USING SKIN TEMPERATURE AND MUSCLE THICKNESS TO ASSESS MUSCLE RESPONSE TO STRENGTH TRAINING

UTILIZANDO A TEMPERATURA DA PELE E A ESPESURA DO MÚSCULO PARA AVALIAR A RESPOSTA AO TREINAMENTO DE FORÇA

USO DE LA TEMPERATURA DE LA PIEL Y EL ESPESOR DEL MÚSCULO PARA EVALUAR LA RESPUESTA AL ENTRENAMIENTO DE FUERZA

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ABSTRACT

Introduction: Several studies already reported the response of many biomarkers after strength training, but studies using low cost diagnostic imaging tools are rare. Objective: To evaluate the usage of skin temperature and muscle thickness (MT) to monitor muscle response (until 96 hours after) to high-intensity strength training. Methods: This is a short-term longitudinal study with 13 trained, healthy male volunteers. Volunteers performed five sets of biceps bi-set exercise with their dominant arm with dumbbells, with load of 70% of one-repetition maximum (1RM). The ultrasound (US) and thermal images were acquired before and immediately after the last set, 24, 48, 72 and 96 hours after exercise. Results: The analysis was divided in two stages: acute muscle response (until 24 hours after training) and delayed muscle response (from 24 to 96 hours after training). The elbow flexors thickness showed the peak value immediately after the last set of training. Skin temperature (on elbow flexors) and the elbow flexors thickness grew continuously from 24 to 96 hours after strength training. Conclusions: The US images showed high sensibility for muscle physiological changes on the first 24 hours after exercise. On the other hand, the thermal images had higher sensibility for muscle physiological changes than US images from 24 to 96 hours after training.

Keywords: musculoskeletal system, musculoskeletal physiological phenomena, ultrasonics, thermography, resistance training.

RESUMEN

Introducción: Varios estudios ya relataram a la respuesta de muchos biomarcadores después de entrenamiento de fuerza, mas los estudios que utilizan herramientas de diagnóstico por imagen de bajo costo son raros. Objetivo: Evaluar el uso de la temperatura de la piel y del espesor del músculo (EM) para monitorear la respuesta muscular (hasta 96 horas después) al entrenamiento de fuerza de alta intensidad. Métodos: Este es un estudio longitudinal de corta duración con 13 voluntarios entrenados y saludables del sexo masculino. Los voluntarios realizaron cinco conjuntos de ejercicios bi-set para bíceps con el brazo dominante, con pesas, con carga de 70% de una repetición máxima (1RM). Las imágenes de ultrasonido (US) y térmicas fueron obtenidas antes y inmediatamente después de la última serie, 24, 48, 72 y 96 horas después del ejercicio. Resultados: El análisis fue dividido en dos etapas: respuesta muscular aguda (hasta 24 horas después) y respuesta muscular tardía (hasta de 96 horas después) al entrenamiento de fuerza de alta intensidad. Métodos: Este es un estudio longitudinal de corta duración con 13 voluntarios entrenados y saludables del sexo masculino. Los voluntarios realizaron cinco conjuntos de ejercicios bi-set para bíceps con el brazo dominante, con pesas, con carga de 70% de una repetición máxima (1RM). Las imágenes de ultrasonido (US) y térmicas fueron obtenidas antes e inmediatamente después de la última serie, 24, 48, 72 y 96 horas después del ejercicio. Resultados: El análisis fue dividido en dos etapas: respuesta muscular aguda (hasta 24 horas después) y respuesta muscular tardía (hasta de 96 horas después) al entrenamiento de fuerza de alta intensidad. Conclusión: Las imágenes de US mostraron alta sensibilidad para alteraciones fisiológicas en el músculo en las primeras 24 horas después del ejercicio. Por otro lado, las imágenes térmicas mostraron mayor sensibilidad para alteraciones fisiológicas que las imágenes de US entre 24 y 96 horas después del entrenamiento.

Palavras-chave: sistema musculoesquelético, fenómenos fisiológicos musculoesqueléticos, ultrassom, termografia, treinamento de resistência.

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INTRODUCTION

During the performance of physical exercise, there is an increased metabolic rate and therefore increased internal heat\(^1\). This changes the heat balance and activates the mechanism responsible for heat loss mediated by hypothalamic complex feedback system. This system controls the redistribution of blood flow from the inactive areas for the active ones during exercise\(^2\). Later, with the continuity of the exercise, occurs the redirection of blood flow to the skin, in order to exchange heat with the environment\(^2\).

Among subjects physically active, most of them aim to muscle hypertrophy, which can be obtained through the so-called strength training (ST). This method is usually accomplished with the use of extracorporeal load and leads to stimulation of satellite cells and metabolic stress\(^3\). All this makes the exercised muscle develop some level of inflammation that is repaired during the recovery period\(^4\).

The muscle inflammation resulting from strength training reflects the muscle damage (destruction of muscle fibers and liberation of metabolites) that occurs during muscle contraction performed with high loads\(^5\). This process also involves volume changes in muscle fibers, the release of several biochemical markers and local heat production\(^6\). There are many methods that can be used to assess the extent post-exercise muscle damage: creatine kinase\(^4\), magnetic resonance imaging (MRI)\(^7\), thermography\(^8\) and ultrasoundography\(^9\).

