# Case Study in Thermal Monitoring of Physiotherapy Treatments to Ankle Sprains in Rugby Athletes

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**Abstract** — Actually, injuries are identified as persistent and serious problems in the sports activity. Ankle sprains compose a significant part of these injuries and present high frequency, which increases the associated costs. Among other issues, this condition is related to the common persistence of sequel and re-occurrences. The disregard for its severity and a reduced follow-up of the treatment may be pointed as associated causes.
In this work, two Rugby athletes that were recovering from ankle sprains and receiving physiotherapeutic treatment were monitored. Infrared thermography, a non-contact, non-invasive, non-ionizing, precise and fast medical imaging modality, has been used for analyzing the skin surface temperature distribution of the affected area. The analysis of the collected thermograms has shown a positive evolution of treatment to the ankle sprain in both cases examined. From the statistical analysis of the data, it was possible to differentiate the two cases presented, evidencing different recoveries. In conclusion, by applying the developed and proposed methodology in these the two cases, it has been possible to confirm that infrared thermography may assume a relevant role in monitoring ankle sprains.
**Keywords:** infrared thermography, ankle sprain, physiotherapy.

**Resumo** — Atualmente, as lesões são vistas como um problema sério e persistente no desporto. As entorses do tornozelo constituem uma parte significativa destas lesões e apresentam elevada frequência e custos associados. Entre outras questões, esta condição está relacionada com a comum persistência de sequelas e reincidências. A baixa importância atribuía à gravidade destas lesões e o reduzido acompanhamento dos tratamentos prestados podem ser apontadas como causas associadas a este problema. Neste trabalho, dois atletas de Râguebi em recuperação de entorses do tornozelo que se encontravam a receber tratamento fisioterapêutico foram monitorizados. A termografia de infravermelhos, uma modalidade de imagiologia médica não-invasiva, não-ionizante rápida foi usada para analisar a distribuição da temperatura à superfície da pele área afetada. A análise dos termogramas recolhidos demonstrou uma evolução positiva da patologia em ambos os casos examinados. Através da análise estatística dos dados, foi possível diferenciar os dois casos apresentados, evidenciando diferentes recuperações. Em conclusão, aplicando a metodologia desenvolvida e proposta nestes dois casos, foi possível confirmar que a termografia pode assumir um papel relevante na monitorização de entorses do tornozelo.
**Palavras-chave:** termografia de infravermelhos, entorse do tornozelo, fisioterapia.

## 1. INTRODUCTION

The ankle is the most commonly injured joint in the human body (1), accounting for 25% of all locomotor system trauma (2). Ankle sprains represent 85% of all the injuries suffered in this region and present the higher frequency. They occur when a sudden twisting movement of the foot makes the supporting ligaments stretch or tear (3).

In sports, particularly in those involving sharp cutting movements, such as basketball, soccer, rugby and volleyball, ankle sprains are a persistent problem (3, 4). For being a contact sport with hard collisions, rugby is associated with high injury risk, mostly musculoskeletal, concussions or related to joints (5).

Actually, ankle sprains are considered an actual public health problem, mainly because of its high frequency and associated increase in costs (2). Although no estimation is found for several countries, considering the values known from Netherlands, an average of 360€ is spend in every sprained ankle rehabilitation case (6). The financial impact of this injury in sports is not only related to the treatment costs but also with the absence of important athletes that have a key role in the success of the team and, therefore, in its economical revenue (7).

There is often a disregard for the importance of this injury, by patients and physicians. Since diagnosis tests are not always conclusive and the pain experienced by the patient is subjective, ankle sprains are sometimes seen as trivial injuries and their treatment is underrated. For this reason, there are sequels and reoccurrences cases both in athletes and in the general population. Only with a careful supervision by the physiotherapist and with the patient cooperation, a complete recovery is accomplished and the risk of re-sprain is minimized (2). The decision of returning to play is based on subjective information that sometimes leads the athletes to take serious risks. Therefore, a rehabilitation monitoring tool would help in these decisions, through providing quantitative information about the injury regression (8).

