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Review

The use of thermal imaging to monitoring skin temperature during cryotherapy: A systematic review

Filipe Matos [a,*], Eduardo Borba Neves [a,b,c], Marco Norte [a], Claudio Rosa [a], Victor Machado Reis [a,d], José Vilaça-Alves [a,d]

[a] Sports Department, Trás-os-Montes e Alto Douro University, Quinta de Prados St, 5001-801 Vila Real, Portugal
[b] Brazilian Army, Quartel General do Exército, Setor Militar Urbano 4° Andar, 70.630-901 Brasília, DF, Brazil[1]
[c] Graduate Program of Biomedical Engineering, Federal Technological University of Paraná, Sete de Setembro Ave 3165, 80230-901 Curitiba, PR, Brazil
[d] Research Center for Sports, Health Sciences and Human Development, CIDESD, University of Trás-os-Montes & Alto Douro, Vila Real, Portugal

HIGHLIGHTS

- Information about multiple cryotherapy modalities and application protocols.
- Cryotherapy modalities seem to be effective in reducing skin temperature.
- Thermal image is a safe and trustworthy method for monitoring skin temperature during and after a cryotherapy application.
- This review provides evidence for thermal imaging on investigations involving application of cryotherapy modalities.

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ABSTRACT

Cryotherapy has been applied on clinical injuries and as a method for exercise recovery. It is aimed to reduce edema, nervous conduction velocity, and tissue metabolism, as well as to accelerate the recovery process of the muscle injury induced by exercise. *Objective:* This review aim to investigate the applicability of thermal imaging as a method for monitoring skin temperature during cryotherapy. *Method:* Search the Web of Science database using the terms "Cryotherapy", "Thermography", "Thermal Image" and "Cooling". *Results:* Nineteen studies met the inclusion criteria and pass the PEDro scale quality evaluation. Evidence support the use of thermal imaging as a method for monitoring the skin temperature during cryotherapy, and it is superior to other contact methods and subjective methods of assessing skin temperature. *Conclusion:* Thermography seems to be an efficient, trustworthy and secure method in order to monitoring skin temperature during cryotherapy application. Evidence supports the use of thermography in detriment of contact methods as well as other subjective ones.

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* Corresponding author.
E-mail addresses: filipejosematos@gmail.com (F. Matos), borbaneves@hotmail.com (E.B. Neves), marco.r.t.norte@gmail.com (M. Norte), claudiorosa23@yahoo.com (C. Rosa), victormachadoreis@gmail.com (V.M. Reis), josevilaca@utad.pt (J. Vilaça-Alves).
[1] Permanent address.

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1. Introduction

Exercise, by itself, induces a natural aggression to muscle-skeletal tissue, causing an inflammatory response, proportional to duration, strength and muscle mass recruited. The body's recovery to that muscle inflammation will depend on the course of time, the severity of pain and the level of muscular dysfunction [1–3,15]. This pain and muscular dysfunction induced by exercise peaks 1–2 days after the exercise session has taken place, usually called Delayed Onset Muscle Soreness (DOMS). Athletes experience this pain usually when the load is increased or they perform an unaccustomed exercise [30].

The recovery between training sessions is a highly relevant factor in a long-term adaptation to unaccustomed exercise and in the performance of the following sessions. The recovery timing is particularly important for athletes who are often subjected to daily and weekly training sessions, which have yet to be combined with competitions [32]. Many studies have researched the recovery process of the muscle inflammation induced by exercise, in order to find methods to reduce the magnitude of the inflammation and accelerate the recovery process. Stretching, low intensity exercise, ultrasound, massage therapy, antioxidant supplementation and nonsteroidal anti-inflammatory drugs are the most popular recovery methods [1]. However, the cryotherapy methods have been a major focus on these investigations.

By definition, cryotherapy is aimed to cooling the body, or body parts, through Cold Water Immersions (CWI), Ice Bags (Cryo Cuff), Whole Body Cryotherapy (WBC) (cryochambers with synthetic air with a temperature between −60 °C and −160 °C) or Cooling Gel (GP) [1,10,15,28,38]. These method's were originally created for treatment of chronicle diseases such as multiple sclerosis and rheumatoid arthritis [10]. Recently, cryotherapy has been used for immediate soft tissue treatment, applied by doctors, physiotherapists and coaches.