Thermography is a harmless, non-invasive, non-ionizing able to measure the skin temperature, at a distance, with high precision and displaying high resolution images. This technique quantifies the information in real time, differentiating temperature differences smaller than 0.05°C\(^1\). The use of thermal imaging in fusion with MRI images has been recommended for the diagnosis and monitoring of muscle damage due to high sensitivity to physiological changes (temperature) in muscle level\(^6\).

Ultrasoundography has lately been used in research as a way to assess muscle damage and the muscle volume\(^6,8\). Studies have applied this technique both in trained subjects as untrained by the assessment of muscle thickness, which variation was associated with the occurrence of edema in the post-workout period\(^9,10\).

Several studies\(^11-13\) already reported the response of many biomarkers after strength training, but studies using low cost diagnostic imaging tools (as ultrasoundography and thermography) are rare. Authors\(^14\) have reported a high correlation in the diagnosis of handle repetitive strain injuries (RSI) and work-related musculoskeletal disorders (WMSD) between the assessment by ultrasound and thermography, however, although there are studies evaluating muscle recovery through ultrasound\(^9,10\) or by thermography\(^1,4\) in isolation but there is no known correlation between the results of these assessment tools in the post-workout period or the best period to use one or another. Thus, the aim of this study was to evaluate the usage of skin temperature and muscle thickness (MT) to monitoring the muscle response (until 96 hours) to high-intensity strength training.

METHODS

This work is a short-longitudinal study made with 13 trained male apparently healthy volunteers. All volunteers (age of 24.92±2.7 years; weight 75.52±7.78 Kg; and height 1.77±0.07 m) were selected by the inclusion criterion: a) were used to strength training for at least 3 month; b) did not had any physical activities during the data collection period (three weeks); c) signed the Free and informed Consent term that has been approved by the Human Research Ethics Committee of Centro Universitário Campos de Andrade (UNIANDRADE) under number 28901414.3.0000.5218.

Experimental Protocol

The muscle group selected was the elbow flexors (biceps brachii and brachialis). This muscle group was chosen because it has a low subcutaneous fat layer, which allows a good heat transfer from muscle to skin\(^15,16\).

The sample (13 volunteers) made one-repetition maximum test (1RM) seven days before the beginning of the tests. The 1RM was determined using the Kraemer and Fry protocol\(^17\), with three to five attempts for bi-set exercise. No exercise was performed between the 1RM tests.

The first experimental day began with the acclimatization of the volunteers during 15 minutes in a room with controlled temperature of 24°C ± 0.3°C before the thermal images acquisition and after that the US images were acquired.

Volunteers performed five sets of biceps bi-set exercise with dominant arm (eight bicep curl repetitions and eight biceps hammer curls each set) with dumbbells. The load of exercise was 70% 1RM, with constant velocity of 1 second in the concentric phase and 1 second of eccentric phase (60rpm) controlled by a metronome. The rest time between sets was 90s.

The thermal images were acquired before the exercise and immediately after the last set, sitting the volunteer in a chair 1.5m from the thermal camera on anatomic position. The US images were obtained after the thermal images acquisition applying the US probe parallel to the muscle fiber orientation, in the middle distance of acromion process and lateral epicondyle of humerus, before and after volunteers perform all the practice protocol.

At the four following days, were obtained the thermal and US images exactly 24, 48, 72 and 96 hours after exercise. All days, were recorded thermal image after 15 minutes acclimatization, following the US image.
Instrumentation and Data Acquisition

The first part of thermal images acquisition protocol was the muscle delineation using tapes (which reduces the emission of infrared radiation) in order to help identify the region of interest (ROI). Thermal images were acquired from both arms (figure 1) with thermographic camera (FLIR® Systems Inc. Model SC2000, United States of America (USA)), and a computer (with specific software for acquisition and processing of thermographic images: ThermaCam™ Researcher Pro 2.9 from FLIR®). To monitor the temperature and humidity of the room was used a term digital hygrometer. The thermographic camera used has a high resolution (320 x 240 pixels), which measures temperatures ranging from -20° C to +120° C. This camera has a sensitivity to detect differences of less than 0.1°C temperature and provides accuracy of ± 1°C of the actual temperature (figure 1).

Ultrasonographic images are an established method of assessing muscle thickness11. The ultrasonographic images were acquired at the midpoint of biceps brachii, as illustrated in figure 2, using an Aloka SSD 500V real time scanner equipped with a linear probe of 7.5 MHz. This measurement was performed to evaluate the muscle thickness in all studied moments.

