Physiological evaluation post-match as implications to prevent injury in elite soccer players

Leonardo Matta[1], Matt Rhea[2], Alex Souto Maior[1]

[1]Augusto Motta University Center (UNISUAM). Brazil. [2]Still University of Health Sciences. Mesa. Arizona. USA.

Recibido: 04.07.2018
Aceptado: 14.09.2018

Summary

Introduction: The accumulated stress measured post-soccer match, often temporarily delays players' physical performance and, as a result, players may experience acute and chronic fatigue contributing to underperformance and/or injury.
Objective: This study investigatedchanges in physiological parameters such as thermographic profiles of the lower limbs, serum creatine kinase (CK) level, and skin conductance in elite soccer players post-match. Furthermore, perceived wellness was examined in relation to physiological parameters in an attempt to identify a possible relationship that might prove valuable to strength and conditioning and sport coaches in planning and implementing training schedules.
Methods: Ten healthy male professional soccer players (25.3 ± 4.6years; 178.4 ± 6.3cm; 76.3kg ± 6.2 kg; body fat 10.2 ± 4.2 %) from a club of the Brazilian first division soccer league participated in this study. GPS sensors were used to quantify the demand of match conditions among all participants along with post-match measures of serum CK, skin conductance, and thermographic images of lower limbs. These same measures, along with a psychometric questionnaire were administered 24 and 48 hours post-match.
Results: No significance difference ($p>0.05$) was found in contralateral thermal symmetry in the lower limbs. But, both values (maximal and mean values) of skin temperature shown significant difference ($p<0.05$) at rest when compared to 24h and 48h post-match. In addition, Serum CK level remained elevated for up to 48h post-match in relation to rest.
Conclusion: The results showed that 48 hours post-match is not sufficient to full recovery of soccer players. The use of physiological measures, wellness questionnaires, and thoughtful planning based on readiness may help reduce over-stress injuries and enable athletes to perform at their peak throughout the season.

Key words:
Recovery.
Physiological assessment.
Soccer players.

Evaluación fisiológica tras el partido como implicaciones para prevenir lesiones en jugadores de fútbol elite

Resumen

Introducción: El estrés acumulado medido después del partido de fútbol, a menudo retrasa temporalmente el rendimiento físico de los jugadores y, como resultado, los jugadores pueden experimentar fatiga aguda y crónica que contribuyen con un bajo rendimiento y/o lesión
Objetivo: Este estudio investigó los cambios en los parámetros fisiológicos, como los perfiles termográficos de las extremidades inferiores, el nivel de creatina quinasa sérica (CK) y la conductancia de la piel (SC) en los jugadores de élite de fútbol después del partido
Métodos: Diez jugadores profesionales de fútbol (25,3±4,6 años; 178,4±6,3 cm; 76,3±6,2 kg; grasa corporal 10,2±4,2%) de la liga de fútbol de primera división brasileña participaron en este estudio. Los sensores de GPS se utilizaron para cuantificarla demanda de esfuerzo entre todos los participantes junto con las mediciones posteriores al partido de la CK, la SC y las imágenes termográficas de las extremidades inferiores. Estas mismas medidas, junto con un cuestionario psicométrico, se administraron 24 y 48 horas después del partido.
Resultados: No se encontró diferencia de significancia ($p>0,05$) en la simetría térmica contralateral en las extremidades inferiores. Sin embargo, ambos os valores (valores medios y máximos) de la temperatura de la piel mostraron una diferencia significativa ($p<0,05$) en reposo en comparación con las 24 horas y 48 horas después de la partida de fútbol. Además, el nivel sérico de CK se mantuvo elevado durante hasta 48 horas después del partido en relación con el descanso.
Conclusión: Los resultados mostraron que 48 horas después del partido no es suficiente para La recuperación total de los jugadores de fútbol. El uso de medidas fisiológicas, cuestionario psicométrico y una planificación cuidadosa basada en la preparación pueden ayudar a reducirlas lesiones por sobrecarga.

Palabras clave:
Recuperación.
Evaluación fisiológica.
Jugadores de fútbol.

Correspondencia: Alex Souto Maior
E-mail: alex.bioengenharia@gmail.com

Introduction

In soccer games, players need to make quick, precise movements that can be characterized as intermittent muscle actions with high demands on several physical components[1,2]. Physical stress during training and/or match playpromptsmorphological, metabolic, and functional adaptations that consequently enable an increase in performance[3,4]. At the same time, accumulated stress, measured post-soccer match, often temporarily delays players physical performance and, as a result, players may experience acute and chronic fatigue contributing to underperformance and/or injury[5]. A majority of injuries occur in the lower limbs (~70%), related to the nature of the sport (i.e. during jumping, after movements with a large eccentric component, or in response to a period of intensified training), consequently, resulting in a decline in physical performance during the hours and days following competition[6-8].

