CAN THERMOGRAPHY AID IN THE DIAGNOSIS OF MUSCLE INJURIES IN SOCCER ATHLETES?

ORIGINAL ARTICLE

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ABSTRACT

Introduction: Since muscle injuries trigger inflammatory processes and inflammation generates heat due to increased local metabolism, hence the level of inflammation can be measured by the temperature gradient. Objective: To assess the feasibility of application of thermography in the diagnosis of injuries caused by physical training. Methods: The study was conducted with adolescent athletes of the Paraná Club, Curitiba, Brazil, who were divided into two groups, namely control and experimental. The control group attended a training session of low intensity and the experimental group a high intensity one. First, a thermographic image of the quadriceps of each athlete was acquired before the training session. After the training session, a blood sample was collected to check the level of serum lactate of each athlete. Subsequently, 24 hours after training, an extra blood sample was performed to check the level of serum CK of each athlete. Another individual thermographic image of the quadriceps was acquired at that stage. Results: The correlation between the lactate and CK was positive and statistically significant rho value = 0.661 (p = 0.038). There was no statistically significant correlation between CK values 24 h post-training and the change in temperature (24 h post-training - pre-training) in the muscles evaluated for the control group. There was a statistically significant difference in temperature (24 h post-training - pre-training) ($p<0.05$) for the three muscles studied only in the experimental group. Conclusion: The results of this study suggest the possibility of use of thermographic images, together with creatine kinase, in order to determine the intensity and location of post-training muscle damage, since the previously mentioned biochemical marker cannot determine the anatomic location of the muscle injury.

Keywords: muscle inflammation, creatine kinase, thermography.

INTRODUCTION

Soccer has been suffering changes in competition levels concerning the number of games and championships, imposing an increase of the competitive load and physical performance to the athlete[1,2]. This sport is characterized as being physically demanding and having short duration efforts, but of high power and intensity[3].

In the soccer athletes, the oxygen consumption corresponds to approximately 75 to 80% of VO_2 maximum[3-7]. The exercise is considered of high intensity when it reaches values above 60% of VO_2 maximum[8], and this high metabolic demand has as consequence the delayed sensation of discomfort, pain and/or muscle injury[1]. In order to evaluate the tissue injury after exercise, the plasma activity of the creatine-kinase (CK) has been used as a biochemical marker[9,10] and it seems to be one of the best indirect indicators for this purpose[11-14]. Usually, the creatine-kinase enzyme is confined inside the cells[14] and its serum concentration is very low[15]. The serum level of enzymes like the CK may increase from two to 10 times in situations of muscular cell injury[14].

After the cellular injury, the neutrophils infiltration and consequent release of CK in the blood stream take place[15-17], considerably increasing its serum concentration[18].

Thus, high serum amount of CK suggests the occurrence of some type of tissue damage[14,19] and indirectly allows determining the level of aggression caused by the exercise[20].

Since these injuries trigger inflammatory processes and the inflammation causes heat[19] due to the increase of local metabolism, the inflammatory level can be assessed through temperature gradients. Thermography is a non-invasive method used to register body gradients and thermal patterns[21,22], being used to measure the thermal radiation (heat) emitted by the body or its parts, can, therefore, be used to diagnose injuries caused by training.

Since thermography is characterized by detecting small temperature variation (gradient), the thermographic images early show the beginning of an inflammatory process which still have not presented classic signs and symptoms (pain, edema and paresthesia), acting hence in a preventive manner[23].

Thermography has been used among other things, to determine injuries of the musculoskeletal system[24]. It use as diagnosis of muscular injuries after training is justified by the easiness of the process and by being a non-invasive technique. In case this hypothesis is correct, it will be possible to easily spot the points of muscular inflammation derived from intense training. Thus, the aim of this study was to verify the possibility of thermography use in the diagnosis of injuries caused by physical training.

METHODOLOGY

The study was carried out with adolescent athletes from the Paraná Clube (series A of the state championship team) during the month of March, 2011.

Participants

18 male athletes, aged between 15 and 17 years, who regularly trained in the soccer U-17 team from the Paraná Clube participated in this study.

