THE USE OF THERMOGRAPHY AND ITS CONTROL VARIABLES: A SYSTEMATIC REVIEW

ABSTRACT

Introduction: Muscle injuries are the most frequent cause of physical disability in sports, representing a large percentage of all sports injuries. In high-performance sports in particular, there is great interest in optimizing the process of diagnosis and rehabilitation of muscle injuries in order to reduce the amount of time taken off by athletes due to their injuries. Infrared thermography, or cutaneous thermometry, is a technique used for complementary investigation of pain. It provides thermal imaging with an infrared camera, to measure the surface temperature of the body. Objective: To conduct a systematic review of the use of thermography as a functional evaluation for the identification and prevention of muscle injuries, and of the control variables used in its applicability. Methods: A systematic review was conducted in the MEDLINE, ResearchGate and Scielo databases, using the search terms: “thermography”, “muscle injury”, “rehabilitation” and “diagnosis”, searching on articles published from 2000 to 2017, in Portuguese, English and Spanish. The eligibility criteria for the studies was the use of thermography as an outcome, and the reporting of standards for evaluating skin temperature variation in athletes. Results: Following the systematic review, 94 studies were retrieved. Of these, only 12 met the criteria for inclusion in the study. Conclusion: Thermography is a suitable tool for the evaluation and prevention of muscle injuries in athletes, and care should be taken with the control variables during its use. The most efficient variables for capturing the thermographic image appear to be an environment with a temperature of between 18 and 25ºC, for 15 minutes for acclimatization, and with the individual placed in a pre-determined position, depending on the body segment being evaluated, without contact with another object. Level of evidence I; Systematic review.

Keywords: Thermography; Injury; Sport; Rehabilitation; Diagnosis.

RESUMO

Introdução: As lesões musculares são a causa mais frequente de incapacidade física nos esportes, representando uma grande porcentagem de todas as lesões esportivas. Principalmente nos esportes de alto desempenho, há um grande interesse em otimizar o processo de diagnóstico e reabilitação das lesões musculares, a fim de reduzir o período perdido pelos atletas devido às lesões. A termografia infravermelha ou termometria cutânea é uma técnica utilizada para investigação complementar da dor. Ela apresenta imagens térmicas com uma câmera infravermelha para medição da temperatura da superfície do corpo. Objetivo: Realizar uma revisão sistemática sobre o uso da termografia como uma avaliação funcional para a identificação e prevenção de lesões musculares e das variáveis de controle utilizadas em sua aplicabilidade. Métodos: Foi realizada uma revisão sistemática nas bases de dados MEDLINE, ResearchGate e Scielo utilizando os seguintes termos: “thermography”, ”muscle injury”,”rehabilitation” e ”diagnosis”, com busca nos artigos publicados no período compreendido entre 2000 e 2017, nos idiomas português, inglês e espanhol. Os critérios de elegibilidade para os estudos era a utilização da termografia como um desfecho e o registro dos parâmetros para avaliação da variação da temperatura da pele nos atletas. Resultados: Após a revisão sistemática, 94 estudos foram encontrados, sendo que desses apenas 12 atenderam aos critérios para inclusão no estudo. Conclusão: A termografia é uma ferramenta adequada para avaliação e prevenção de lesões musculares em atletas e deve-se considerar as variáveis de controle durante o seu uso. As variáveis mais eficientes para captura da imagens termográfica parece ser um ambiente com temperatura entre 18 e 25ºC, por 15 minutos para acclimatização e com o indivíduo disposto em uma posição pré-determinada, dependendo do segmento corporal a ser avaliado, sem contato com outro objeto. Nível de evidência I; Revisão sistemática.

Descritores: Termografia; Lesão; Esportes; Reabilitação; Diagnóstico.