Muscle damage is characterized by a temporary decrease in muscle function, an increase in intracellular proteins in the blood, increased muscle soreness, and increased swelling in and around the involved muscle group[1,6-8]. Recovery is considered complete when the player is able to reach or exceed his benchmark performance in a particular activity such as strength, power, or balance[5]. The development of new technologies for diagnoses among soccer players is necessary to better understand the physiological responses to competition and advance injury risk prevention methods associated with training load and match intensity[1]. Valuable information may be identified regarding optimal recovery time following matches, more detailed evaluations of injury risk and performance, and other factors that may signal injury risk.

Biochemical markers (i.e. serum CK level) have previously been used to determine the magnitude of physical stress on the skeletal muscle system imposed on players participating in a soccer match[1,9]. Because this biomarker is correlated with the number of muscle micro traumas that lead to the secretion of this enzyme into the extracellular medium, analyzing post-match CK may provide relevant information about the physical state of athletes[10,11]. However, only one method of physiological evaluation may be insufficient for evaluatingpost-match soccer status. Biochemical markers combined with thermal imaging assessments may provide valuable information in this regard[1]. Infrared thermography is a non-invasive method used to visualize human body temperature changes in response to physiological processes or pathological reactions related to the control of the temperature of the skin, without exposing the patient to any type of radiation[12-14]. This technique has been used increasingly in medical and sports areaswith applications related to the diagnosis of musculoskeletal disorders and in the evaluation of muscle recovery after training or soccer matches[1,15]. Thermal symmetry of the human body is similar between the sides of the body which are identical in shape and size, being taken at the same angle[1]. On the other hand, injuries lead to vasodilatation and increase of inflammatory mediators in the area, which result in an increase of the metabolism and blood flow in the region, consequently, increase local body temperature and disturb this normal symmetric pattern[1,14,15]. However, no scientific studies have been identified that used these physiological evaluations post-match in elite soccer players.

In addition to physical stress of competition, match outcome (win vs. loss) may influence mood state, compromise sleep, increase psychological stress, and affect mental fatigue post-match in elite soccer players. Measures are needed to enable an evaluation of psychometric status with autonomic responses that are objective, sensitive, reliable, and easy to implement. Sympathetic nervous system activity is strongly associated with central activations related to the processing of cognitive and emotional information[16]. Skin conductance (SC) is another method of evaluating activity of sweat glands exclusively under sympathetic control[17,18]. SC has been used to identify human emotions, suggesting different levels of sympathetic activation in different emotional stages, which along with both tonic and phasic components can aptly identify subtle psychobiological changes in athletes[17,19]. Therefore, psychometric questionnaires and SC can be methods useful tool for monitoring perceived wellness, psychometric status and psychobiological changes of elite athletes[17,20]. However, scientific researchers are limited with use of SC during recovery post-match in professional soccer players.

Resulting from an examination of existing literature and professional interest, the aim of this study was to investigate changes in physiological parameters such as thermographic profiles of the lower limbs, serum CK level, and skin conductance in elite soccer players post-match. Furthermore, this study examined perceived wellness in relation to physiological parameters in an attempt to identify a possible relationship that might prove valuable to strength and conditioning and sport coaches in planning and implementing training schedules.

Material and method

Approach to the problem

To investigate the impact of competition on physiological measures and wellness, ten professional soccer players were recruited to participate in this study, which was approved by the local institutional Ethical Committee for Human Experiments and was performed in accordance with ethical standards in sport and exercise science research. Subjects provided written informed consent after all methods were explained to them. Various tests were performed at rest, immediately following a soccer match, and at 24- and 48-hours post-match for comparison. Statistical analyses were conducted to examine changes in test scores as well as possible relationships amongst the different assessments.

Participants and anthropometric measurements

The study included 10 healthy male professional soccer players (25.3 ± 4.6years; 178.4 ± 6.3cm; 76.3kg ± 6.2 kg; body fat 10.2 ± 4.2 %) from a club of the Brazilian first division soccer league that participates in national and international competitions organized by the Brazilian Soccer Confederation (CBF) and South American Soccer Confederation (CSF). The current training frequency was 6.3 ± 0.7 days/week and the training programs consisted of jumps, ball fights, sprints, accelerations and decelerations.

