ABSTRACT

Objective: to determine the individual profile of blood concentration of creatine kinase (CK) in elite soccer players as well as to analyze the CK concentrations in different periods during the Professional Brazilian Championship. Methods: resting CK of 17 soccer players was evaluated before the competition (pre-season) and after the matches (36 and 46 hours after the games) (CK_{game}) for the individual blood CK. The Chi-square test was used to analyze the individual CK during the season. The competitive season was divided into three periods: initial, intermediate and final. The one-way ANOVA with repeated measurements followed by post hoc Student-Newman-Keuls test was used to compare the individual CK of each soccer player in each competitive period. The significance level was set at p < 0.05. Results: the highest frequency of individual CK was found in the second quartile (71 observations) and the lowest frequency in the first (26 observations) and the fourth quartile (40 observations) compared to the expected number of 45.8 (x² = 22.21). CK concentrations were lower in the intermediate (mean = 66.99%) and final (mean = 60.21%) periods than in the initial period (mean = 89.33%). Conclusion: soccer players did not show elevated muscle damage and probably a muscle adaptation occurred in the competition, due to the reduction of CK concentrations observed.

Keywords: soccer, muscle strength, creatine/blood.

RESUMEN

Objetivo: determinar el perfil individual de las concentraciones sanguíneas de creatina quinasa en jugadores de fútbol de elite, así como analizar las concentraciones de CK en diferentes períodos durante el campeonato brasileño. Métodos: a CK de reposo de 17 jugadores de fútbol fue evaluada antes de la competición (pre-temporada) y después de los partidos (36 y 46 horas después de los juegos) (CK_{game}) para obtener la CK sanguínea individual. La prueba de Chi-cuadrado fue utilizada para analizar la CK individual durante la temporada. La temporada competitiva se dividió en tres períodos: inicial, intermediario e final. A ANOVA one-way con medidas repetidas seguida pelo test post hoc Student-Newman-Keuls foi utilizada para comparar a CK individual de cada jugador de fútbol en cada período competitivo. O nivel de significación adotado foi de p < 0.05. Resultados: a maior frequência da CK individual foi encontrada no segundo quartil (71 observações) e a menor frequência no primeiro (26 observações) e no quarto quartil (40 observações) em comparação com o número esperado de 45.8 (x² = 22.21). As concentrações de CK foram menores nos períodos intermediário (média = 66.99%) e final (média = 60.21%) do que no período inicial (média = 89.33%). Conclusão: os jogadores de futebol não apresentaram dano muscular elevado e provavelmente uma adaptação muscular ocorreu na competição, devido à redução observada das concentrações de CK.

Palavras-chave: futebol, força muscular, creatina/sangue.
studies reported no changes in CK concentration\(^9,12\) others showed CK stream\(^7\). Among these enzymes, creatine kinase (CK) has been described in the muscle membrane and the release of cytoplasmatic enzymes into the bloodstream\(^7\). Among these enzymes, creatine kinase (CK) has been described as a good marker of muscle damage and the peak CK concentration has been associated with changes in the peak of maximal isometric strength as well as the changes in the knee-joint range of motion\(^9\).

Although CK concentration during a soccer competition has been investigated\(^6,10\) and the results have contributed to enabling the adjustment of the training load, it lowered the imbalance between stress and muscle recovery and the injury risk\(^11\). These studies are contradictory. While some studies reported no changes in CK concentration\(^6,12\) others showed CK concentration decreases during a competition\(^10\). In addition, the absolute values of CK concentration have been used in some of the previous studies which evaluated CK concentration of soccer players\(^6,11,13,14\).

In sports, the use of fixed reference values for CK concentration has been proposed for monitoring training load, these fixed reference values indicate a threefold for injury risk augmented\(^13,15\). The reference value of physiological parameters are important for interpretation of data\(^16\). However, the use of fixed reference values for CK concentration as indicators of severe muscle damage is made difficult due to rather high inter and intra individual variability\(^6,17\). Another concurring factor might be the training status of the athletes\(^17\). Therefore, the use of a fixed reference value may underestimate or overestimate the presence of muscle damage. Moreover, recently, a joint consensus statement about monitoring training status of athletes suggested the definition of a range of meaningful differences by determination of individual ranges to the markers utilized\(^18\).

We have not found studies describing the CK concentration profile of elite soccer players during a competitive season based on individual values. Therefore, the main purposes of the present investigation were a) to determine the individual’s profile of blood CK concentration of elite soccer players and b) to analyze the CK concentration in different periods during a Professional Brazilian First Division Championship.