The athletes were divided in two groups called control group and experimental group. Each group participated in a training session. The control group participated in low-intensity training, while the experimental group participated in high-intensity training. Only the experimental group performed determination of the biochemical markers, but both obtained thermographic images.

Procedures

The thermographic image of the quadriceps femoris of each athlete was before the beginning of the training session was obtained. After this training session, a blood sample was collected to verify the lactate serum level of each athlete in the experimental group. Subsequently, 24 hours after training, another blood collection was performed, this time to verify the CK serum level of each athlete of the experimental group. In that stage, an extra individual thermographic image of the quadriceps femoris was also obtained. The thigh skinfold of the athletes was verified in order to check the influence of this variable in the temperature measured by the camera. In this investigation, the right lower limb of the athletes was selected for study so that the influence of the subcutaneous fat in the thermographic images could also be evaluated[25-28].

Activity definition

The control group performed low-intensity activity which consisted of a continuous run with heart rate monitoring with target--zone established between 50 and 60% of maximum heart rate.

The experimental group performed three body building exercises (squat, rack and leg extension), with 80% of maximum load of the athlete in each machine.

Individual maximum was determined following the recommendations adapted from Kraemer and Fry, mentioned by Martins[29], which consist of: 1) warm-up of five to 10 repetitions with loads of 40 to 60% of estimated maximum repetition (RM); 2) 1min rest, followed by three to five repetitions with 60% of estimated 1RM and a 3min rest; 3) increase of weight with the aim to reach the 10RM in three to five attempts, with 5min rest between attempts; 4) the value of 10 repetitions, with maximum lifter weight in the last successful attempt was recorded.

The exercises consist in consecutive sets, with maximum repetitions in each of them and 90s rest between sets. After each set, 10kg of load from each machine was removed and the athlete performed the new set until there was only 20kg of load in the machine; at that moment, the training was finished. All athletes performed the exercises following the same order: squat, rack and leg extension.

Determination of the physiological markers

In the control group, there was no analysis of the lactate dehydrogenase (LDH) and CK markers due to resources restriction and consideration that the low-intensity activity would not bring muscular injuries in this group[30]. On the other hand, it is known that high-intensity physical activities[18,31,32] contribute to the post-exercise muscular injury and consequently increase of the LDH and CK levels[10,18].

The plasma samples were collected immediately after training for lactate dehydrogenase (LDH) and 24h after training for creatine-kinase (CK) ($U.L^{-1}$). Commercial kits were used for enzymatic determinations (CELM®).

Acquisition of the thermographic image

The thermographic image was taken in an acclimatized room with temperature of 23ºC. The athletes remained for 15min in the room for thermal balance reach before the images acquisition process began. The following material was used: a thermographic camera (FLIR Systems Inc. model A-325); a computer (with software specific to thermographic images acquisition and processing - ThermaCam™ Researcher Pro 2.9); and a digital thermo-hygrometer (Minipa® model MT241) for room temperature and humidity monitoring.

The thermographic camera used has real integrated resolution of 320 x 240 pixels, which has sensors which allow measuring the temperatures ranging from –20°C to +120°C. This camera presents sensitivity to detect differences in temperature lower than 0.08ºC and has accuracy of ± 2ºC of absolute temperature, according to the manufacturer's guidelines[33].

Images analysis

Each image taken was analyzed in the following manner: a mask with the digitalized image of the quadriceps femoris, printed on clear paper, which was attached on the computer monitor so that the anatomic localization of the muscles to be analyzed in this study could be done (rectus femoris – RF; adductor longus – AL; vastus medialis – VM). This procedure was carried out because the ThermaCAM™ Researcher[33] software was regulated so that the thermal image acquired had the same size of the reference image attached on the screen. After these muscles were marked, the highest and the lowest temperatures, mean temperature and standard deviation of the selected region of the muscle were collected according to figure 1.

Data analysis

The data statistical analysis was carried out in the SPSS 13.0 software, in which the Kolmogorov-Smirnov (K-S test), the Spearman correlation (rho) among the many variables measured; the Wilcoxon Signed Ranks and the Mann-Whitney tests were applied to verify the difference between temperature means of each muscle obtained before the exercise (pre-training) and 24h after physical training (post-training).

