Changes in Skin Temperature During Muscular Work: a Pilot Study

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Abstract — What mechanism has greater influence on skin temperature during, and after, the muscular work: peripheral vasoconstriction or muscle heat dissipation? And yet, at what time each one preponderates? In this sense, the present study aimed to analyze, in time domain, the skin temperature variations during muscular exercise. This study can be characterized as a short-term longitudinal study. The study was conducted with two male able-bodied volunteers, with 22 and 23 yrs, both physically active. The exercise proposed was the unilateral biceps curl, with dominant arm. The data from the contralateral arm was used as control. A Visual Analogue Scale (VAS) for pain was used to monitor the muscular pain perception during 48 hours after the exercise. The results show the temperature decreases during the first minute (between the start and the end of the first set of exercise). The end of 3rd set can be observed an average increase in the temperature of study arm of approximately 8.4% compared to the initial temperature and an average difference of approximately 6.6% compared to the control arm. In conclusion, the temperature of the skin over the main muscle of high-intensity exercise (performing until fatigue) decreases at the initial stage and then increases continuously until muscle fatigue. The exercise induced muscle damage (EIMD) can be predicted by assessment of muscle skin temperature 24 hours after exercise.

Keywords: skin temperature, exercise, thermography.

Resumo — Que mecanismo tem maior influência sobre a temperatura da pele durante e após o trabalho muscular: a vasoconstrição periférica ou a dissipação de calor do músculo? E, ainda, em que momento cada um deles prepondera? O objetivo foi analisar, no domínio do tempo, as variações de temperatura da pele durante o exercício muscular. Este estudo pode ser caracterizado como um estudo longitudinal de curto prazo. O estudo foi realizado com dois voluntários sãos do sexo masculino, com 22 e 23 anos, fisicamente ativos. O exercício proposto foi a rosca bíceps unilateral, com o braço dominante. Os dados a partir do braço contralateral foram utilizados como controle. A Escala Analógica Visual (VAS) para dor foi utilizada para monitorar a percepção da dor muscular durante 48 horas após o exercício. Os resultados mostram que a temperatura diminui durante o primeiro minuto (entre o início e o fim da primeira série de exercício). Ao fim da terceira série pode ser observado um aumento médio na temperatura do braço do estudo de cerca de 8,4% em comparação com a temperatura inicial e uma diferença média de aproximadamente 6,6% em relação ao grupo de controle. Em conclusão, a temperatura da pele sobre o músculo principal do exercício de alta intensidade (realizando, até a fadiga) diminui na fase inicial e, em seguida, aumenta continuamente até a fadiga muscular. A lesão muscular induzida pelo exercício pode ser estimada pela avaliação da temperatura da pele sobre o músculo, 24 horas após o exercício.

Palavras-chave: temperatura da pele, exercício, termografia.

1. INTRODUCTION

Thermography is recognized diagnostic method by American Medical Association since 1987(1). This method involves the detection of infrared radiation emitted by the skin and provides the analysis of physiological functions related to the skin temperature control noninvasively, without exposing the patient to any radiation (2). Authors (2) point out that the training of high performance leads the locomotor system to physiological limits and that thermography could be a tool for monitoring this process.

Studies (3, 4) have evaluated the recent behavior of skin temperature (SKt) in response to exercise . A common point of these studies was a SKt reduction on several body parts in the initials moments of the training. To the authors researched, this initial reduction occurs due an action of directing blood flow to the active muscles, generated by a reflex cutaneous vasoconstriction.

Moreover, the study of Formenti *et al.* (5) showed that the surface of the skin in the area where the muscle activity is happening showed an increase in its temperature during and after physical activity. Thus, one important question what mechanism has greater influence on skin temperature during, and after, the muscular work: peripheral vasoconstriction or the dissipation of muscle heat? And yet, at what time each one preponderates? In this sense, the present study aims to analyze, in time domain, the skin temperature variations during and after muscular exercise.