Infrared Thermography (IRT) is a non-invasive, non-contact, non-ionizing, objective and, therefore, harmless and fast medical imaging method, which registers skin surface temperature that reflects the physiology (cutaneous microvascular and autonomous nervous systems) in real-time. This technique has already a long history in medical applications. It was first used to evaluate pain in 1964 (9) and since then it has proven to be a reliable and appropriate tool to address many conditions.

The human body emits an amount of infrared (IR) radiation, which is detectable by thermal cameras and computationally processed in order to produce corresponding images, called thermograms, where each pixel corresponds to a temperature value (10, 11). In cases of pathologies associated with infection or inflammation, skin temperature increases and reflect the affected areas. Ankle sprains are typically hyperthermic and appear as non-homogeneous regions in the thermograms (12).

The studies already conducted sustain the possibility of using IRT for addressing other injury cases. However, there are not many works regarding the application of IRT to ankle sprains. Nevertheless, some important observations have been made: Asagai et al. (13) reported some cases of high temperature around the trauma site and reduced temperature in the periphery, on the first day after the injury; this cold skin pattern was interpreted as indicative of poor prognosis and long recovery time (14); Schmitt and Guillot (15) reported that the thermal distribution of temperature in ankle sprains was related to the recovery time recommended due to: a bilateral isothermia reflected a minor injury treated in 1-2 weeks; a thermal asymmetry between sprained and healthy ankle of 1.5°C to 2.0°C required usually a recovery of 4 weeks. Based in this scenario IRT may assume an important role in the monitoring of physiotherapeutic procedures.

In this study, infrared thermography was applied in the monitoring of physiotherapy procedures for two cases of ankle sprain in rugby players. In the methodology section, the samples used and the environmental conditions will be characterized and a protocol of thermal imaging capture and analysis for the follow-up of ankle sprains will be presented. The descriptive and statistical results for the follow-up evaluation will then be demonstrated and further discussed. Finally, relevant conclusions will be drawn.

## 2. METHODOLOGY

The methodology used in this work comprises 3 sections: sample characterization, experimental procedure and image analysis.

*A. Sample Characterization*

This study was conducted in 2 rugby athletes from CDUP (Centro de Desporto da Universidade do Porto) team, suffering from ankle sprains and receiving physiotherapy treatment, which provided informed consent signed to participate in the study. The characterization of the sample in terms of age, height, weight and Body Mass Index (BMI = weight/height$^2$) are presented in Table 1.

**Table 1.** Anthropometric characterization of the sample.

| Subject | Age | Height (m) | Weight (Kg) | BMI |
|---|---|---|---|---|
| **1** | 18 | 1.75 | 75 | 24.5 |
| **2** | 23 | 1.86 | 85 | 24.6 |

*B. Experimental Procedure*

The thermal images acquisitions procedures were developed in a previously prepared room, absent of airflow or incident artificial light directed to the subject. The relative humidity and temperature were measured in different moments using a digital calibrated device, Testo™ 410-2 Digital Pocket, with temperature sensor and hygrometer for measuring ambient variables in the examination days. Their mean values and respective standard deviations are presented in Table 2.

**Table 2.** Mean values and standard deviations (SD) obtained for environmental conditions: temperature and relative humidity.

| Mean Temperature ± SD (ºC) | Mean Relative Humidity ± SD (%) |
|---|---|
| 18.97 ± 2.98 | 71.98 ± 9.85 |

It is possible to observe that the temperature values have been kept within the recommended range. However, and do to practical difficulties (examination room conditions) that have not been possible to overpass, the humidity values were above the indicated maximum. Since all the collections were conducted in the same space and within the similar conditions, this factor has been constant, not affecting the further analysis.

The subjects were previously informed about the procedure and asked to avoid large meals, medication and drugs intake, physical exercise and topical applications before the exam.

Before the collection, they were asked to remove the lower limbs clothing and jewelry covering the examined region and to sit for 10 minutes, avoiding contact between the different body parts. This period is saved in order so that a process of body acclimatization occurs, enforcing thermal equilibrium between the body and surrounding environment.