Ethical aspects

The study followed the ethical aspects recommended by the Resolution 196/96 of the National Health Board and was approved by the Ethics Committee of the Campos de Andrade University Center under protocol 382/2011.

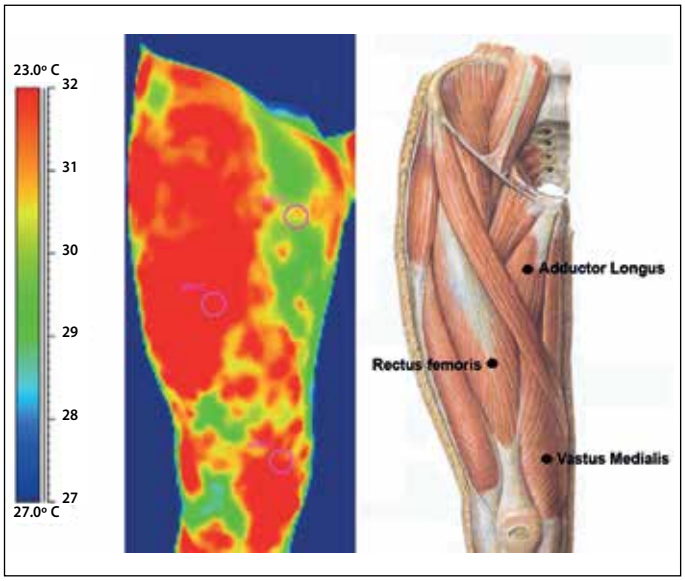

Figure 1. Protocol of thermographic images analysis: (a) example of a termal image analyzed; and (b) reference image (modified from Sobotta, 2006).

RESULTS

The mean temperature measured by thermography in the region of the muscles (adductor longus, vastus medialis and rectus femoris), the values of the thigh skinfold, of the lactate (evaluated immediately after the activity) and of the CK (evaluated 24h after the activity) are presented in table 1.

In figure 2, a sequence of four images can be seen. The two first ones refer to an athlete from the control group, obtained before training (1) and 24h after training (2). The two following images belong to an athlete from the experimental group, and were also obtained before training (3) and 24h after it (4). The athlete from the experimental group who is in the two last images presented CK of 348 $U.L^{-1}$, 24h after training.

Table 2 presents the values of the correlation between mean temperature measured by the thermograph in the regions corresponding to the adductor longus, vastus medialis and rectus femoris muscles with the thigh skinfold values of the entire sample studied.

The correlation between the lactate and CK indices was positive and statistically significant, with rho value equal to 0.661 ($p = 0.038$). There was not statistically significant correlation between the CK values 24h post-training and the temperature variation (24h post--training – pre-training) in the muscles evaluated. Table 3 presents the result of the Wilcoxon Signed Ranks test for the comparison of the temperature variation (24h post-training – pre-training) in each muscle analyzed within each group (control and experimental), indicating that there was temperature difference (24h post-training – pre-training) statistically significant for the three muscles studied only in the experimental group.

The results of the table 3 suggest that the exercises performed by the experimental group were able to produce micro injuries and, consequently, trigger an inflammatory process which increased the temperature in the region of the studied muscles. Moreover, this low temperature gradient may be perceived through the analysis of the thermographic images obtained (figure 2).

The Mann-Whitney test indicated statistically significant difference ($p < 0.05$) between the temperature variation of the muscles of the group which performed eccentric exercises (experimental group) and the temperature variation of the muscles of the group which performed aerobic exercises (control group), according to what is listed on table 4.

Table 1. Results of the response of the biochemical markers and of the temperature variation after physical activity in soccer adolescent athletes.

