter-individual variability include age, race, gender, muscle mass, quadriceps diameter, training status, climate, renal clearance rate and plasma volume.[4] Elevation of CK may also occur as a result of acute muscle, heart or brain injury.[4] Specifically, it is well known that athletes record a much higher CK concentration than non-athletes.[6] Furthermore, sports-specific responses have been reported from a variety of different sports, accentuating that CK concentration is athlete- and activity-dependent.[6] In a team sport context, playing level, fitness level, playing position, on-field playing time and match intensity would be expected to each contribute to the variations in CK values but as yet have not been studied extensively.[4,13] It is clear that certain markers of athlete performance, recovery and wellness are linked to CK concentration, with notable relationships evident between CK and lower body force and power measures,[7] movement demands data[14] and tackle number.[15]

Highlighting these differences, upper limits of normal (ULN) have been determined for soccer[6,16,17] and swimming,[6] with the ULN for the response to soccer match-play being three times that of the response to competitive swimming. ULN are considered to be a more worthwhile value than measures of central tendency for examining the medical risks and heightened physiological responses to exercise.

The time course change of CK concentration in blood following a single bout of exercise has been documented across a variety of different sports,[4] however, little information exists regarding the longitudinal changes of CK over an entire season or between multiple seasons of team sports. Of the limited studies longitudinally assessing CK in the team sport setting, the maximum number of games assessed were eight out of a single season of 15 games in a rugby league (RL) team,[5] indicating a clear need for more extensive research. There is also a paucity of data examining intra-individual differences in CK responses. A recent task-force on muscle damage expressed the need to represent CK not only as a raw score but as a factor of change from the individual's usual baseline in order to alleviate the inter-individual variability of CK raw scores.[11] Further, a contemporary study demonstrated that individualised reference values for CK performed significantly better compared to a group-based classification.[18]

Accordingly, this study aimed to determine the ULN for CK following professional AF match-play. It was hypothesised that CK would be higher than reported for other football codes given the heightened match demands, including body contact and greater relative running distances.[2] The determination of the ULN of the CK response in this context provides reference values for professional AF and other team-based sports. The outcomes of the research will assist in the determination of whether elevated CK concentration of an individual player following professional AF is a normal response to competition or an indicator of an elevated response. If the CK concentration is found to be elevated, the player will require an extended period of rest from activity and regular monitoring until values normalise. The research will also aid coaching and conditioning staff in the appropriate prescription of recovery or training loads based on the post-match CK value.

2. Methods

All players from the seniors and reserves list from one single AFL club between 2011–2013 were recruited for this study. The senior team finished 1st out of 18 teams in the AFL in 2012 and 3rd in 2011 and 2013 while the reserves team finished 2nd in the North-Eastern Australian Football League (NEAFL) competition in each of these years. Approval of the methodology and procedures used during this study was granted from the Human Research and Ethics Committee of the local institution. Inclusion criteria required participants to have played a minimum of 60 min of the weekly match, either for the senior or reserve grade team. Athletes who suffered injuries that prevented them from training, including muscle tears and concussions, as clinically diagnosed by the team doctor, did not have their CK measured and were therefore excluded for that assessment week. These criteria led to the inclusion of 62 participants (age: 23 ± 2.3 y, body mass: 87.95 ± 11.66 kg, stature: 187 ± 7 cm). There were 1565 CK samples collected during the three-year period (316 samples from 2011, 637 samples from 2012, and 612 samples from 2013). The mean number of samples taken per player was 25.6 ± 13.7 (range: 3–63). All samples were included in the analysis.

As a component of the athlete monitoring strategy of the club, serial weekly samples of serum CK were taken from all participants 36–48 h post-match. Weekly AF matches (AFL or NEAFL) were played over the duration of the competitive season from March to September over three consecutive seasons with a total of 60 matches analysed. The day after each match, all players participated in a recovery session involving aquatic-based activities including water wading and low-intensity swimming. No further exercise was conducted between the cessation of the match and the CK sample period as training loads are known to interfere with CK sampling.[17] The water based session may have a small effect on the CK concentration.[19] However, since all participants completed the same session, any effect on CK has been minimised across the athlete cohort and also further attenuated via the use of the CK%diff values. Previous research with team sport athletes suggests that CK is highest at 24 h post-match.[7,14,15] In some weeks, logistical reasons prevented the collection of CK data between 36–48 h post-match resulting in the data being excluded.

Blood samples were taken in an aseptic manner via a pinprick of the index finger. A 32 μL sample of blood was collected using a sterile capillary tube. The finger was not squeezed with excessive force so as to minimise the chance of haemolysing the specimen or diluting the sample with interstitial fluid. CK was measured with a Reflotron analyser® (Reflotron Plus®, Roche Diagnostics, UK) at a temperature setting of 37 °C. The results from this method of blood sampling have demonstrated a strong correlation to venous CK blood sampling (r = 0.997),[20] with an intra-assay reliability of <3% coefficient of variation.[20] Prior to each analysis, the Reflotron® analyser was cleaned and quality control checks were performed as per the manufacturer's recommendations. Although plasma volume was not assessed in this study it was assumed that the players were adequately rehydrated by 36–48 h post-game.

Descriptive statistics were calculated from the raw data, with the focus being the ULN, calculated as the 90th,[17] 95th,[16] and 97.5th[6,17,21] percentiles. The 90% confidence intervals (CI) of each ULN were also calculated. The determination of the upper limits of normal, such as the 97.5th percentile, are representative of CK concentrations that may be associated with heightened requirements for recovery and monitoring. Alternatively, in the professional sport setting, lower thresholds of 90% or 95% are commonly used.[16,17] These lower thresholds may increase the number of suspected cases of excessive muscle damage and concomitantly increase the number of falsely identified positive cases of heightened muscle damage, however, this cautionary approach is not detrimental in the sport setting. Along with raw values, the data was represented as a percentage difference from the player's season mean response (CK%diff) to alleviate the variability of raw CK scores between individuals. A CK%diff score of 0% reflected the average

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