RESUMEN

Introducción: Las lesiones musculares son la causa más frecuente de incapacidad física en los deportes, representando un gran porcentaje de todas las lesiones deportivas. Principalmente en los deportes de alto desempeño, hay un gran interés en optimizar el proceso de diagnóstico y rehabilitación de las lesiones musculares, a fin de reducir el período perdido por los atletas debido a las lesiones. La termografía infrarojo o termometría cutánea es una técnica utilizada para investigación complementaria del dolor. Presenta imágenes térmicas con una cámara de infrarrojos, para medir la temperatura de la superficie del cuerpo. Objetivo: Realizar una revisión sistemática sobre el uso de la termografía como una evaluación funcional para la identificación y prevención de lesiones musculares y de las variables de control.
The muscle injuries (MI) are the most frequent cause of physical disability in sports practice, representing 90% of the acute sports injuries.1,2

The MI occur when the force exerted on the muscle leads to an excessive stretching of the myofibrils and to break next to the myotendinous junction, and may be caused by bruising or stretches.3 The risk of LM increases in professional-level athletes and their high prevalence is well documented in several sports, as in elite football, which represents 20 to 37% of injuries.3

The LM constitute almost one-third of injuries that lead to the absence of sports practice in elite football athletes, and represent more than a quarter of the time dedicated to the rehabilitation of injuries.4 In a men’s elite soccer team, the MI takes a mean time of 223 days of absence, with the loss of 148 training sessions and absence in 37 official games, which justifies great relevance for the detection and treatment of MI not only for athletes, but also for the sports clubs.1 From an economic point of view, a study done in England showed that the mean cost of an elite athlete away during a month, for recovery due to injury, is approximately 50 thousand euros.5 For this reason, mainly in the sport of high yield, there is great interest in optimizing the process of identification of MI, to decrease the time of absence of the athlete from its role.6

Once the muscle tissue has been injured, the ruptures of cytoskeletal structures cause morphological and biochemical changes in muscle fibers, as a result of injuries on fibers, with subsequent inflammatory process.5

Yet, due to the increased blood flow near the area in which the injury occurred, there are thermal variation with increased local temperature.5 Although the diagnosis of MI occurs usually by clinical examination, the complementary tools are important for a better understanding of the extent and location of the injury, prognosis, estimated time of recovery, appropriate time to return to sports activities and risk of recurrence.1,7

The decision on the correct moment to return to the sport is of extreme relevance, since, when carried out so early, is one of the main factors for relapse of MI.8,9 In addition, the prognosis, done in a more precise way, facilitates the planning of sports training and the composition of the team of a sports club.8

The infrared thermography (IRT) is a technique in which to obtain images with an infrared camera, which measures the surface temperature of the body.10,11 The analysis of infrared images have as advantages: efficacy, safety, be a noninvasive technique, be painless, without contact, without ionizing radiation, without side effects and without contraindications.5,12,13 In addition to providing the temperatures on a surface in real-time images, enabling the location of the injury and be able to demonstrate physiological changes through a functional examination.12,13 The IRT is an important support tool for physiotherapists, aiding in the interpretation of the treatment performed with the athlete.14

The objective of this technique is not to replace the clinical examination, but rather enhance it, and serves as instant feedback.13

To obtain good results of the images and the values of skin temperature, some experts have suggested to control and manipulate some variables, such as temperature, relative humidity, time of acclimatization and position of the subject evaluated during its use. In this context, the objective of this study was to perform a systematic review on the use of the TIR for the functional evaluation for identification and prevention of muscle injuries, and on the control variables used in its applicability.

**METHODS**

Search was performed in databases MEDLINE, Research Gate e Scielo Using the following terms: “thermography”, “muscle injury”, “rehabilitation” and “diagnosis”. The search was conducted initially with the combination of terms “thermography” and “muscle injury”, and subsequently with these terms plus the term “rehabilitation” and the term “diagnosis”, in distinct searches, both connected by boolean AND. In the Scielo database were used the same terms to search in portuguese: “termografia”, “lesão muscular”, “reabilitação” and “diagnóstico”. Were included articles published in the period between 2000 and 2017, in portuguese, english and spanish.