Cod	Lactate (mmol/L)	Ck ($U.L^{-1}$)	Group	Adductor longus		Vastus medialis		Rectus femoris		Thigh skinfold (mm)
				Temperature (°C)		Temperature (°C)		Temperature (°C)		
				Pre	After 24hs	Pre	After 24hs	Pre	After 24hs	
1	X	X	Control	29.5±0.2	29.6±0.2	29.0±0.3	28.7±0.3	29.5±0.6	29.0±0.2	10.6
2	X	X		32.0±0.5	31.4±0.3	29.5±0.3	29.7±0.2	30.8±0.4	30.5±0.2	13.8
3	X	X		32.7±0.4	29.7±0.3	30.1±0.2	28.7±0.2	31.2±0.6	29.2±0.2	9.7
4	X	X		32.0±0.2	30.8±0.2	29.6±0.4	28.7±0.4	29.3±0.4	29.0±0.2	11.6
5	X	X		32.2±0.4	31.6±0.2	29.3±0.3	30±0.4	30.6±0.4	30.6±0.2	15.5
6	X	X		33.1±0.4	32.9±0.3	30.7±0.5	31.7±0.2	31.2±0.5	32.0±0.4	9.8
7	X	X		33.5±0.2	34.0±0.2	30.2±0.3	31.0±0.5	31.5±0.4	32.2±0.4	10.6
8	X	X		30.5±0.4	30.8±0.3	27.2±0.3	29.5±0.3	28.5±0.6	30.2±0.3	13.6
9	8.1	259	Experimental	29.8±0.2	31.3±0.1	29.2±0.2	30.9±0.1	29.6±0.2	30.8±0.4	13.0
10	5.8	129		31.4±0.2	31.9±0.1	30.3±0.3	31.2±0.2	31.0±0.1	32.0±0.2	8.3
11	6.6	216		32.2±0.1	33.8±0.2	30.8±0.3	32.1±0.3	31.3±0.6	32.3±0.5	5.7
12	7.3	270		31.0±0.4	31.8±0.3	29.7±0.3	30.3±0.3	29.3±0.6	30.6±0.4	10.3
13	11.3	962		30.2±0.4	31.1±0.3	27.8±0.2	28.9±0.2	28.8±0.5	29.7±0.4	17.6
14	6.9	1020		33.5±0.3	33.8±0.1	30.5±0.3	31.5±0.3	31.2±0.8	32.0±0.5	9.7
15	9.8	3150		31.5±0.2	33±0.2	26.8±0.4	29.3±0.4	29.4±0.8	30.9±0.4	7.2
16	9.7	278		31.8±0.2	31.4±0.1	29.8±0.3	30.8±0.3	30.9±0.3	31.5±0.3	13.8
17	9.3	317		30.3±0.2	30.7±0.3	28.5±0.2	29.2±0.3	29.2±0.3	29.6±0.1	12.4
18	8.7	348		31.5±0.3	32.2±0.1	28.4±0.3	29.9±0.3	30.8±0.5	31.5±0.2	12.0