**METHODS**

Seventeen players from a first-division Brazilian soccer team volunteered for the study. At the beginning of the season, the age and body mass of the soccer players were registered, 26.6 ± 3.7 years and 77.8 ± 5.6 kg, respectively. At baseline, body mass was measured using standardized procedures, with a calibrated scale (Filizola, Brazil), their percent of body fat was estimated by using the Jackson and Pollock\(^19\) equation (i.e. sum of chest, axilla, triceps, subscapular, abdomen, supraillium, and thigh skin folds). The VO\(_{2max}\) was estimate by specific soccer test, Yoyo Endurance Test level 2\(^4\), with the players using their soccer shoes in the field\(^4\). This test was performed at the beginning of the season.

This study had the approval of the Ethics Committee of the Minas Gerais Federal University, Brazil (Protocol 485/10) and all volunteers signed an informed consent form prior to participation in the study.

**Procedures**

Blood CK concentration was assessed by reflectance photometry at 37°C (Reflotron Plus; Roche, Germany), previously calibrated. After the finger asepsis by using alcohol, a 30-μl blood sample was drawn out into a heparinized capillary tube and it was later put on specific reagent strips which were inserted into the instrument. The CK concentration baseline values (CK\(_{\text{Bas}}\)) and the maximal concentration of CK were employed to determine the individual’s profile of blood CK concentration of elite soccer players. The CK\(_{\text{Bas}}\) were obtained during the soccer players’ presentation after a 30-day rest from any physical activity.

During the competitive season, CK concentration was evaluated between 36 and 46 hours post games (CK\(_{\text{Game}}\)) a period in which the peak of CK concentration is most likely reached\(^1,20\). The maximal concentration of CK\(_{\text{Game}}\) found throughout the season, was denominated as CK\(_{\text{Max}}\). In the period encompassing the end of the game and the evaluation of CK\(_{\text{Game}}\), the soccer players simply rested or performed activities considered to be light.

The maximal difference of blood concentration of CK (ΔCK\(_{\text{Max}}\)) was calculated by using the following equation 1:

\[
\Delta \text{CK}_{\text{Max}} = \text{CK}_{\text{Max}} - \text{CK}_{\text{Bas}}
\]

Therefore, the ΔCK\(_{\text{Max}}\) was considered to be 100% and this value was employed to relativize the difference between the CK\(_{\text{Game}}\) and CK\(_{\text{Bas}}\). The percentage relation between ΔCK\(_{\text{Game}}\) and ΔCK\(_{\text{Max}}\) was denominated as %ΔCK\(_{\text{Game}}\) (Equation 2):

\[
\% \Delta \text{CK}_{\text{Game}} = \frac{\Delta \text{CK}_{\text{Game}}}{\Delta \text{CK}_{\text{Max}}} \times 100
\]

The %ΔCK\(_{\text{Game}}\) was thus grouped into quartiles (i.e., 1\(^{st}\), 2\(^{nd}\), 3\(^{rd}\), 4\(^{th}\)):

- ≤25%, >25 and ≤50%, >50 and ≤75%, more than >75%, respectively.

This recording procedure of CK was similar to that of Yamin et al\(^21\).

The CK\(_{\text{Game}}\) measurements were included only if the soccer players played more than 75 minutes per game\(^4\), did not sustain any muscle strain injury and had not taken any kind of medicine. The occurrence of muscle injury was confirmed by the magnetic resonance imaging (MRI) (Magnetom Vision Plus 1.5 Tesla, Siemens, Germany). Moreover, to be included in the study, the soccer players should have had at least four CK concentration evaluations throughout the season.

The blood CK concentrations of the players were evaluated after each of the 25 official games of the 2010 Brazilian championship from July to December. The CK concentration response during the competition was shown in accordance with the division of the competitive calendar in three periods (i.e., initial, intermediate and final). That division was done in accordance with the number of evaluated games, thus each period would have a similar number of evaluations. The initial period was arranged by grouping the first nine analyses of the games which took place between July and August. The intermediate period corresponded to the month of September when the 10\(^{th}\) to the

**INTRODUCTION**

The main Brazilian Soccer Championship has been played with a variation of one game or two per week for seven months. The interval between games may not be enough for an adequate recovery and that can expose the soccer players to an elevated muscle damage\(^1,3,5\). Moreover, soccer is an intermittent and high intensity sport\(^4\) presenting many eccentric muscle actions as jumps and direction changes during a match\(^7\). Thus, muscle actions are the main causes of skeletal muscle damage\(^6\) which increase the permeability of the plasmatic membrane and the release of cytoplasmatic enzymes into the bloodstream\(^7\). Among these enzymes, creatine kinase (CK) has been described as a good marker of muscle damage and the peak CK concentration has been associated with changes in the peak of maximal isometric strength as well as the changes in the knee-joint range of motion\(^9\).

This recording procedure of CK was similar to that of Yamin et al\(^21\).