All soccer players included in the study participated of one official match for 88.6 ± 9.1 minutes. Data collection post-match were compared to data collection carried out at the beginning of the training season. Exclusion criteria included: 1) smoking history during the previous three months; 2) presence of any cardiovascular or metabolic disease; 3) systemic hypertension (≥ 140/90 mmHg or use of antihypertensive medication); 4) use of anabolic steroids, drugs or medication with potential impact on physical performance (self-reported); 5) recent musculoskeletal injury; or 6) pain in any region of the body. The study was approved by the local institutional Ethical Committee for Human Experiments (CAAE: 76189817.0.0000.5235) and was performed in accordance with ethical standards in sport and exercise science research.

Body composition was measured using a bioelectrical impedance analyzer with hand and foot electrodes (InBody 720, inbody.com). The otherwise clothed subjects stood upright with their bare feet on the analyzer's foot electrodes and their arms abducted while grasping the hand electrodes. All analyses were performed after 8h of fasting. All biometric measures were carried out in a thermoneutral room (21º C). No clinical problems occurred during the study.

Training load monitoring and global position system (GPS)

During one official match, all soccer players' activity levels were monitored and quantified by means of portable global position system (GPS) devices (Minimax X, v.4.0, Catapult Innovations) operating at a sampling frequency of 10 Hz and incorporating a 100 Hz triaxial accelerometer. Each player wore a special harness which enabled this device to be fitted to the upper part of his back. The GPS devices were activated 10 min prior to the start of each official match, in accordance with the manufacturer's instructions. After the match, GPS files were downloaded to a computer and analyzed with the software provided by the manufacturer (Logan Plus v4.2.3 software; Catapult Innovations, Scoresby, Australia). The subjects' data were excluded from analysis if they failed to complete the match due to injury and /or replacement during match.

The GPS devices used in this study did not delineate among forward, backward, or lateral movement.The indicators of external load were as follows: 1) total distance covered; 2) frequency of efforts ≥18 km/h); 3) frequency of efforts ≥24 km/h); 4) maximal speed during matches. In addition, data obtained combining the accelerations produced in three planes of body movement by means of a 100 Hz triaxial accelerometer in the GPS device were used to classify external training load using the Player-Load equation. Player-Load is an indicator of the external load because acceleration is proportional to force and may provide a useful measure of the total load applied to a player in a match. Player-Load was calculated by Logan Plus software via thefollowing equation:

$$(ay1 - ay{-}1)^2 + (ax1 - ax{-}1)^2 + (az1 - az{-}1)^2$$

Where ay = antero-posterior acceleration, ax = medio-lateral acceleration, and az= vertical acceleration.

Procedures Plasma CK monitoring

Plasma CK monitoring was assessed by reflectance photometry at 37°C using the ReflotronAnalyser Plus (Reflotron Plus; Roche, Germany), previously calibrated. After the finger asepsis, by using 70% ethyl alcohol, a lancet device with an automatic trigger was used for puncturing finger and the blood was drained into strips for specific analysis (heparinized capillary strips). Blood sample (32 µl) was immediately pipetted into a CK test strip which was inserted into the instrument.All measurements were performed 24h and 48 h post-match between 8:00 and 9:00 A.M. with anthermoneutral room, temperature of 21ºC and relative humidity of 65%.Absolute values of CK were used for analysis.

Skin conductance recording

Skin conductance (SC) was recorded using a ProComp Infiniti multi-modality encoder from Thought Technology (Montreal, Canada) and a laptop computer. SC was recorded from two 10 mm diameter Ag–AgCl electrodes, attached with adhesive collars on the middle phalanges of the index and middle fingers of the participant's non-dominant hand. A constant voltage (0.5 V) was applied between the two electrodes and EDA was sampled at a frequency of 256 Hz. The signal was displayed in real-time on the computer screen as visual feedback for the participant and investigator. For the case wherein physiological filtering was attempted, the participant donned a piezoelectric belt positioned around the thoracic area, which translated the stretch due to expansion and contraction of the lung cavity into changes in voltages. These changes were recorded simultaneously with EDA by the Pro Comp Infiniti system. All records occurred 24h and 48h post-match with soccer players in supine position at normal room temperature (21ºC) in a quiet place under dim light with sound insulation