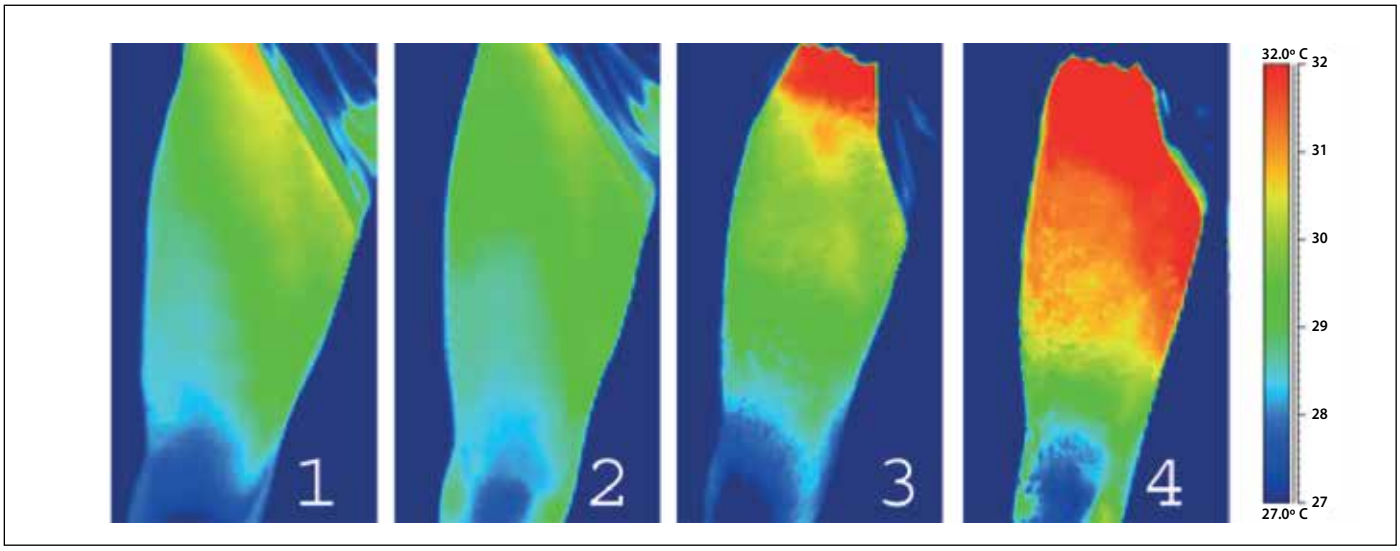

Figure 2. Comparison of the pre-training and 24h post-training thermal image. (1) Subject of the control group, pre-training; (2) subject of the control group, 24h post-training; (3) subject of the experimental group, pre-training; and (4) subject of the experimental group, 24h post-training.

Table 2. Correlation between the temperatures measured at rest (before training) and the thigh skinfold.

Anatomic site	Spearman's rho	p value
Adductor longus	–0.336	0.086
Vastus medialis	–0.499	0.017*
Rectus femoris	–0.488	0.020*

* p < 0,05.

Table 3. Results of the Wilcoxon Signed Ranks Test for the comparison of temperature variation (24 hours post-training – pre-training) in each muscle analyzed within each group (control and experimental).

	Group	Temperature difference (24 hours – pre-training)		
		Adductor longus	Vastus medialis	Rectus femoris
Z Asymp. Sig. (2-tailed)	Control (n = 8)	–1.402(b) 0.161	–0.560(a) 0.575	–0.169(a) 0.866
Z Asymp. Sig. (2-tailed)	Experimental (n = 10)	–2.552(a) 0.011	–2.805(a) 0.005	–2.805(a) 0.005

a – based on the rank negative.
b – based on the rank positive.

Table 4. Results of the Mann Whitney test for the comparison of temperature variation (24h post-training – pre-training) in each muscle analyzed between the experimental and control groups.

	Variation in the adductor longus	Variation in the vastus medialis	Variation in the rectus femoris
Mann-Whitney U	7.000	16.000	16.500
Wilcoxon W	43.000	52.000	52.500
Z	–2.938	–2.137	–2.093
p value	0.003*	0.033*	0.036*

* p < 0,05.

DISCUSSION

The great variation found among the CK level of the athletes may be explained by individual variations such as age, muscular mass, lipid profile and ethnic group[30], training level of the individual[34], post-exercise moment which the CK reaches at its peak, and the use of some medication or drugs[18]; all variables which affect the activity of this enzyme. Balnave and Thompson[35] state that the CK reaches its peak after 24h. Brancaccio et al.[18] report that the CK level may keep increasing up to 72h after exercise. Moreover, Brancaccio et al.[34] show that the CK values present great variability and the enzyme levels are associated to the individual muscular properties.

Souza et al.[36] found rest CK values in adult indoor soccer athletes of 256.1 ± 23.6U/L, while after the end of the first and second matches, the values found were 372.6 ± 53.4 and 408.8 ± 68.8U/L, respectively.

This study evidenced slight variability of thigh skinfold among the volunteers, possibly due to the fact the sample is composed of high-performance athletes. The superficial skin temperature inversely correlated to the thigh skinfold thickness, corroborating the information that the subcutaneous fat provides good thermal isolation to the heat flow. Such fact was expected, since Mcardle et al.[17] and Guyton and Hall[37] state that fat presents relatively low thermal conductivity, which makes it an excellent thermal isolation choice. Savastano et al.[38] found similar results when measured the central body temperature through the ingestion of telethermia capsules and of the abdominal skin through infrared thermography and adhesive contact strips of two groups (obese and normal weight) and did not find significant difference between central body temperature groups; however, the abdominal skin temperature was significantly lower in the obese group when compared to the participants with normal weight, suggesting hence that fat acts as thermal isolation. Moreover, it is known that the skin temperature will depend on the heat amount which reaches it[39]; therefore, Mcardle et al.[17] reported that a small amount of body heat is continuously moved through conduction (one of the four ways of dissipating

body heat), which occurs through direct heat transference from one molecule to another.

