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Research Article

Tracking the injury recovery of professional football players with infrared thermography: Preliminary Study

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Abstract

Infrared thermography is a non-invasive method of translating and viewing the radiating heat from the target surface collected by the infrared sensor into temperature as a digital image. Infrared thermography contains very useful data, especially for medical reasons. However, it has been accepted just recently. Although its usage is still questioned in sports medicine, recent studies claimed that infrared thermography can be used to examine muscle problems, injuries, and joint problems, etc. Sports medicine, physiotherapists, and medical imaging have vital importance for football teams and its' success. During a season football teams lose a lot of matches because of the high rate of injury. That is why preventing an injury has more importance for a football team than healing an existing injury. In consequence physiotherapists use many methods to prevent football players from being injured and monitorise the injury such as creatine kinase tests, muscle strength measurements, MRI, etc. However, these methods are either not enough successful or expensive. In our study, we have developed an image processing software to examine lower extremities muscle problems of football players when they occur and after they rested a day. With this software, we aim to help physiotherapists to regulate rehabilitation plan and decide when to end the rehabilitation. Thanks to this, physiotherapists can decide to rest the football players or start treatment so that they will not get injured unnecessarily and will have a lower risk of injury. Thorough this the success of the football teams will increase because the football players will not miss matches because of the extreme training or overlooked injuries. In our proposed method, with infrared thermography, 3 football players with documented injuries were observed. They have studied again after the football players rested for 1 day and the findings were analyzed. For that the thermographic color palette's RGB values are calculated in such a way that the upper and lower color values are discovered. In the next step, a binary mask is created, and this mask is blended with the grayscale original image, and the areas with muscle problems are displayed colored so that the physiotherapists can detect and examine problems easier. In the results part, it is shown that the areas are detected better than the human eye. It is concluded that with the help of the image processing algorithm muscle problems are detected successfully and the healing process after the resting is observed.

Keywords: Infrared thermography, computer vision, image processing, sports medicine, injury recovery tracking.

Profesyonel futbolcuların sakatlık iyileşiminin kızılötesi termografi ile takibi: Ön Çalışma

Öz

Kızılötesi termografi, kızılötesi sensör tarafından toplanan hedef yüzeyden yayılan ısıyı dijital bir görüntü olarak sıcaklığa çevirmek ve görüntülemek için kullanılan invazif olmayan bir yöntemdir. Kızılötesi termografi, özellikle tıbbi nedenlerle çok faydalı veriler içermektedir. Ancak yeni yeni araştırmacılar ve bilim adamları tarafından medikal alanda kabul görmeye başlamıştır. Spor hekimliğinde kullanımı hala sorgulanmakla birlikte, son araştırmalar kızılötesi termografinin kas problemlerini, yaralanmaları ve

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eklem problemlerini vb. incelemek için kullanılabileceğini kanıtlamaktadır. Futbol takımlarının başarısı için spor hekimliği, fizyoterapistler ve tıbbi görüntüleme hayati önem taşımaktadır. Bir sezonda futbol takımları, yaralanma oranının yüksek olması nedeniyle çok fazla maç kaybetmektedir. Bu nedenle, bir futbol takımı için bir sakatlığın önlenmesi, mevcut bir sakatlığı iyileştirmekten daha önemli hale gelmektedir. Bu nedenle fizyoterapistler, futbolcuların sakatlanmasını önlemek ve sakatlıkları izlemek için kreatin kinaz testleri, kas gücü ölçümleri, MRI vb. gibi birçok yöntem kullanmaktadırlar. Ancak bu yöntemler ya yeterince başarılı değildir ya da pahalı olmaktadır. Çalışmamızda, futbolcuların alt ekstremite kas problemlerini ortaya çıktığında ve bir gün dinlendikten sonra incelemek için bir görüntü işleme yazılımı geliştirdik. Bu yazılımla fizyoterapistlerin rehabilitasyon planını düzenlemelerine ve rehabilitasyonu ne zaman bitireceklerine karar vermelerine yardımcı olmayı amaçlamaktayız. Bu sayede fizyoterapistler, futbolcuların gereksiz yere yaralanmaması ve yaralanma riskinin daha düşük olması için futbolcuları dinlendirmeye karar verebilir veya tedavi uygulayabilir. Bununla birlikte futbol takımlarının başarısı artacaktır çünkü futbolcular aşırı antrenman veya gözden kaçan sakatlıklar nedeniyle maçları kaçırma problem minimize edilmiş olacaktır. Önerdiğimiz yöntemde ilk olarak, kızılötesi termografi ile sakatlıkları belgelenmiş 3 futbolcu gözlemlendi. Futbolcular 1 gün dinlendirildikten sonra tekrar gözlemlendi ve bulgular analiz edildi. Gerekli yazılım için termografik renk paleti, üst ve alt RGB renk değerlerini bulmak için kullanılmıştır. Bir sonraki adımda binary bir maske oluşturularak bu maske gri tonlamalı orijinal görüntü ile harmanlanmış ve kas sorunu olan alanlar renkli olarak görüntülenmiştir, böylece fizyoterapistler sorunları daha kolay tespit edip inceleyebilecek duruma gelmişlerdir. Sonuçlar bölümünde, sorunlu alanların insan gözünden daha iyi ya da daha hızlı bir şekilde tespit edildiği gösterilmiştir. Sunulan görüntü işleme algoritması yardımıyla kas problemlerinin başarıyla tespit edildiği ve dinlenme sonrası iyileşme sürecinin gözlemlendiği sonucuna varılmıştır.