2. METHODS

This study can be characterized as a short-term longitudinal study. The study was conducted with two male able-bodied volunteers, aged 22 and 23 years old, and physically active.

Inclusion criteria were: (a) regular physical activity for more than three times per week in the last year, (b) agree with not to do any type of regular physical activity during the period of the experiment, (c) report no history of previous biceps muscle injury, and (d) not ingest thermogenic substances that may influence the collection and interpretation of data.

The exercise proposed was the unilateral biceps curl (Figure 1), with the dominant arm. The data from the contralateral arm was used as control. The volunteers performed the proposed exercise per three sets with 50% of the weight of eight maximal repetition (MR), speed performance was 2 seconds per cycle, the sets was performed until fatigue, with 90 seconds rest interval between them.

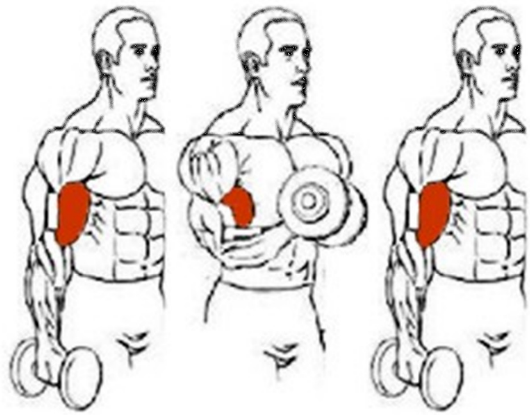

Figure 1. Ilustration of the exercise unilateral biceps curl.

The data collection was performed with 26°C environment temperature. The volunteers remained in the room for 15 minutes to achieve thermal balance before the protocols.

Thermal images were acquired at the following times : (a) before the first set, (b) immediately after the first set, (c) before the second set, (d) immediately after second set, (e) before the third set, (f) immediately after the third set, (g) 24h after training, and (h) 48 hours after training.

Thermal images were acquired with a thermal imager FLIR Systems Inc., model SC2000 and analyzed by software ThermaCam™ Researcher Pro 2.9. The thermographic camera used has a resolution of 320 x 240 pixels , which has sensors that measures temperatures ranging from -20 ° C to 120 °C , with sensitivity to detect differences of less than 0.1 °C temperature. A digital term hygrometer was used to monitor the environment temperature and humidity. The emissivity of the device was adjusted to 0.98 and the relative humidity was kept at 60% during the experiment, and Thermal images were acquired at a distance of 1.5 m.

The considered values of temperatures were collected at the medial point of the brachial biceps muscle, as illustrated in Figure 2 (6).

A Visual Analogue Scale (VAS) for Pain, illustrated in Figure 3, was used to monitor the muscular pain perception in the 24 hours and 48 hours after training. The scale had a 10 cm (100mm) long line marked "Without Pain" at one end, and "Unbearable Pain" at the opposite end.

To fill the VAS, the volunteers were asked to carry out the execution of three repetitions of the biceps curl exercise with 20% a weight of 8 MR.

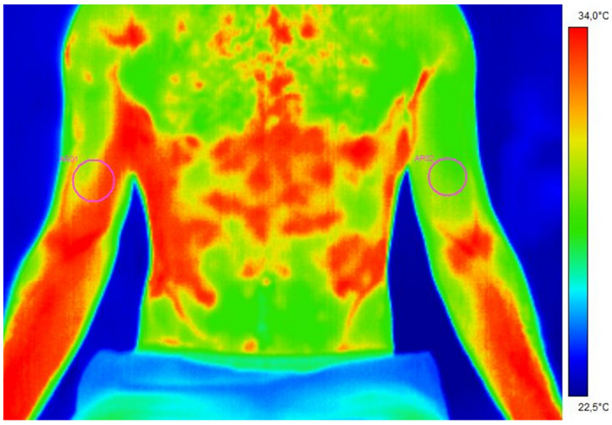

Figure 2. Ilustration of protocol analysis of thermal images.