From the reading of the titles, abstracts and articles in their entirety, were selected articles that contain information about the parameters used for the thermography collection, having as outcomes the use of thermography, with standardized parameters for evaluation of the variation of skin temperature, variables to control the temperature, the relative humidity of the air, the time to acclimate and the position of the individual. Were excluded narrative review articles, systematic and meta-analysis.

**RESULTS**

After the completion of the systematic review were found 94 studies. Of these, 30 were selected after reading the titles and 12 were included after the reading in its entirety, which used the TIR with standardized parameters for evaluation of the variation of skin temperature. Table 1 describes the sample, the parameters used in the applicability of TIR, musculoskeletal injuries assessed and conclusion.

| Table 1: Sample and Parameters Used in the Applicability of TIR |
|---------------------------------------------------------------|
| Athlete and Injury Type | Parameters Used |
|-------------------------|-----------------|
| Acute MI                | TIR with parameters |
| Elite Athletes          | TIR with parameters |

In Table 2 are presented the descriptions of control variables that the present study proposed to analyze, in addition to the number of studies that used the same parameter and the bibliographic references. In this sense, the Table 2 describes the ambient temperature, the relative humidity of the air, the time to acclimate and the position of the individual during the use of the TIR.
Table 1. Description of the sample, the parameters used in the applicability of the thermography, musculoskeletal injuries assessed and the completion of the studies.