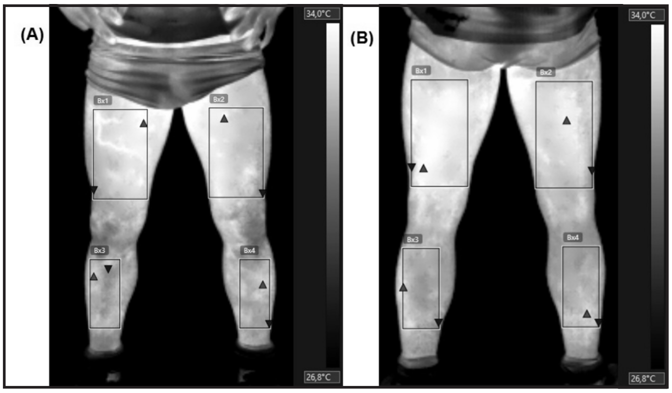
Acquisition of the thermographic images

All thermographic images were performed 24h and 48h post-match between 8:00 and 9:00 A.M. with anthermoneutral room with temperature of 21ºC with a relative humidity of 65%. The equilibration periodto evaluate skin temperature was set at 15 minutes. Thermal images sequences of lower limbs (thighs and legs) were acquired in an anteroposterior manner (i.e., frontal and dorsal views) by a digital infrared thermo-camera (Flir Systems Inc®, model T-420, USA) with a measurement range of 20 °C to 650 °C (accuracy of ± 2 °C or 2 %; sensitivity of ≤ 0.05 °C), an infrared spectral band from 7.5 to 14 microns, a refresh rate of 60Hz and an FPA (Focal Plane Array) of 320 x 240 pixels. The distance between the subject and the camera was standardized at four meters and the index of human skin emissivity was set to 0.98. Analyze of the body regions of interest (ROI) were selected by a drawing rectangular areas by the software (Smartview 3.1 - Fluke®, Everett, USA), which provided us with the average and maximum temperatures from each analyzed ROI[15,21,22]. Selection of the ROI utilized 5 cm above the upper border of the patella and groin line for the thigh, and for the leg, 5 cm below the lower border of the patella and 10 cm above the malleolus[15]. Figure 1 shows representative anterior and posterior thermal images from thighs and legs. Coffee, tea and alcohol intake was prohibited for four hours before testing. Soccer players not use physiotherapy before the test (e.g. massage, electrotherapy, ultrasound, heat treatment, cryotherapy, hydrotherapy) and without cosmetics products before the measurements to obtain thermal images most meaningful of skin temperature. All soccer players reported the absence of any type of sports injury according to these criteria.

Psychometric questionnaire

A psychometric questionnaire was used 24h and 48h post-match between 8:00 and 9:00 A.M. to assess general indicators of player

Figure 1. Thermal images anterior (A) and posterior (B) views from thighs and legs.



wellness[23,24]. The questionnaire comprised of 5 questions relating to perceived fatigue, sleep quality, general muscle soreness, stress levels and mood, with each question scored on a five-point scale (ranging from 1-5, with 1 and 5 representing very poor and very good wellness ratings, and 3 representing normality)[23]. Overall wellness was then determined by summing the five scores.

Statistical Analysis

Sample size calculation was performed for the physiological responses as the main outcome. A sample size of 10 participants was found to be required to detect a difference in the physiological responses between baseline and post-match follow-up (power = 0.9, alpha = 0.05) (G*Power, version 3.1.9).All data are presented as mean ± SD. The statistical analysis was initially performed using the Shapiro–Wilk normality test and the homocedasticity test (Bartlett criterion). Comparisons within-groups for physiological variables and psychometric questionnaire were performed with ANOVA one-way repeated-measures followed by Tukeys post hoc tests. Correlation between variables was assessed using Pearson correlation coefficients and corresponding 95% confidence intervals. The level of significance was set at p<0.05 for all statistical comparisons. The significance level was set p<0.05 for all statistical comparisons; the software used was GraphPad® (Prism 6.0, San Diego, CA, USA).

Results

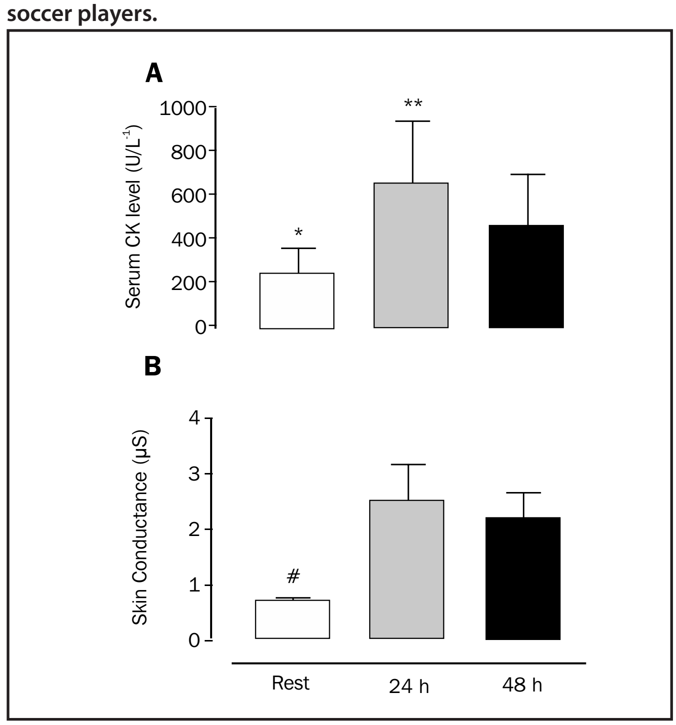
Table 1 shown descriptive statistic of theindicators of external load during match. Serum CK level revealed significant differences (p<0.0004) between rest, 24 h, and 48 h post-match (Figure 2A). On the other hand, SC recording showed significant difference (p<0.0001) only between restand 24h post-match (Figure 2B).