In this work, it was used a FLIR A325 SC thermal camera, with a field of view of 25º×18.8º, a spatial resolution of 1.36 mrad, an IR resolution of 320x240 pixels, a measurement accuracy of 2% of overall reading and a thermal sensitivity of 50mK at 30ºC. The camera was operated with the FLIR ThermaCAM Researcher v2.10 software package.

The camera was placed in a tripod at a distance of 70 cm from the subject, in order to capture the larger area possible of the anatomical region in analysis (16). Considering that the main objective of this experiment was to characterize and monitor ankle sprains, front and lateral views of this region were captured (Figure 1).

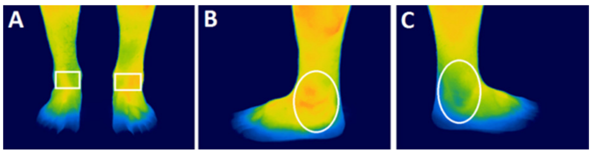


**Figure 1.** Views considered in this study: A. Front (ROIs: FL and FR). B. Lateral Left (ROI: LL). C. Lateral Right (ROI: LR).

*C. Image Analysis*

The thermograms were analyzed with the FLIR ResearchIR® MAX v3.2 software, an updated version of the capture software, which provides the possibility of defining different regions of interest in each view, determining the respective mean temperature and standard deviation (Figure 1): Front view - Left side (FL, A); Front view -Right side (FR, A); Lateral view - Left side (LL, B); Lateral view - Right side (LR, C).

The values of thermal symmetry were used to quantify the temperature distribution between the two sides of the body. Thermal symmetry of the human body has been defined as the 'degree of similarity' of two Regions of Interest (ROI) mirrored across the main human body longitudinal axis, which are identical in shape and size, and were taken at the same angle (17). The 'degree of similarity' was calculated by applying the subtraction of the mean temperature of the right ankle ROI to the mean temperature of the left ankle ROI.

Considering these values, the evolution of the thermal distribution and symmetry in the affected area during the rehabilitation period was studied. A graphical representation of this follow-up was created and a statistical analysis was performed with the IBM SPSS® (Statistical Package for the Social Sciences) 21 software.

From Subject 1, samples of day 1, 2, 4, 8, 11, 15, 16, 25 and 29 were collected. From Subject 2, only 5 samples were obtained, corresponding to days: 1, 5, 13, 15 and 19. Therefore, the values of thermal symmetry of the front and lateral views of the first 19 days (mutual period) were estimated for both subjects, using a linear regression.

The resulting values were analyzed with a Mann-Whitney U test, in order to verify whether there was a significant difference between the evolutions of these two cases. Thus, the sample used had a dimension (N) of 38, 19 of each subject.

In this analysis, the thermal symmetry variables were used in absolute values, since the side where the injury occurred was not relevant in this comparison. On the contrary, for the follow-up evaluation signed values were used, since it was intended to make a thorough examination of the changes of thermal distribution of each subject, also considering which ankle had higher temperature and more intense inflammation.

## 3. RESULTS

### A. *Descriptive Evaluation*

The analyzed athletes had different medical histories and their injuries had different severity and causes, each case was analyzed separately.

Subject 1 suffered a severe sprain in the left ankle with ligaments tear. The physiotherapist recommended the athlete to rest for 15 days before start receiving therapy. Thermograms of the injured region were captured before the first physiotherapy session (Figure 2 - Day 1) and showed evidence of an intense inflammatory process in the affected area. The extreme difference between the temperatures recorded in the two ankles was clear in both frontal and lateral views.