The CK\(_{\text{Game}}\) measurements were included only if the soccer players played more than 75 minutes per game\(^4\), did not sustain any muscle strain injury and had not taken any kind of medicine. The occurrence of muscle injury was confirmed by the magnetic resonance imaging (MRI) (Magnetom Vision Plus 1.5 Tesla, Siemens, Germany). Moreover, to be included in the study, the soccer players should have had at least four CK concentration evaluations throughout the season.

The blood CK concentrations of the players were evaluated after each of the 25 official games of the 2010 Brazilian championship from July to December. The CK concentration response during the competition was shown in accordance with the division of the competitive calendar in three periods (i.e., initial, intermediate and final). That division was done in accordance with the number of evaluated games, thus each period would have a similar number of evaluations. The initial period was arranged by grouping the first nine analyses of the games which took place between July and August. The intermediate period corresponded to the month of September when the 10\(^{th}\) to the
17th games were evaluated. At the final period, eight games that took place between October and November were analyzed. For this analysis, a higher CK concentration was used for each soccer player from each period. Beyond the inclusion criterion above, for this analysis, there was an inclusion criterion that the soccer players should have at least one CK concentration evaluation in each period and not have remained more than 20 consecutive days without any training at all, which is considered to cause detraining in soccer players\textsuperscript{22}.

Monitoring training load

In the training sessions, the workload was recorded by counting the minutes of effective training for each soccer player, to determine the training volume (i.e., minutes trained in each period) and by the training intensity defined as the heart-rate percentage (i.e., \%HR\textsubscript{Max}) (Polar Team System\textsuperscript{8}; Polar, Finland). The highest heart-rate value reached by the soccer players during training sessions or friendly games was used as their maximal heart rate (HR\textsubscript{Max})\textsuperscript{23}. The training volume was recorded during games and training sessions. However, the intensity training was recorded only in the training sessions, since according to soccer rules, it is not allowed to use the heart rate monitors in official games. The environmental conditions during the season was recorded according to data supplied by the National Institute of Meteorology.

Statistical analysis

The normality of data was analyzed using the Kolmogorov-Smirnov test. The data that have not shown normality were presented as median and amplitude between the minimal and maximal values and the ones that presented normality were expressed as mean, standard deviation, median and frequency distribution.

RESULTS

The percent of body fat (%fat) and VO\textsubscript{2max} of the soccer players were 9.5 ± 1.4 % and 55.5 ± 3.6 mL.kg\textsuperscript{-1}.min\textsuperscript{-1}, respectively.

For the individual’s profile of CK concentration of elite soccer players, the frequency higher than the expected of %ΔCK\textsubscript{Game} for each soccer player in each period was used. To verify whether CK\textsubscript{Game} was different from CK\textsubscript{Bas}, the paired t-test was used, in which the lowest value of CK\textsubscript{Game} of the season was considered. The Sperman correlation coefficient was performed to verify the relationship between changes in training volume, training intensity and CK during the season. The adopted significance level was p<0.05. The data were analyzed using the sigma Stat 3.5 pack. The descriptive analysis of data was expressed in terms of mean, standard deviation, median and frequency distribution.

The comparison of CK concentration between the periods was performed, made with the data of 12 soccer players. Two soccer players were excluded because of injury and for having remained inactive for more than 20 consecutive days. In addition, three others were excluded for not having at least one CK concentration analysis in each period. In the three analyzed periods during the competition, it was observed that the highest %ΔCK\textsubscript{Game} of the intermediate and final periods was lower than the highest %ΔCK\textsubscript{Game} of the initial period (figure 1). Moreover, it was observed that all soccer players reached the CK\textsubscript{Max} between the 1\textsuperscript{st} – 13\textsuperscript{th} games (value of median in the 5\textsuperscript{th} game). During the competition, there were four soccer players who sustained muscle injury. Among them, two soccer players had the post-injury CK\textsubscript{Game} measured as 577 and above 2000 U/L (value above the detectable by the instrument), well above their respective CK\textsubscript{Max} of 558 e 573 U/L. Using these measures between periods CK concentration, the standard error of measurement according to Weir\textsuperscript{24} was 31.1%.

CK\textsubscript{Game} was higher than CK\textsubscript{Bas} (p<0.001) and the CK\textsubscript{Game} showed a non-normal distribution, with values ranging from 141 to 1830 U/L (figure 2). The median of CK\textsubscript{Bas}, CK\textsubscript{Max}, ΔCK\textsubscript{Max}, CK\textsubscript{Game} and Δ%CK\textsubscript{Game} was 120 U/L (range 26.3-475 U/L), 626 U/L (range 350-1830 U/L), 478 U/L (range 251.8-1355 U/L), 376.5 U/L (range 141-1830 U/L) and 47.30% (range 6.6-100.0%) respectively. During the competition, the soccer players had their CK concentration measured 10.8 times on the average.