However, despite the development of clinical guidelines, the literature is inconclusive as to its applicability. There is no consensus on the effectiveness of these methods, continuing with ambiguous protocols, without optimal application times [15,19,28,34,41].

The theoretical condition for applicability of cryotherapy methods is the reduction on the skin temperature by contact with water, or ice, at low temperatures. It is known, that skin temperature is more easier to access than intramuscular temperature, and both are closely correlated [19]. The responsible interface for keeping the heat balance of the body is the cutaneous tissue, the largest thermoregulatory organ [6]. This attribute seems to be a good parameter for diagnosis, highlighting the importance of monitoring the surface skin temperature during cryotherapy methods [13,38].

Studies have been investigating the optimum temperature application, and timing, during cryotherapy. The body's response to a decrease in skin temperature, stimulated by cold, is the peripheral vasoconstriction [43]. With the optimal skin temperature reduced, the sympathetic nervous system stimulates the neurotransmission by the localized noradrenergic nerves in order to cause a powerful peripheral vasoconstriction, to be able to reduce the blood flow on skin tissue and redirect to the internal organs. This mechanism minimizes the heat lost to the environment [25].

In response to this powerful peripheral vasoconstriction, hyperemia reaction is to be expected. Increase in blood volume in the internal organs stimulates the arterial baroreceptors, in the aortic arch and carotid sinus, working as an essential role in negative feedback regulation of blood pressure, responsible for the shifting this sympathetic activity control of heart rate to a parasympathetic control [9]. This mechanism once more induces a reflux in the blood flow to the periphery. Vasodilatation of the periphery occurs as a reflex control of the heart rate and blood pressure, changing the permeability of capillaries [25,27,43].

The skin's microcirculation is extremely complex in structure and function, but very important in a clinical approach. It is this microcirculation that the exchange of material between the intravascular and interstitial space occurs, and for those reasons it needs further studies in order to better understand its mechanisms [25]. According to the recent PRICE guidelines (by The Association of Chartered Physiotherapists in Sports and Exercise Medicine), a reduction in a skin temperature of at least 5–15 °C is necessary in order to achieve analgesia, however, with the possible adverse effects, the absolute value of skin temperature cannot decrease below 5 °C [1,5].

The effectiveness in the research for more conclusive results about cryotherapy methods is affected by methodological errors. Small samples, inadequate methodologies, unreliable assessment methods to monitoring the skin temperature, during cryotherapy, are the most common practiced errors [34,36]. The need for more studies around the cryotherapy methods and credible assessment methods to monitoring the skin temperature during cryotherapy brings us to the purpose of this systematic review, to investigate the use of Infrared Thermal Imaging as a tool for tracking and monitoring skin temperature during the therapeutic cryotherapy protocols.

The technological breakthroughs now allow many devices to measure skin temperature, highlighting the thermocouples, pyrometers, optical and radiation thermometers [13]. Thermography has been recognized as a diagnostic method by The American Medical Association since 1987. Completely safe, painless, with no ionizing radiation, the contact or contrast, methods involve the detection of infrared radiation emitted by the skin and provides the analysis of physiological functions related to the skin temperature [2,3,29].

2. Method

2.1. Study design

The systematic literature review was conducted between January 2015 and May 2015, on the "Web of Science" databases, using the following terms and combinations: *"Cryotherapy"*, *"Thermography"*, *"Thermal Image"*, *"Skin Temperature"*, *"Cold Bath"*, *"Water Immersion"*, *"Cooling"* (*"Cryotherapy"* and *"Thermography"*), (*"Cryotherapy"* and *"Thermal Image"*), (*Cryotherapy* and *"Skin Temperature"*), (*"Cold Bath"* and *"Thermography"*), (*"Cooling"* and *"Thermography"*) and (*"Thermal image" and "Water immersion"*).

2.2. Article protocol selection

During the research process, 129 scientific articles were found to have been subjected to the selection process shown in Fig. 1. For better quality of selection the following inclusion criteria were established: (1) Original studies about cryotherapy methods