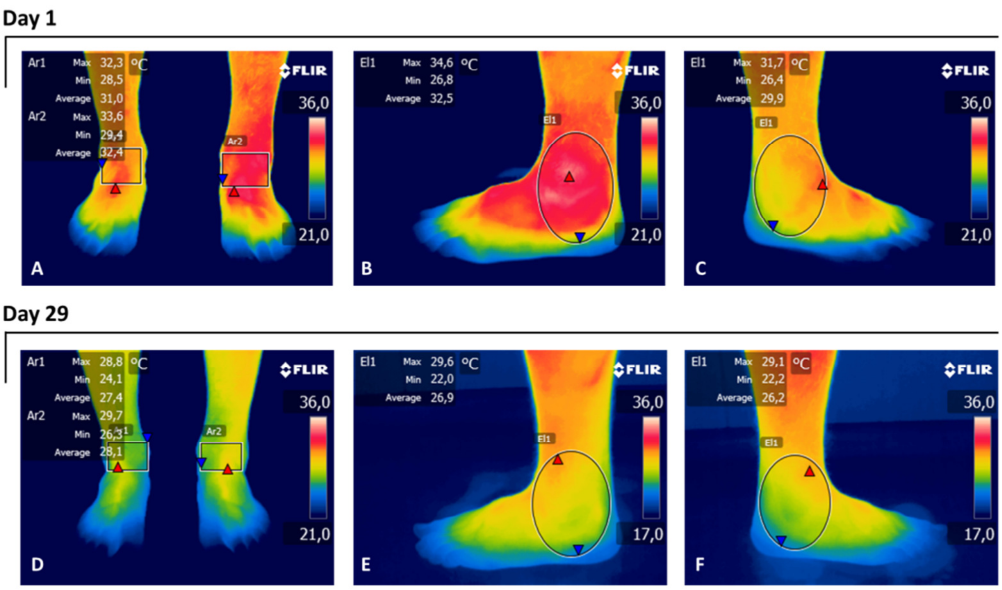


**Figure 2.** Thermograms of Subject 1 in the different days of examination (1 and 29): A. Front view (day 1). B. Left lateral view (day 1). C. Right lateral view (day 1). D. Front view (day 29). E. Left lateral view (day 29). F. Right lateral view (day 29).

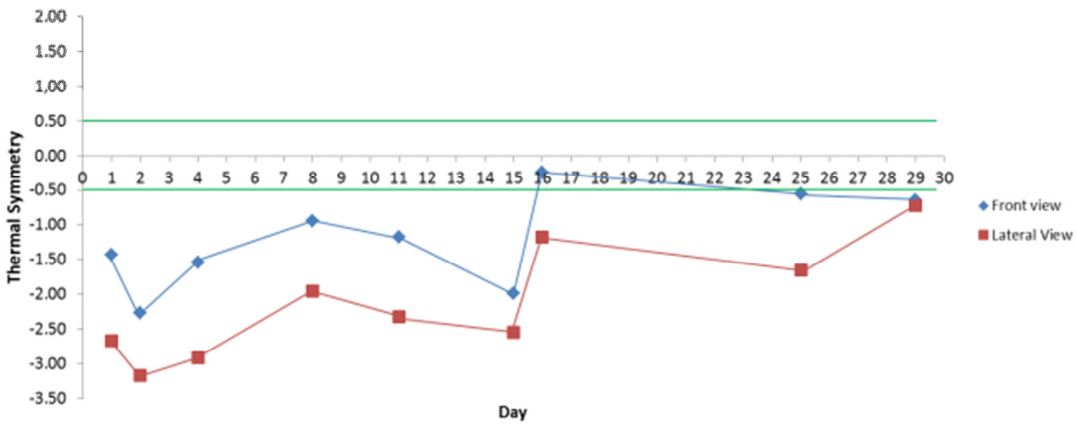


**Figure 3.** Graphical representation of the Subject 1 evolution during the thermal examination period.

Thermography was used to monitor the rehabilitation of this subject, being collected a set of images of the injured region before each treatment session. The athlete did not return to practice during the follow-up period. However, it was possible to report a notorious improvement of the sprain due to the applied therapy and performed exercises (Figure 3).

There is a clear approximation of the thermal symmetry values to 0, which is due to the decrease in mean temperature of the injured ankle. This decrease is related to the end of the inflammatory process, showing the regression of the sprain. This evolution may also be confirmed through the examination of the thermograms collected in the last day of observations (Figure 2 - Day 29).