Moreover, the monitoring of training volume, training intensity and their correlations with %ΔCK\textsubscript{Game} are in the table 2. During the all season, their mean playing official soccer match was 1505.9 ± 571.4 min. The mean values for temperature and air relative humidity during the study were 20.9 ± 4.6ºC e 69.0 ± 0.2%, respectively.

### Table 1. Observed and expected frequencies in each quartile of %ΔCK\textsubscript{Game} from 17 soccer player.

<table>
<thead>
<tr>
<th>Quartile</th>
<th>N Observed</th>
<th>N Expected</th>
</tr>
</thead>
<tbody>
<tr>
<td>1\textsuperscript{st} Quartile</td>
<td>26 (14.2%) *</td>
<td>45.8</td>
</tr>
<tr>
<td>2\textsuperscript{nd} Quartile</td>
<td>71 (38.8%) *</td>
<td>45.8</td>
</tr>
<tr>
<td>3\textsuperscript{rd} Quartile</td>
<td>46 (25.1%)</td>
<td>45.8</td>
</tr>
<tr>
<td>4\textsuperscript{th} Quartile</td>
<td>40 (21.9%) *</td>
<td>45.8</td>
</tr>
<tr>
<td>Total analyses</td>
<td>183</td>
<td>183</td>
</tr>
</tbody>
</table>

Value of chi-square 22.21. * Observed frequency different to the expected (p< 0.01).

Figure 1. Highest %ΔCK\textsubscript{Game} in each period. N = 12. Significant difference in comparison to Initial Period. (p<0.05).

Figure 2. Frequencies of observations of CK\textsubscript{Game} of 17 soccer players during a Brazilian championship.
The present study was the first, to our knowledge, that evaluated the CK concentration after official games and which had an elevated number of measurements on the same individual. The protocol we used, measuring CK concentration after every game appears to be more adequate to detect alterations in that marker than the protocol used in previous studies.

Throughout the competition the CK concentration of the soccer players remained above the resting and reference values accept for the sedentary population. This corroborates the results of other studies with soccer players during a competition\textsuperscript{9,10} and studies that analyzed the increase of CK concentration 48h after a single game\textsuperscript{11,20,29}. Moreover, the median blood CK\textsubscript{Game} concentrations (i.e., 376.5 U/L which corresponded to a %ΔCK\textsubscript{Game} 47.30%) of the present study were similar to the mean values of plasmatic concentrations of studies with soccer players in competitions\textsuperscript{9,10} and slightly lower than studies that evaluated the players after a single soccer match\textsuperscript{12,20,30}. One limitation of the present study was the one assessment of CK\textsubscript{Max}, however, the CK\textsubscript{Max} about the values of sedentary adult men\textsuperscript{21} and soccer players in rest remained\textsuperscript{1}.

At the end of the competition, the soccer players in the present study showed a CK\textsubscript{Max} of 626 U/L. The CK concentration of 14 soccer players remained below the threshold value for the increased risk of injury suggested by Mougios\textsuperscript{13} (1492 U/L) and Lazarim et al\textsuperscript{10} (975 U/L). It should be noted that the CK concentration of three soccer players was above 975 U/L and the highest being above 1492 U/L, but no clinical problems were reported. Lazarim et al\textsuperscript{19}, reported that in his study, one soccer player whose CK concentration exceeded the proposed reference value was injured. During the present study, four soccer players underwent muscle injury, with two of them presenting CK\textsubscript{Game} above their CK\textsubscript{Max}. This may suggest the occurrence of a higher rupture of the muscle tissues, resulting in a larger extravasation of CK into the blood stream\textsuperscript{11}.

The observed positive correlation between training volume and %ΔCK\textsubscript{Game} as well as the absence of correlation with training intensities indicates that training volume, likewise type of exercise\textsuperscript{22} might be, among others, one factor that influences the CK concentration\textsuperscript{1}. However, only 12% of common variance exists between training volume and CK concentration. The remaining 88% is originated from others variables. Thus, CK concentration should be interpreted along with other variables such as training status and the individual response to %ΔCK\textsubscript{Game}.

Due to the high variability found in CK concentration response to exercise in this as well as in other studies\textsuperscript{15,21}, the CK\textsubscript{Max} of soccer players during a competition may not reach the proposed reference values, even knowing that the soccer players are being subjected to elevated muscle damage. Therefore, the use of a fixed CK threshold value may not be warranted. It is likely that different soccer players have different thresholds and the individualized CK concentration profile should be used to monitor each soccer player during a championship.

CONCLUSIONS

The individualized CK concentration responses of the elite soccer players during a Brazilian championship in the present study indicate that they did not remain at elevated muscle damage. One probable muscle adaptation may occur based on reduced CK concentration.

All authors have declared there is not any potential conflict of interests concerning this article.
REFERENCES