No significance difference (p>0.05) was found between left and right sides for anterior and posterior measurements of thighs and legs for maximal (Table 2) and mean (Table 3) values of skin temperature. However, both values (maximal and mean) of skin temperature showed significant differences (p<0.05) at rest when compared to 24 h and 48 h post-match.

Table 1. Indicators of external load during match.

Variables	Mean±SD	Maximal	Minimal
Total distance covered (m)	8740±1516	10489	5605
Horizontal velocity (m/min)	103.1±13	119	80
Frequency of efforts ≥18 km/h	48.7±19	77	17
Frequency of efforts ≥24 km/h	7.3±5	14	0
Maximal speed (km/h)	28.75±2	31.1	25.5
Player Load (A.U.)	878.3±167	1132	536
Player Load per minute (A.U.)	10.5±1	11	10
Total minutes	88.6±9	95	70

Figure 2. Mean ± SD values from serum CK level and Skin conductance in rest, 24h, and 48h post-match of professional soccer players.



*p<0.0004 - Rest vs. 24h and 48h post-match.
**p<0.0004 - 24h vs. 48h post-match.
#p<0.0001 - Rest vs. 24h post-match.

Table 4 showed psychometric variables of fatigue, sleep, and pain were lower at 24 h and 48 h post-match when compared to rest. Sleep was also significantly lower at 24 h when compared with 48 h post-match (p<0.05). In addition, SC showed significant correlation with fatigue (r=0.73; p<0.01) and sleep (r=0.65; p<0.04).

Discussion

Few studies evaluated the physiological response post-match of the elite soccer players which mean anessential to strategies of recovery post-match. The results obtained in the present study related significant difference between rest and up to 48 hours post-match, which showed

Table 2. Maximal values of skin temperature (ºC) of thigh and leg in elite soccer players.

Body regions of interest	Rest	24 hours Post-match	48 hours Post-match	Δ 24h Post-math	Δ 48h Post-math
Anterior thigh Right	33.25±0.62*	34.60±0.63	34.44±0.52	1.4±0.96	1.2±0.58
Posterior thigh Right	33.04±0.49*	34.00±0.54	34.27±0.70	1.15±0.89	1.25±0.71
Anterior leg Right	32.38±0,73*	33.80±0.44	33.87±0.62	1.3±0.69	1.2±0.67
Posterior leg Right	32.43±0,45*	33.74±0.86	33.41±0.67	1.15±0.91	1.15±0.75
Anterior thigh Left	33.18±0,72*	34.73±0,62	34.60±0.56	1.45±1.09	1.3±0.57
Posterior thigh Left	33.13±0,52*	34.09±0.53	34.34±0.54	1.15±0.87	1.1±0.65
Anterior leg Left	32.37±0.68*	33.59±0.86	33.92±0.69	1.3±1.3	1.65±0.65
Posterior leg Left	32.45±0.60*	33.26±0.89	33.49±0.86	0.75±0.83	1±0.74

*p<0.05 - Rest vs. 24h and 48h post-match. Δ values were calculated in relation to rest.

Table 3. Mean values of skin temperature (oC) of thigh and leg in elite soccer players.

Body regions of interest	Rest	24 hours Post-match	48 hours Post-match	Δ 24h Post-math	Δ 48h Post-math
Anterior thigh Right	32.12±0.81*	33.32±0.49	33.28±0.55	1.06±0.9	1±0.47
Posterior thigh Right	32.16±0.47*	33.03±0.63	33.36±0.63	1.03±0.6	1±0.77
Anterior leg Right	31.28±0.94*	32.78±0.42	32.77±0.90	1.4±1.10	1.5±0.81
Posterior leg Right	31.23±0.31*	32.88±0.59	32.53±0.66	1.5±0.78	1.35±0.67
Anterior thigh Left	31.98±0.75*	33.26±0.56	33.26±0.43	1.13±1	1.15±0.46
Posterior thigh Left	32.16±0.46*	33.16±0.62	33.40±0.68	1.25±0.90	1.25±0.78
Anterior leg Left	31.11±0.78*	32.78±0.42	32.81±0.66	1.6±0.94	1.6±0.66
Posterior leg Left	31.34±0.43*	32.39±0.73	32.46±0.70	1.25±1.13	1.15±1.02

*p<0.05 - Rest vs. 24h and 48h post-match. Δ values were calculated in relation to rest.