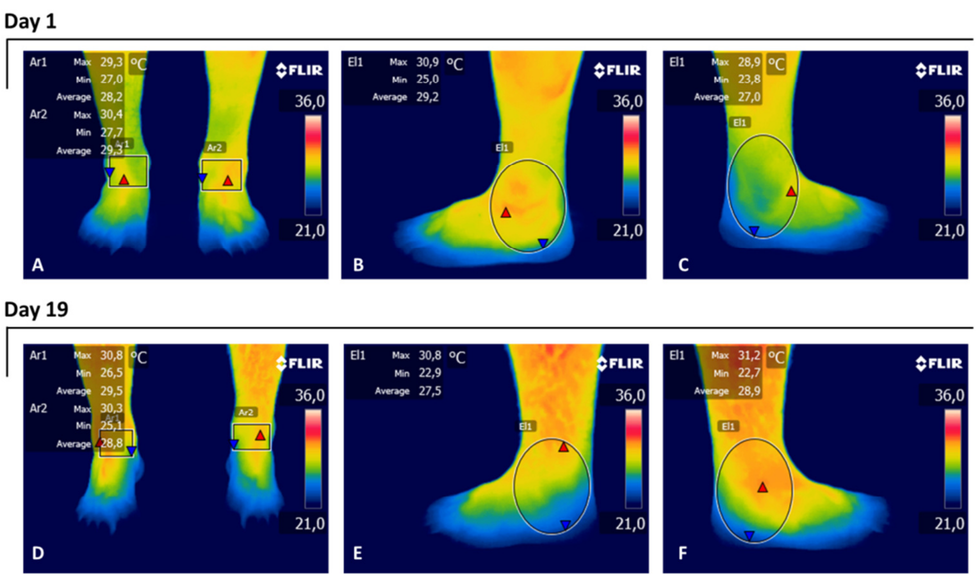


**Figure 4.** Thermograms of Subject 2 in the different days of examination (1 and 19): A. Front view (day1). B. Left lateral view (day 1). C. Right lateral view (day 1). D. Front view (day 19). E. E. Left lateral view(day 19). F. Right lateral view (day 19).

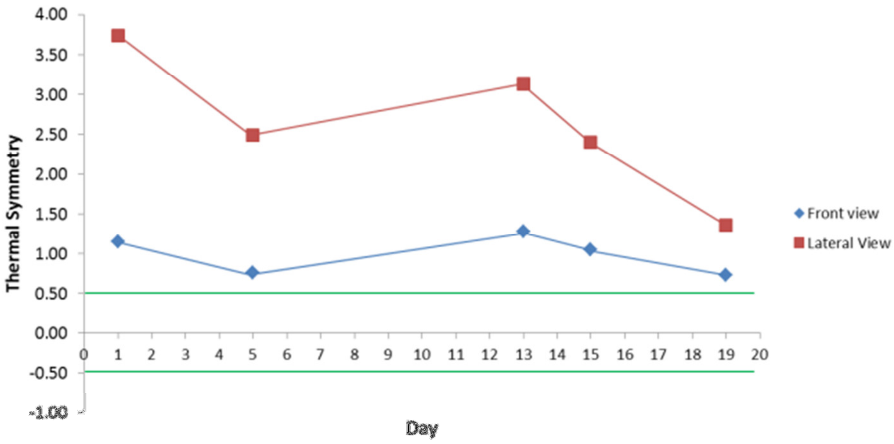


**Figure 5.** Graphical representation of the Subject 2 evolution during the thermal examination period.

Subject 2 suffered an ankle sprain in the right foot one day before the first examination. This injury was considered, by the physiotherapist, to be less severe than the presented by Subject 1. The state of the injury at this point was recorded in thermograms (Figure 4) and confirms this assumption. However, it is possible to observe a clear difference between the temperatures of the right and the left ankle, indicating an intense inflammation in the right foot.

The last thermograms collected from the subject show an improvement in the affected region, with a decrease in the thermal symmetry value. This evolution is evidence of an adequate physiotherapeutic treatment, with positive and visible results. This recovery process is possible to observe in the graphical representation of the thermal symmetry values presented in Figure 5.

The values resultant from both views are tending to zero, as rehabilitation occurs. The applied treatment and the natural healing phenomenon results in the decrease of the inflammatory process, which consequentelly leads to a decrease in the temperature of the injured ankle.

*B. Statistical Evaluation*

A statistical analysis was also performed, being conducted a Mann-Whitney test.The resultant p-values obtained (Table 3) were inferior to 0.05.