Heat transference rises by the increasing blood flow of the peripheral tissues[17,38,40]. The result found in this study confirms the low thermal conductivity of fat. Guyton and Hall[37] reported that fat has one third of conductibility when compared to the other tissues and Mcardle et al.[17 and] Guyton and Hall[37], that subcutaneous fat is an excellent thermal isolator, avoiding hence that great heat transference from the inner environment to the outside body takes place, offering certain resistance to body heat loss[17].

The results point to a good correlation rho = 0.661 (p = 0.038) between creatine-kinase (CK) and lactate dehydrogenase (LDH). Both enzymes are normally used as common markers of post-exercise muscular injury[17,32,41].

Such result is also evidenced in the investigations by Córdova and Navas[42], who report that the CK and the LDH are related to muscle damage. At rest, these enzymes are found in low serum concentration; however, after intense exercise, they usually considerably increase their concentration[18]. Such increase is caused by the release of these and other enzymes in the blood stream after some kind of cellular damage, allowing hence that these enzymes, which are not normally able to cross the sarcoplasmatic membrane[31], do it[14]. This increase may represent cellular necrosis after the onset of a muscular injury[34].

In the present study, there was no correlation between the temperature difference and the creatine-kinase values. This result may be justified by the direct correlation of this enzyme and the individual characteristics of the athlete, and also by the blood peak moment after exertion[43]. The increase in the CK activity may remain for up to 72h after exercise[18,36].

Significant difference was found in the muscular temperature gradient (temperature 24h after training – temperature before training) between the control and experimental groups. Studies report that the muscular injury caused by the physical exercise generally results from the practice of an unusual physical activity or a series of eccentric muscular actions[10,44-46], especially when the exercise is intense or of long duration[47].

These minute lacerations cause damage to the contractile components and consequently release of creatine-kinase in the blood stream[14,17,44]. These injuries may be followed by an inflammatory response[44], since intense physical activities tend to increase the leukocytes counting, suggesting that there is tissue inflammation[14]. According Garcia[48], inflammation causes heat, which would explain the higher temperature found in the group which performed intense anaerobic training compared to the group which performed low-intensity aerobic training. It is worth highlighting that, despite the fat acting as a thermal isolator, it was possible to visualize differences between the two groups (figure 2).

The results found in the present study agree with the statement by Brioschi[23] when it suggests that thermography can be used as a supporting exam for medical diagnosis. In the occupational medicine field, Rosenblun and Liebeskind[49] also state that the use of thermography in the medical expert report helps in the study of the pain evolution and in the inflammation diagnosis in musculoskeletal conditions.

This study was limited by the volunteers' profile, since the results of a similar study conducted with athletes with high fat percentage, may not present the same support possibilities to the diagnosis. Another limitation was the athletes' training routine, since it did not permit the CK follow-up during the 72 hours post-training.

CONCLUSION

The results of the present study suggest the possibility of use thermography to, joined to the creatine kinase, determine the intensity and site of the post-training muscular injuries, since the cited biochemical marker is not able to determine the anatomic site of the muscular injury.

It was verified in this research the importance to control the fat layer of the evaluated area since it interferes in the temperature absolute values and can significantly influence on the results of the studies with subjects with heterogeneous lipid profile.

Thus, it can be said that thermography presents good potential to support the diagnosis of muscular injuries in athletes of many modalities. Its operationalization requires environment with controlled temperature and acquisition of equipment similar to the one used in this study. The mean cost of this equipment is R$ 50,000.00. Finally, further studies with soccer athletes ando f other modalities using besides creatine kinase, imaging diagnosis methods should be carried out.

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