Table 4. Mean±SD values of psychometric questionnaire in rest, 24h, and 48h post-match.

Psychometric questionnaire	Rest	24 hours Post-match	48 hours Post-match
Fatigue (A.U.)	4.4±0.51*	2.9±0.31	3.4±0.51
Sleep (A.U.)	4.5±0.52*	2.4±0.51**	3.5±0.97
Pain (A.U.)	4.4±0.51*	2.9±0.56	3.5±0.7
Stress (A.U.)	4.4±0.51	3.6±0.96	3.9±0.99
Mood (A.U.)	4.9±0.31	4.1±1.1	4.3±0.05

*p<0.05 - Rest vs. 24h and 48h post-match; **p<0.05 - 24h vs. 48h post-match

that the athletes were not fully recovered. Scientific literature comments that recovery time between 48h and 72h post-match may be insufficient to restore normal homeostasis within soccer players[5]. In present study did not find a high correlation between physiological variables, possibly because this variable shows individual characteristics for each soccer players. However, the use of infrared thermography and CK plasma level can together estimate the magnitude of muscle damage, but SC also seems to be quite important to autonomic evaluation to shown significant correlation with fatigue and sleep described in the psychometric questionnaire.

Exercise intensity contributes with damages to the skeletal muscle cell structure at the level of the sarcolemma, including membrane damage, myofilament disorganization and loss of Z-disc integrity that results in an increase in total CK[10,11]. Our results showed increase significant of serum CK level 24h post-match, possibly by a greater recruitment of fast-twitch fibers at high-intensity exercise during match[11,25]. Some studies suggested that some specifics movement in field sports (accelerations, decelerations, and eccentric contractions) and speeds >25 km/h seem to have a strong correlation with CK levels[26,27]. A recent study showed a significant increase in serum CK level after more of 4 repetitions greater than 20 km/h in sprinters athletes when compared to endurance athletes[26]. In our study, despite of the low correlation between CK level and efforts > 24 km/h (r=0.14), were realized 7.3 ± 5 repetitions > 24 km/h. In addition, how increase the repetitions and intensity of efforts greater will be muscle cell disturbance and delays the appearance of a CK serum peak compared to less disruption and may be linked to the time course of inflammation[28]. Such muscle damage induced by intensity exercise altersthe muscle cell permeability and leads to cellular protein leakage, ultimately increasingthe serum activity of many enzymes[28,29]. Thus, serum CK level response observed after exercise induced muscle damage may be due to leukocytes infiltrating and destabilizing the cell membrane during the process of repair[28,29].

Considering that CK levels increase after exercise or soccer matches, applying two methods for muscle activity ismore accurate. Thus, the use of infrared thermography and CK plasma level can together determine muscle damage, because only biochemical markers do not show the anatomic location of the muscle injury. A recent study published by our research group showed thermal symmetry of the human body is similar between the sides of the body at rest, being identical in shape and size[1]. On the other hand, no studies were found that evaluated profile of infrared thermography in elite soccer players 24 h and 48 h post-match. Some studies shown that differences greater than 0.7°C between contralateral limbs or body areas have been associated with structural or physiological abnormalities in athletes[1,12,13]. Additionally, a temperature increase between 0.25°C to 0.9°C in a deep lesion situated in muscle is associated to inflammation, but a temperature decrease between –0.2°C to –0.5°C is considered local ischemia[30]. Our results showed maximal and mean values > 0.7ºC 24h and 48h post-match in front and back lower limbs in which an increase in thermal image (>0.7ºC) can contribute to decrease of quadriceps power in 7.9%[31]. We propose that a ROI below 27°C may be related to a condition of hypothermia caused by reduced local blood flow, whereas a ROI above 35°C could suggest an inflammatory process. This thermal response could be related to several physiological changes (e.g., increased muscle metabolism, anaerobic energy reserve, density of capillaries and nerve conduction rate) showing a relationship between muscle skin temperature change and muscle fatigue[1,31,32].