This indicates that there is enough statistical evidence to conclude that the thermal symmetry values of both views allow to differentiate these two cases.

**Table 3.** Results from the Mann-Whitney U test conducted for the two cases followed during rehabilitation: p-value, statistic (U) and Z value.

| Variable | p-value | U | Z |
|---|---|---|---|
| Front view (absolute thermal symmetry) | 0.000 | 49.500 | -3.826 |
| Lateral view (absolute thermal symmetry) | 0.020 | 101.000 | -2.321 |

## 4. DISCUSSION

Over the last years, thermography has been introduced in sports (11, 12, 18, 19), proving to be a powerful tool for evaluating the training intensity, the athletes' health condition and also for detecting and aid in the diagnoses of some pathologies. Even though, there is still few information regarding its use for injuries follow-up, which has already been pointed as an interesting application of IRT (18). This work has met this purpose, using thermal imaging for monitoring two rugby players that were recovering from ankle sprains, a recurrent problem in the most different types of sports.

Pathological conditions, such as musculoskeletal disorders and traumatic injuries, affect the thermal distribution of the skin surface, leading to changes in its natural symmetric pattern (20).

The thermal symmetry values have been important to consider for the evaluation of these athletes evolution after an injury. Since a subject's thermal distribution is different from one day to other, as well as the bias caused by small changes in environmental conditions of the examination room, the raw mean temperature values reported in the different days of collection would not be of high interest. Considering the thermal symmetry reported, it has been possible to verify, in both cases, a continuous approach of these values to zero, during the recovery period, showing evidence of a marked improvement in the injured ankle.

It is always difficult to verify how physiotherapeutic procedures are affecting the rehabilitation process and to know what would be the natural healing process of the injury. Nevertheless, the analyzed athletes had positive and fast recoveries, which has been perceived by the thermographic assessment and corroborated by the physiotherapist, confirming the importance of this approach in the assessment of this type of rehabilitation cases.

Being a common injury, ankle sprains are many times diagnosed by taking only into account the athlete's perception, without further exams. Since the tolerance to pain is a totally subjective parameter, the severity of the injury is many times misclassified. For this reason, patients that should receive treatment for a longer period and be object of a closer vigilance are frequently allowed to practice. Incomplete recoveries naturally lead to the re-occurrence of the injury and to more severe consequences in a long term. It is important to state that IRT is not presented as a replacement tool for other examination techniques used in the present moitoring and diagnosis, such as radiography, magnetic resonance imaging and ultrasound. This method is suggested to complement the already existing methods in injuries follow-up. Medical exams are expensive and, when frequently made, are sometimes harmful if requiring subject exposure to radiation. Therefore, those imaging modalities cannot be repetitively used in the same subject to address the evolution of a pathology. By this means, IRT rises as a fast, safe, relatively cheap, non-invasive and extremely useful tool for injury monitoring and for preventing re-occurrences.

## 5. CONCLUSION

Recently, medical treatment has gained more importance in sports, revealing a growing necessity of providing high-quality assistance for athletes. More attention is being given to the prevention, treatment and continuous monitoring of injuries, which have a great impact not only in teams' productivity but also in the long-term health condition of athletes, allowing the reduction of injuries associated costs.

In this work, a methodology for using infrared thermography in the evaluation of injuries during physiotherapy treatment was developed. Rugby players who had suffered ankle sprains have been monitored during the rehabilitation period. The applied protocol allowed a continuous follow-up of the athletes and a quantitative comparison between this two cases. This work has corroborated the assumption that thermography is an adequate tool for assessing the injury regression during the recovery period, helping determine if the inflammation process has already ceased. With this type of evaluation, a more informed decision can be made when considering whether an athlete is fully recovered and, therefore, avoid premature returns to practice with incomplete recoveries.

In future work, in order to validate the method proposed for the thermographic analysis of ankle sprains, a wider examination is suggested, considering a larger number of pathological cases, longer evaluation periods and covering different types of injuries. A study regarding the thermal evaluation of athletes before returning to play may also be relevant to determine whether an incomplete recovery is possible to identify and avoid using this approach.

## ACKOWLEGMENTS

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