| Reference          | Sample                        | Parameters used          | Injury                                      | Conclusion                                                                                       |
|--------------------|-------------------------------|--------------------------|---------------------------------------------|--------------------------------------------------------------------------------------------------|
| Bandeira et al. 1(2014) | 21 rugby athletes             | Temperature: between 22 e 23°C  | NA                                          | It can be concluded that the thermography can be used as a method of location of muscle injury in athletes, associated with the use of CK. However, it is suggested the option for analysis by visual inspection, as is the case of other imaging exams. |
|                    | Male                          | Humidity: 50%            |                                             |                                                                                                  |
|                    | Aged between 19 e 31 years    | Time to acclimate: 30'    |                                             |                                                                                                  |
|                    | (mean age 25,06)             | Orthostatic position     |                                             |                                                                                                  |
|                    | Dresses only with underwear  |                          |                                             |                                                                                                  |
| Lima et al. 13(2015)| 50 subjects                  | Temperature: 22°C         | Chronic pain                                | The thermographic study of whole body with the acquisition of images following the protocol described in patients with chronic pain allowed the identification and classification of secondary injuries and dysfunctions of great importance in comparison to a thermographic analysis if they were restricted only to the topography of the main complaint. |
|                    | Female and male              | Humidity: below 60%       |                                             |                                                                                                  |
|                    | Aged between 20 e 83 years   | Time to acclimate: 15'    |                                             |                                                                                                  |
|                    | Orthostatic position         |                          |                                             |                                                                                                  |
| Salazar-López et al.13 (2010)| 62 workers                  | Temperature: 20°C         | LER/DORT                                    | The skin thermography by infrared thermography showed itself as a supplementary method useful and objective to support the expert evaluation of the variables that interfere with the ability to work, since its validity and maximum degree the inability. |
|                    | Female and male              | Humidity: 55%             |                                             |                                                                                                  |
|                    | Mean age 32 ± 13 years       | Time to acclimate: 15'    |                                             |                                                                                                  |
|                    | Orthostatic position         |                          |                                             |                                                                                                  |
| Merla et al. 18 (2009)| 7 asymptomatic subjects females | Temperature: 24°C       | Tendinopathy patellar and anterior cruciate ligament injury |                                                                                                  |
|                    | Aged between 26 e 46 years   | Time to acclimate: 15'    |                                             |                                                                                                  |
|                    | Orthostatic position         |                          |                                             |                                                                                                  |
| Ammer (2002)       | 18 athletes                  | Temperature: 23°C         | NA                                         | The temperature changes observed immediately after the manual therapy can be caused by manual examination of the cervical spine. |
|                    | Male                          | Time to acclimate: 15'    |                                             |                                                                                                  |
|                    | Aged between 15 e 17 years   | Orthostatic position     |                                             |                                                                                                  |
| Chudecka et al. 17(2015)| 200 athletes                | Temperature: 25°C         | NA                                         | Difficulties in the interpretation of temperature changes in body areas in people with various conditions may be associated with the lack of studies on large populations and representative of healthy individuals. |
|                    | Female and male              | Humidity: 60%             |                                             |                                                                                                  |
|                    | Time to acclimate: 20'       | Orthostatic position     |                                             |                                                                                                  |
| Merla et al. 16 (2009)| 15 athletes                 | Temperature: between 23 e 24°C | NA                                        | The results of this study suggest the possibility of use of thermography, in conjunction with the creatine kinase, determine the intensity and location of muscle injuries post-training, once the aforementioned biochemical marker is not able to determine the anatomic location of the muscle injury. |
|                    | Female                       | Humidity: 50 ± 5%         |                                             |                                                                                                  |
|                    | Mean aged between 25,2 ± 3,1 years | Time to acclimate: 20'  |                                             |                                                                                                  |
|                    | During the implementation of the program of exercises on the treadmill |                      |                                             |                                                                                                  |
| Oliveira et al. 15(2016)| 19 patients                 | Temperature: 21,4 ± 1°C   | Ankle Sprain                                | The validation potential of infrared thermography, a secure technology, not harmful, quick and economical, for the classification of lesions of ankle sprain, can be an important indicator of classification of diagnosis in both emergency hospital settings, as well as in amateur and professional sports environments. |
|                    | Female and male              | Humidity: 37 ± 5,5%       |                                             |                                                                                                  |
|                    | Time to acclimate: 15'       | Orthostatic position     |                                             |                                                                                                  |
|                    | Position: Sitting in a chair with his limbs parallel to each other |                      |                                             |                                                                                                  |
| Salazar-López et al.20(2015)| 120 subjects                | Temperature: between 18 e 25°C | NA                                        | Thermography is a useful tool with great potential to address scientific and philosophical questions on subjective experiences, mental states and emotions. |
|                    | Female and male              | Humidity: 50%             |                                             |                                                                                                  |
|                    | Aged between 24 e 47 years   | Time to acclimate: between 10 e 15'  |                                             |                                                                                                  |
| SILVA et al. 21 (2017)| 45 subjects                  | Temperature: between 22 e 24°C | NA                                         | Thermography was more sensitive in the evaluation of exercises with different loads when expressed as a fee relating to the temperature of the forehead. These results support the use of cryoimmersion protocols to minimize the deleterious effects of heavy exercise on muscle function. |
|                    | Aged between 18 e 25 years   | Humidity: Below 50%       |                                             |                                                                                                  |
|                    | Orthostatic position         |                          |                                             |                                                                                                  |
|                    | Time to acclimate: 15'       | Orthostatic position     |                                             |                                                                                                  |
| Zaproudina et al. 22(2006)| 85 subjects                 | Temperature: between 23 and 25°C | Lowback pain                               | Temperature measurements may be useful as a test in the evaluation and documentation of thermal abnormalities and sympathetic disorders in patients with lowback pain. |
|                    | Female and male              | Humidity:                |                                             |                                                                                                  |
|                    | Aged between 30 e 49 years   | Time to acclimate: 15'    |                                             |                                                                                                  |
|                    | Orthostatic position         |                          |                                             |                                                                                                  |

NA = not apply; = minute; LER/DORT = Repetitive Strain Injury/work-related musculoskeletal disorders
Table 2. Description of the control variables: ambient temperature, relative humidity, time of acclimatization, position used, number of studies that used the same parameter and the bibliographic references.

