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Use of infrared thermography for the diagnosis and grading of sprained ankle injuries

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ABSTRACT

Ankle joint sprains are a common medical condition estimated to be responsible for 15–25% of all musculoskeletal injuries worldwide. The pathophysiology of the lesion can represent considerable time lost to injury, as well as long-term disability in up to 60% of patients. A percentage between 10% and 20% may complicate with chronic instability of the ankle joint and disability in walking, contributing to morbidity and poor life quality. Ankle sprains can be classified as grade I, II, or III, based on the extent of damage and number of ligaments affected. The diagnostic grading is important for setting further treatment and rehabilitation, since more severe injuries carries risk of recurrence, added morbidity and decrease in life quality.

The aim of this work was to evaluate the adequacy of infrared thermography as a potential complimentary diagnostic tool of the distinct lesions grades. Evaluation of different thermographic values of the ankle region (in both affected and non-affected foot) was conducted for this purpose.

The principal results to be highlighted are that some of the regions, namely anterior view for non defined time after injury analysis, and anterior, frontal, posterior and anterior talofibular ligament regions and proximal calcaneofibular ligament regions in acute lesions (herein defined as less than 6 h post-traumatic event) presented consistent profiles of variation. The analyses were performed considering affected and non-affected ankles results on plotted graphics representing termographic evaluation and grading of these lesions performed using ultrasound by experimented medical radiologists. An increase in temperature values was observed when progressing from mild to severe ankle sprain injuries, with these regions presenting lower values for the affected ankle when compared to the non-affected ankle in all the analysis performed. The remaining analysed regions did not present the same variations. Statistical analysis using Kruskal–Wallis tests for non-parametric samples, however, did not confer statistical significance to the differences encountered in the graphics analysis ($p > 0.05$).

The major conclusions were that thermographic analysis of ankle sprain injuries might have some potential to be used clinically, especially in acute settings such as those that occur in hospital emergency areas and in sports practice. There is currently no practical technology to be used for grading ankle sprain lesions, with the gold standard being magnetic resonance imaging. Thermography provides results rapidly and without the need for extensive equipment operating expertise. Based on scientific data present in the literature, this is the first description of the use of this technology with such an objective regarding ankle sprain lesions. Further work is needed, nonetheless, to amplify the sample number with the herein chosen parameters and possibly use dynamic thermography.

1. Introduction

1.1. Definition

Ankle injuries are among the most common events presenting in primary care settings and emergency departments. Among ankle injuries, ankle sprains comprise a large percentage of these. An ankle sprain can be defined as a stretching (plastic deformation) of, partial rupture of, or complete rupture of at least one ligament of the ankle [1].

1.2. Epidemiology, social burden and costs

It is estimated that approximately 1 ankle sprain occurs per 10,000 person/days worldwide level. The annual aggregate health

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care cost of acute ankle sprains management and treatment approaches $2 billion, according to some reports. Ankle sprains can result in considerable time lost to injury, as well as long-term disability in up to 60% of patients. Among younger, more athletic populations, ankle sprains account for up to 30% of injuries overall [1,2]. Moreover, the ankle also constitutes one of the most common sites for recurrent injury [3]. Therefore, many subjects will maintain residual instability, making them more prone to recurrent lesions and contributing to the chronicity of such lesions [4]. Such pathological changes reflect primarily on motion disability and locoregional pain. Nonetheless, their negative contribution is wider in the long course, contributing to decreased physical activity, post-traumatic ankle osteoarthritis, and sedentarism [5,6].

1.3. Types of lesions

Ankle sprain lesions can be classified as grade I, II, or III, ranging from mild to severe (I–III) based on the extent of damage and number of ligaments affected. The grade I sprain is characterized by the stretching of the anterior talofibular and calcaneofibular ligaments. In grade II sprain, the anterior talofibular ligament tears partially, and the calcaneofibular ligament stretches. The grade III sprain is characterized by rupture of the anterior talofibular and calcaneofibular ligaments, with partial tearing of the posterior talofibular and tibiofibular ligaments [7,8]. In a global overview of these injuries, it seems that the vast majority of ankle sprains involve the lateral ligament complex, being these also referred to as inversion sprains. Those concerning other ankle ligaments, especially eversion sprains that affect the medial ligament compartment, are much less frequent [9].