The research protocol was explained for both volunteers, who signed the informed consent before participation in the study, in accordance with the Declaration of Helsinki.

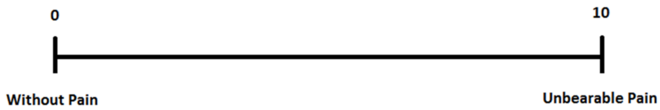

Figure 3. Visual Analogue Scale (VAS) for pain.

The statistical analysis was performed with descriptive values and graphics created by custom-written MatLab® software version R2008a.

3. RESULTS

The volunteers presented good physical conditions. The body mass index was 25.51 and 22.15 for the volunteers 1 and 2, respectively. The Figure 4 shows the results of biceps brachial SKt in all instants during the exercises.

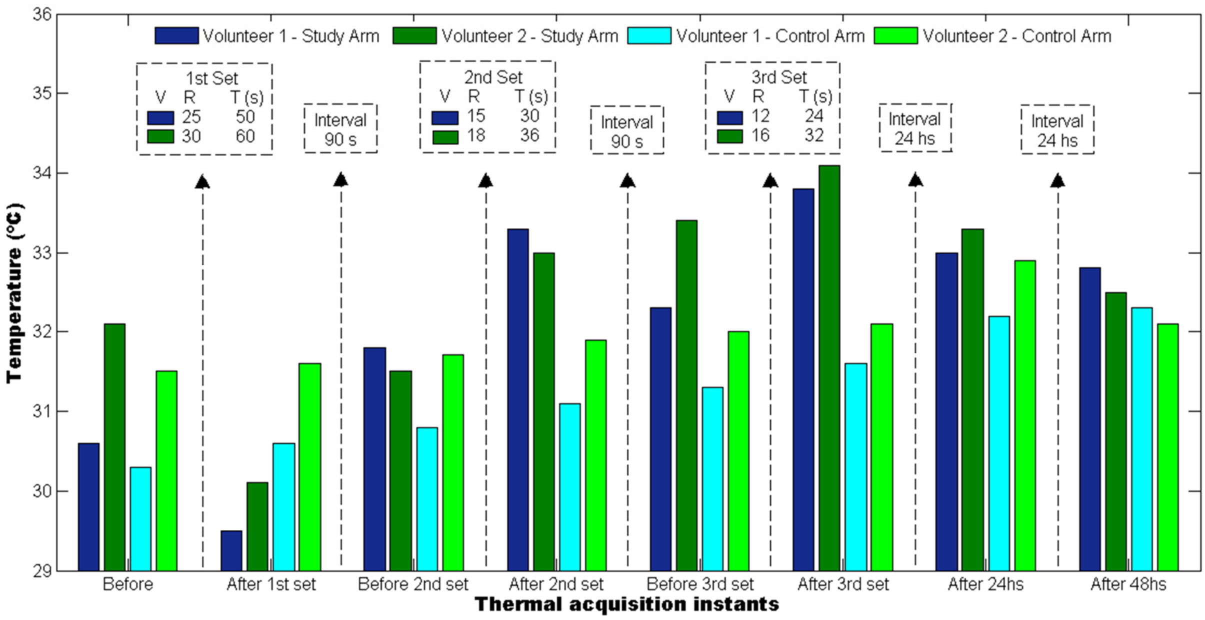

Figure 4. Experimental research design.
Legend: V= volunteer, R = repetition, T = Period

The Figure 4 shows that the temperature decreases during the first minute (between the start and the end of the first set of exercise). The end of 3rd set can be observed an average increase in the temperature of study arm of approximately 8.4% compared to the initial temperature and an average difference of approximately 6.6% compared to the control arm. The total period of exercise was 284s and 308s to volunteer 1 and 2, respectively. Moreover, the temperature difference between study and control arm have remained constant during the 48hs after training. However, the values of SKt were increased during this time.