| Ambient temperature used in studies | Number of studies | Bibliographic reference |
|------------------------------------|-----------------|------------------------|
| Between 18 e 25ºC                  | 1               | Salazar-López et al. (2015) |
| 20ºC                               | 1               | Broschi et al. (2009) |
| 21.4ºC                             | 1               | Oliveira et al. (2016) |
| Between 21,5 e 22.3ºC              | 1               | Hildebrandt et al. (2010) |
| Between 22 e 23ºC                  | 1               | Bandeira et al. (2014) |
| Between 22 e 24ºC                  | 1               | Silva et al. (2017) |
| 23ºC                               | 2               | Bandeira et al. (2012); Lima et al. (2015) |
| Between 23 e 24ºC                  | 1               | Merla et al. (2009) |
| Between 23 e 25ºC                  | 1               | Zaproudina et al. (2006) |
| 24ºC                               | 1               | Ammer (2002) |
| 25ºC                               | 1               | Chudecka et al. (2015) |
| Relative humidity used in studies   |                  |                        |
| Between 35 e 38%                   | 1               | Hildebrandt et al. (2010) |
| 37%                                | 1               | Oliveira et al. (2016) |
| Below 50%                          | 1               | Silva et al. (2017) |
| 50%                                | 3               | Bandeira et al. (2014); Merla et al. (2009); Salazar-López et al. (2015) |
| 55%                                | 1               | Broschi et al. (2009) |
| Below 60%                          | 1               | Lima et al. (2015) |
| 60%                                | 1               | Chudecka et al. (2015) |
| Time to acclimate used in studies   |                  |                        |
| Between 10 e 15'                   | 1               | Salazar-López et al. (2015) |
| 15'                                | 7               | Ammer (2002); Bandeira et al. (2012); Broschi et al. (2009); Lima et al. (2015); Oliveira et al. (2016); Silva et al. (2017); Zaproudina et al. (2006) |
| 20'                                | 3               | Chudecka et al. (2015); Hildebrandt et al. (2010); Merla et al. (2009) |
| 30'                                | 1               | Bandeira et al. (2014) |
| Position used in studies           |                  |                        |
| orthostatic position               | 8               | Ammer (2002); Bandeira et al. (2012); Bandeira et al. (2014); Broschi et al. (2009); Chudecka et al. (2015); Lima et al. (2015); Silva et al. (2017); Zaproudina et al. (2006) |
| During the implementation of the program of exercises on the treadmill | 1 | Merla et al. (2009) |
| Sitting in a chair with his limbs parallel to each other | 1 | Oliveira et al. (2016) |

**DISCUSSION**

The objective of this study was to perform a systematic review of the use of the TIR for the functional evaluation for identification and prevention of muscle injuries and the control variables used in its applicability. The TIR has several advantages, in addition to enabling the location of muscle injuries and the control variables used in its applicability. The usefulness of the TIR has been observed frequently in the sporting environment,13 its use can help prevent MI, as an indirect way of measuring the musculoskeletal damage.10 The thermal asymmetry in the

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area possibly affected can be compared with the contralateral region of the body, and this asymmetry can be able to demonstrate physiological and metabolic changes. However, some doubts in relation to the control variables for the use of the TIR underline the need for further studies that specify and justify best how to control these variables. Despite the number of articles found in the search, few articles have brought all the control variables analyzed in this review. In addition, the articles selected for this review has not brought the justification of the use of many of the control variables used during the applicability of the TIR. All the variables analyzed, when you do not have thorough control, may preclude the use of the TIR for the functional evaluation for identification and prevention of muscle injuries.

CONCLUSION

We can conclude that the TIR is a suitable tool for evaluation and prevention of MI in athletes, and that should be taken into consideration some care with the control variables during its use. Seems to be more appropriate to carry out the capture of the thermographic image keeping the room temperature between 18 and 25°C for 15 minutes to acclimate and with the individual in accordance with the segment to be assessed, without contact with another object. It was not possible to establish a consensus regarding the relative humidity of the air is ideal. Also it would be important to have a program - software that after the thermographic assessment, perform a specific measurement of data captured by the thermographic camera and indicate the scores for the levels of inflammation, the inflammatory process and possible injury. In this way the rater bias and level of knowledge of the evaluator could be minimized.

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