### Table 1. Descriptive statistics for sample characterization (N=13 male volunteers), Vila Real, Portugal, 2014.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Average</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years old)</td>
<td>20.00</td>
<td>33.00</td>
<td>24.77</td>
<td>3.35</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>57.00</td>
<td>94.00</td>
<td>75.38</td>
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<tr>
<td>Height (m)</td>
<td>1.60</td>
<td>1.80</td>
<td>1.73</td>
<td>0.06</td>
</tr>
<tr>
<td>Control biceps temperature (°C)</td>
<td>30.40</td>
<td>33.10</td>
<td>31.75</td>
<td>0.81</td>
</tr>
<tr>
<td>Exercise biceps temperature (°C)</td>
<td>30.20</td>
<td>33.20</td>
<td>31.51</td>
<td>0.78</td>
</tr>
<tr>
<td>Biceps muscle thickness (mm)</td>
<td>27.00</td>
<td>36.00</td>
<td>30.70</td>
<td>2.70</td>
</tr>
</tbody>
</table>

SD: standard deviation.

### Statistical Analysis

Shapiro-Wilk test was performed to test the variable distributions and descriptive statistics (means and SD) were used to summarize the characteristics of the study sample. Pearson correlation coefficient (r) was used for quantify the association between ultrasound images and skin temperature (on elbow flexors) at the following moments: before, immediately after, 24h, 48h, 72h and 96h after exercise. The paired t test was used to compare the skin temperature between both arms, and one-way analysis of variance (ANOVA) was used to evaluation the difference of MT and Skin temperature, among all moments evaluated. The Statistical analyses were performed with significance level of 95% (p < 0.05) using Statistical Package for Social Sciences (SPSS, version 21.0, USA).

### RESULTS

All variables showed Gaussian distribution after performed Shapiro-Wilk test. The studied sample can be characterized by variables showed in table 1.

After exploratory data analysis and considering the time course of physiological events related to high-intensity exercise, it was decided to divide the analysis of the results in two stages: Muscle acute response (until 24h after training), showed in figure 3, and muscle delayed response (from 24h to 96h after training), showed in figure 4. Muscle thickness showed the peak value immediately after the last set of training. It was also analysed the correlation between the thermal response and the muscle thickness (table 2). In this table was presented the Pearson correlation coefficient (r) for some situations of analysis. It can be pointed out that the correlation for delayed response of exercise biceps temperature and biceps muscle thickness (moments showed in figure 4) was 0.941 (p = 0.017).

### DISCUSSION

The aim of this study was to evaluate the usage of skin temperature and muscle thickness (MT) to monitoring the muscle response (until 96 hours) to high-intensity strength training. The values of MT found before training (30.70 ± 2.70mm) agree with those found by Fukunaga et al.,18 who evaluated a sample of 160 university male students and reports an average of 30.00 ± 3.30mm. In the same direction, the temperature
of the biceps before training agrees with that found by Neves et al.\textsuperscript{15} where the mean skin temperature of the biceps was 31.10 ± 0.80°C.

Regarding to the first stage of muscle response to a strength training (until 24h), in the present study, significantly increases of MT were observed immediately after exercise (16.61% more than the before exercise values) with posterior decreasing at 24h (3.26%). This result agrees with those found by Flores et al.\textsuperscript{12} that monitored MT of elbow flexors after a session of exercise performed by eight sets with 10 maximum repetitions of load. They observed significantly increases immediately after exercise (11.94%), decreasing at 24h (7.44%). And it also agrees with statistical differences among the moments 48h, 72h, and 96h and the reference values (before exercise). Authors\textsuperscript{1, 4} have already reported the use of thermal images in the evaluation of muscle damage and monitoring of muscle recovery.

In the present study, thermal images seem to have more sensibility than US images because the last one has not shown statistical differences among the delayed muscle response moments, and the first one did it. On the other hand, at the acute muscle response, the US images were more sensible.

In the present study, it was observed a high correlation between exercise arm temperature and control arm temperature during delayed muscle response (figure 5). Although the explanation for the increase in temperature is a local inflammation, which in this case should occur only in the arm exercise, other authors\textsuperscript{19, 20} have reported that the application of localized vascular stimulus can cause a systemic endothelial adaptation. This could explain the increase of temperature in the control arm during the late response.

In delayed muscle response period (from 24h to 96h), the muscle thickness did not show statistical significance in the present study. On the other hand, in this period, thermal images analysis showed a rise of skin temperature highly correlated with the MT variation ($r=0.941$, $p=0.017$) and with statistical differences among the moments 48h, 72h, and 96h and the reference values (before exercise). Authors\textsuperscript{1, 4} have already reported the use of thermal images in the evaluation of muscle damage and monitoring of muscle recovery.

We would like to thank Exército Brasileiro and CNPq for important funding and financial support.

**CONCLUSIONS**

We may conclude that the skin temperature (on elbow flexors) and the elbow flexors thickness grew continuously from 24h to 96h after strength training. There is a high correlation between skin temperature and muscle thickness during the 96h after strength training. The US images showed higher sensibility for muscle physiological changes than thermal images on the first 24h after exercise. On the other hand, the thermal images had higher sensibility for muscle physiological changes than US images from 24h to 96h after training.

**ACKNOWLEDGEMENTS**

We would like to thank Exército Brasileiro and CNPq for important funding and financial support.

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