Stress perturbs the normal physiological or psychological functioning of an individual. There is a relationship between stress and sympathetic activity, although the electrical change alone does not identify which specific emotion is being elicited[19]. However, SC can identify autonomic sympathetic changes through changes in sweat and blood flow[17]. But it is important to comment that no study to date has used SC as a method for assessing recovery of elite soccer players. In present study was observed high correlation between SC and fatigue and sleep. We hypothesis that in 24 h post-match (score < 3 in psychometric questionnaire to fatigue and sleep) elite soccer players still showed the effects of stress caused by match play. Consequently, the perception of greater risk results in more vigilant autonomic nervous system activityand is reflected in skin conductance activity[18,19]. Thus, under a pre-sleep stressful condition, the increase in electrodermal activity during sleep can be a byproduct of a sleep inhibitory mechanism, which fits the notion that higher vigilance corresponds to higher sympathetic activity and increase fatigue state[33].

A limitation of this type of investigation could be age range, specific position of the soccer players, and climatic condition during match soccer since this parameter could influence serum CK level, skin temperature measurements, and autonomic response. While our sample was quite homogeneous, the sample size was not large enough to provide variations in physiological condition to specific positions. Future research should elucidate the influence of the external training load in the markers biochemical during training and/or matches in elite soccer players.

Conclusions

In conclusion, the combinations of our results contribute to two key findings. Firstly, 48 h post-match remain high levels of serum CK and thermal image in elite soccer players. Secondly, the results showed significant correlation of SC with fatigue and sleep reported in the psychometric questionnaire. Therefore, workouts held the day after a game may be counterproductive and impeded the recovery process, which may take more than 48 hours. The use of physiological measures, wellness questionnaires, and thoughtful planning based on readiness may help reduce over-stress injuries and enable athletes to perform at their peak throughout the season. Thus, these physiological evaluations may be a helpful for athletes, coaches, physicians and physical therapists regarding injury prevention, early detection, and recovery strategies.

Conflict of interest

The authors do not declare a conflict of interest.

Bibliography

1. Maior AS, Leporace G, Tannure M, Marocol M. Profile of infrared thermography in elite soccer players. *Motriz: rev. educ. Fis*. 2017;23:1-6.
2. Prieske O, Muehlbauer T, Borde R, Gube M, Bruhn S, Behm, *et al.* Neuromuscular and athletic performance following core strength training in elite youth soccer: Role of instability. *Scand J Med Sci Sports.* 2016;26(1):48-56.
3. Casamichana D, Castellano J, Calleja-Gonzalez J, San Román J, Castagna C. Relationship between indicators of training load in soccer players. *J Strength Cond Res.* 2013;27(2):369-74.
4. Taylor JM, Macpherson TW, McLaren SJ, Spears I, Weston M. Two Weeks of Repeated-Sprint Training in Soccer: To Turn or Not to Turn? *Int J Sports Physiol Perform.* 2016;11(8):998-1004.
5. Nédélec M, McCall A, Carling C, Legall F, Berthoin S, Dupont G. Recovery in soccer: part I - post-match fatigue and time course of recovery. *Sports Med.* 2012;42(12):997-1015.
6. Ekstrand J, Hagglund M, Walden M. Injury incidence and injury patterns in professional football: the UEFA injury study. *Br J Sports Med.* 2011;45(7):553-8.
7. Jones CM, Griffiths PC, Mellalieu SD. Training Load and Fatigue Marker Associations with Injury and Illness: A Systematic Review of Longitudinal Studies. *Sports Med.* 2017;47(5):943-74.
8. Pfirrmann D, Herbst M, Ingelfinger P, Simon P, Tug S. Analysis of Injury Incidences in Male Professional Adult and Elite Youth Soccer Players: A Systematic Review. *J Athl Train.* 2016;51(5):410-24.
9. Russell M, Sparkes W, Northeast J, Cook CJ, Bracken RM, Kilduff LP. Relationships between match activities and peak power output and Creatine Kinase responses to professional reserve team soccer match-play. *Hum MovSci.* 2016;45:96-101.
10. Brancaccio P, Maffulli N, Limongelli FM. Creatine kinase monitoring in sport medicine. *Br Med Bull.* 2007;81-82:209-30.
11. Magal M, Dumke CL, Urbiztondo ZG, Cavill MJ, Triplett NT, Quindry JC, *et al.*Relationship between serum creatine kinase activity following exercise induced muscle damage and muscle fibre composition. *J Sports Sci*. 2010;28(3):257-66.
12. Chudecka M, Lubkowska A. The use of thermal imaging to evaluate body temperature changes of athletes during training and a study on the impact of physiological and morphological factors on skin temperature. *Hum. Mov*. 2012;13:7.
13. Hildebrandt C, Raschner C, Ammer K. An overview of recent application of medical infrared thermography in sports medicine in Austria. *Sensors.* 2010;10(5):4700-15.
14. Sanchis-Sanchez E, Vergara-Hernandez C, Cibrian RM, Salvador R, Sanchis E, Codoner-Franch P. Infrared thermal imaging in the diagnosis of musculoskeletal injuries: a systematic review and meta-analysis. *AJR Am J Roentgenol.* 2014;203(4):875-82.
15. BouzasMarins JC, Moreira DG, Silva FS, Costa CMA, Pimenta EM, Sillero-Quintana M. Thermographic profile of soccer players' lower limbs. *Rev Andal Med Deporte.* 2014;7:6.
16. Kreibig SD. Autonomic nervous system activity in emotion: a review. *Biol psychol.*2010; 84:394-421.