The Visual Analogue Scale (VAS) for Pain show values of 1.4 and 0.2 for the volunteer 1;

and 1.2 and 1.4 for the volunteer 2, for the 24 and 48 hours after evaluations, respectively.

4. DISCUSSION

Several areas have used image analyses to monitoring body conditions and abilities (7-10). The knowledge about how the physiological process occurs is the most important information to the correct diagnosis. Exercise is associated with skin hemodynamic changes because increase the heat generation within the body and invokes cutaneous thermo-regulatory processes (3).

The results of this study are in agreement with the findings of Formenti *et al.* (5) that investigated thermoregulation of a local gastrocnemius area involved in a localized steady-load exercise (standing heels raise) regarding the time gradual warming of the skin over the muscle that performs the main work. Moreover, the findings of Formenti *et al.* (5) not show SKt decrease during the first minute, as can be seen in Figure 4.

The present study indicated a continuous increase in temperature throughout the exercise period (296 ± 17s), reaching its maximum at the end of the protocol. In the same direction, the similar results were observed during the experiment performed by Formenti *et al.* (5).

In other hand, Merla *et al.* (3) investigated the behavior of the SKt of large body segments during the execution of a protocol running on a treadmill with progressive load for about 12 minutes, and noted the decrease in SKt in all body segments analyzed, including thigh. Moreover, Grzegorz et al.(11) evaluating seven women in athletic tracks found that SKt in all (except shin in front side) body segments analyzed decrease after the exercise. These discrepant findings may be explained by the difference in intensity of exercise protocols and the difference in energy production systems involved in the experiments.

In studies of Merla *et al.* (3) and Grzegorz et al. (11), the subjects used predominantly aerobic system, as in the present study and the experiment performed by Formenti *et al.* (5), there was a predominance of anaerobic lactic system.

The injury diagnosis by thermal images is based in normal pattern of temperature and symmetry. The increased or decreased dermal temperature differentials can be indicative of injury (12). Usually, the muscle injuries present asymmetries high than 0.60°C (2, 6). Thus, the differentials between study and control arms observed before the exercise can be considered normal. In the same direction Ludwig (13) pointed that considering the skin temperature dependent of the blood flow, an explanation to the small thermal asymmetry between body regions is the possibility of different capillarization due to reasons such as level of training or professional activities.

Regarding the change in skin temperature during 48 h after exercise, there was no significant variation in temperature between the study and control arms observed. These results do not agree with those found by Hani *et al.* (14) that conducted a similar study. Those authors observed a significant difference in SKt between the study arm and the control at 24 hours after exercise. This disagreement may be due to differences in sample size studied.

Exercise induced muscle damage (EIMD), also known as delayed onset muscle soreness (DOMS), is commonly experienced in athletes who exercise beyond their normal limits of training (14). According to Frey Law *et al.* (15), the EIMD can be measured using a visual analog scale (VAS). In this study it was observed that increasing the SKt in 24 hours after exercise was accompanied by the appearance of EIMD levels between 1.2 and 1.4. This result was also observed by Hani *et al.* (14). Those authors believe that the SKt 24 hours after exercise is predictive of EIMD.

The present study was limited by the small sample. New studies are recommended in order to confirm these findings during similar exercises.

5. CONCLUSION

In conclusion, the temperature of the skin over the main muscle of high-intensity exercise (performing until fatigue) decreases at the initial stage and then increases continuously until muscle fatigue. Therefore, it can be interpreted that with regard to the control of skin temperature, peripheral vasoconstriction acts mainly during the first minute of an exercise whose primary energy source is anaerobic lactic, and the heat generated by muscle activity reaches the surface of the skin after first minute in this kind of exercise.

Finally, the results suggest that the exercise induced muscle damage (EIMD) can be predicted by assessment of muscle skin temperature 24 hours after exercise. In future work, we intend to increase the sample and compare different intensities of the same exercise, in different genres and age groups.

ACKNOWLEDGMENT

Authors thank to Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES), Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) and Universidade Tecnológica Federal do Paraná (UTFPR) for financial support.

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