1.4. Diagnosis of ankle sprains

Diagnosis of a sprained ankle relies mostly on the medical history and physical examination [8,10]. This physical examination implies a set of provocative manoeuvres to be conducted in order to ascertain the possible grading of the lesion. This step is not consensual, given its ability to potentiate the lesion of the ligaments and worsen the outcome [11].

The adequate diagnosis of the three grades abovementioned is important for setting further treatment and adequate rehabilitation [12]. However, the grading of ankle sprains appears to be somehow overlooked by clinicians, possibly due to the currently available diagnostic tools and their associated costs. After excluding ankle fracture, the diagnosis is performed by evaluating different points of tenderness, range of motion and associated pain in the joint region. Not often, ultrasound or magnetic resonance imaging (MRi) might be requested to evaluate soft tissues injury [12].

Indeed, given the definition of the different grades, these last two methods, ultrasound and MRI, are those capable of delivering information about which ligaments are injured and to what extent, allowing an adequate grade diagnosis. Both demand an experienced professional able to perform and interpret the imaging data, which carries additional costs (especially relevant when considering MRI) and that might not always be available.

1.5. Use of infrared thermography in medicine

Infrared thermography is a non-contact, non-invasive, non-ionizing, fast and cost affordable imaging technique that allows the quick recording of radiating energy being released from the skin surface, which is related to peripheral blood flow [13,14].

In fact, infrared thermography has been used in the study of several medical pathologies [15]. Among some of the most researched, vascular and neuropathic conditions (e.g. diabetic foot ulcers, deep vein thrombosis and associated vascular pathologies and tumors), have generated interesting results with added benefit in monitoring and diagnosis [16–18]. Indeed, the availability of newer and more accurate infrared cameras has conferred additional potential to this technology in the study of a wider range of diseases.

Although variations in skin temperature have been described in the context of ankle lesions the scientific literature appears to be quite scarce concerning the application of infrared thermography in the study of any type of ankle lesions [19–21].

In fact, no information is apparently available on the literature regarding the analysis of ankle sprains using infrared thermography. Given the inflammatory/ischemic nature of the pathological sprain process, a valuable alternative might arise from infrared thermography analysis in the grading of these lesions.

1.6. Aim

Given the worldwide burden of ankle sprains, the current constraints to its grading diagnosis, and the appealing use of infrared thermography in this setting, the aim of this work was the evaluation of infrared thermography in the complimentary diagnosis of different grades of ankle sprain injuries.

2. Materials and methods

2.1. Patient selection

The sample used in this study was part of the population of patients that entered the emergency area at the Orthopaedics Unit of Hospital de São João, Porto, Portugal. A total of nineteen patients were included in this prospective, observational study during 2015.

The research work has been carried out in compliance with the Helsinki Declaration on human rights. Prior approval to its conduction was obtained from the Ethics Committee of Hospital of São João, Porto, Portugal. Participation in the study was conducted following informed written consent given by the individual or its legal representative (if under 18 years old) after explaining the whole procedure. Inclusion criteria were the following: subjects with one sprained ankle, entering the hospital on the basis of this specific event, and have no other known pathologies of the injured ankle.

2.2. Pre-analytical patient clinical assessment

For all evaluated patients, a detailed medical history and physical examination was collected upon admission. The information present in Table 1 was collected form all patients enrolled.

For each patient, height (meters – m) and weight (kilograms – kg) were measured, and body mass index (BMI) was calculated. Also, systolic and diastolic blood pressures (mmHg) were measured using a full-automatic oscillometric blood pressure measurement device (Tensoval® Blood Pressure Monitor – Hartmann, Heidenheim, Germany).

2.3. Thermographic data acquisition and processing

For the thermal images acquisition an uncooled infrared camera FLIR E60 SC (FLIR Systems, Wilsonville, Oregon, USA) with specifications: focal plane array of 320×240, NETD of 0.05 °C at 30 °C, accuracy of ±2% of the overall temperature reading, long wavelength (7–13.5 μm) and using a 24° lens.

The environmental conditions of the examination room were a stabilized air mean temperature (21.4 ± 1.3 °C), relative humidity