17. Pusenjak N, Grad A, Tusak M, Leskovsek M, Schwarzlin R. Can biofeedback training of psychophysiological responses enhance athletes' sport performance? A practitioner's perspective. *Phys Sportsmed.* 2015;43(3):287-99.
18. Widyanti A, Muslim K, Sutalaksana IZ. The sensitivity of Galvanic Skin Response for assessing mental workload in Indonesia. *Work.* 2017;56:111-7.
19. Joshi A, Kiran R, Sah AN. Stress monitoring through non-invasive instrumental analysis of skin conductivity. *Work*. 2017;57:233-43.
20. Moalla W, Fessi MS, Farhat F, Nouira S, Wong DP, Dupont G. Relationship between daily training load and psychometric status of professional soccer players.*Res Sports Med.* 2016;24(4):387-9.
21. Snyder WE, Qi H, Elliott RL, Head JF, WangCX.Increasing the effective resolution of thermal infrared images. *IEEEEng Med Biol Mag*. 2000;19(3):63-70.
22. Toumi J, Saiof F, Bachir W. Algorithm for Analyzing Thermal Images of Laser Irradiated Human Skin. *J Lasers Med Sci*. 2016;7(3):163-6.
23. Buchheit M, Racinais S, Bilsborough JC, Bourdon PC, Voss SC, Hocking J, *et al.* Monitoring fitness, fatigue and running performance duringa preseason training camp in elite football players. *J Sci Med Sport*. 2013;16(6):550-5.
24. Thorpe RT, Strudwick AJ, Buchheit M, Atkinson G, Drust B, Gregson W. Monitoring Fatigue During the In Season Competitive Phase in Elite Soccer Players. *Int J Sports Physiol Perform*. 2015;10(8):958-64
25. Pal S, Chaki B, Chattopadhyay S, Bandyopadhyay A. High intensity exercise induced oxidative stress and skeletal muscle damage in post-pubertal boys and girls: A comparative study. *J Strength Cond Res*. 2018;32(4):1045-52.
26. Cipryan L, Tschakert G, Hofmann P. Acute and Post-Exercise Physiological Responses to High Intensity Interval Training in Endurance and Sprint Athlete. *J Sports Sci Med.* 2017;16(2):219-29.
27. Young WB, Hepner J, Robbins DW. Movement demands in Australian Rules football as indicators of muscle damage. *J Strength Cond Res.* 2012;26(2):492-6.
28. Baird MF, Graham SM, Baker JS, Bickerstaff GF. Creatine-kinase-and exercise-related muscle damage implications for muscle performance and recovery. *J Nutr Metab.* 2012;2012:960363.
29. Paulsen G, Benestad HB, Strøm-Gundersen I, Mørkrid L, Lappegård KT, Raastad T. Delayed leukocytosis and cytokine response to high-force eccentric exercise. *Med Sci Sports Exerc.* 2005;37(11):1877-83.
30. Bhargava A, Chanmugam A, Herman C. Heat transfer model for deep tissue injury: a step towards an early thermographic diagnostic capability. *DiagnPathol.*2014;20: 36.
31. VedranHadžic´ BŠ, Aleš M, Milan Cˇ. Can infrared thermography be used to monitor fatigue during exercise? A case study. *J Sport Health Sci.* 2015; [Epub ahead of print].
32. Abate, M, Di Carlo, L, Di Donato, L, Romani, GL, Merla, A. Comparison of cutaneous termic response to a standardised warm up in trained and untrained individuals. *J Sports Med Phys Fitness.* 2013;53(2):209-15.
33. Delannoy, J, Mandai, O, Honoré, J, Kobayashi, T, Sequeira, H. Diurnal Emotional States Impact the Sleep Course. *PLoS One.* 2015;10(11):e0142721.