Anahtar Kelimeler: Kızılötesi termografi, bilgisayarlı görü, görüntü işleme, spor hekimliği, sakatlık iyileşimi takibi.

1. Introduction

Sports Medicine has grown over the past 30 years as an obvious sub-class of medicine (Edwards et al., 2006). Sports medicine is a branch of medicine aimed at treating sports athletes, changing their workouts, following their diets, following their injuries, and ensuring that they succeed after the injury. In sports medicine, many approaches help sports physicians analyze injuries on sports athletes, such as techniques for medical imaging. Between medical imaging techniques, there is one imaging technique that is considered useful and provides effective outcomes, but not many people regard it as a useful technique like other medical imaging techniques. Many researchers assume that thermography is a subjective technique that can come up with various conclusions from different studies. However, with the recent advances in thermography, the acceptability of the technique is growing. In recent years many studies have been carried on infrared imaging. While some of them were to define the standards in this field (Ring et al, 2004), some of them were to define protocols for recording the data and the evaluation of the images of the body parts of humans (Ammer, 2008). An example of such studies is the one in which, human body's thermographic atlas was described by Tkacova et al (Tkáčová et al. 2011). Another example is Hadzic et al. responded that the query could be used during exercise to track muscle exhaustion (Hadžić et al., 2019). As told before, in recent years the big amount of studies have been carried out on infrared thermography. One of the best studies to Show interest on infrared thermography is the one in which Costello et al. made statistical research on studies. That study showed that just in 2011 about 25000 articles were written with the keyword of skin temperature (Costello et al., 2013).

According to a private statistics provider, in the 2018-2019 football season in the premier league 764 players were injured and this amount is 15% higher than the last season so the graphic is increasing every year. Every injury costs £290.000 to clubs which makes on average total £11 million for all season for a team. These injuries were mostly on lower extremities and these injuries take 22 to 50 days to get better (Marsh, 2019). These injuries' reason is mostly is overusing of muscles while exercising. The problem is the more players exercise the more success increases. That is why football clubs and their physiotherapists try to make players exercise more. But they are searching for a method to observe the player and detect their muscle problems before they turn into an injury. For that they are using creatine kinase tests, isokinetic machines, or MRI to measure muscle strength or to find fatigue. However, these methods are either expensive, not successful enough or vary according to the player. That is why infrared imaging has just started to be used in sports medicine to observe fatigue and muscle problems. But there are not many multidisciplinary studies that merges engineering and medicine so that the problems can be found easily with the help of a software program.

In this study, we have proposed an image processing software to detect muscle problems via infrared imaging to give diagnostic support to physiotherapists and save time. In our proposed method 3 football players with known pains were observed with infrared thermography. After resting the football players for 1 day they were observed again and the results were examined. To examine players with the help of image processing the RGB values of the thermographic color palette are determined so that the upper and lower values of colors were learned. The next step is to detect the areas with higher degrees according to the color palette. After detecting the warmer areas, a binary mask was created with RGB values of warmer areas. Thereafter the pixels of the warmer areas were extracted from the original image. Later the original image converted to grayscale and the extracted colored pixels were blended so the warmer areas are displayed colored which makes the physiotherapist examine areas easier and decide. This method is explained more detailed in the material and method part and the results are shown in the results part of this paper. It is concluded that with the help of the image processing algorithm muscle problems are detected successfully and the healing process after the resting is observed.

2. Material and Method

2.1. The Subject Players and Obtaining the Images

In our research, we tracked professional Turkish Super League football players during their mid-season training camp with the approval of *the KTO Karatay University Medical Faculty Ethics Committee* (date: 24.04.2020 and no: 2020/005). In this camp, football players were observed after the training match with infrared thermography. 3 players were chosen with the known problems of;

Player 1. Grade I hamstring strain problem (Fig 1a),
Player 2. Tendinitis of Achilles (Fig 1b),
Player 3. The scar under his foot so that the player forced his leg more (Fig 1c).

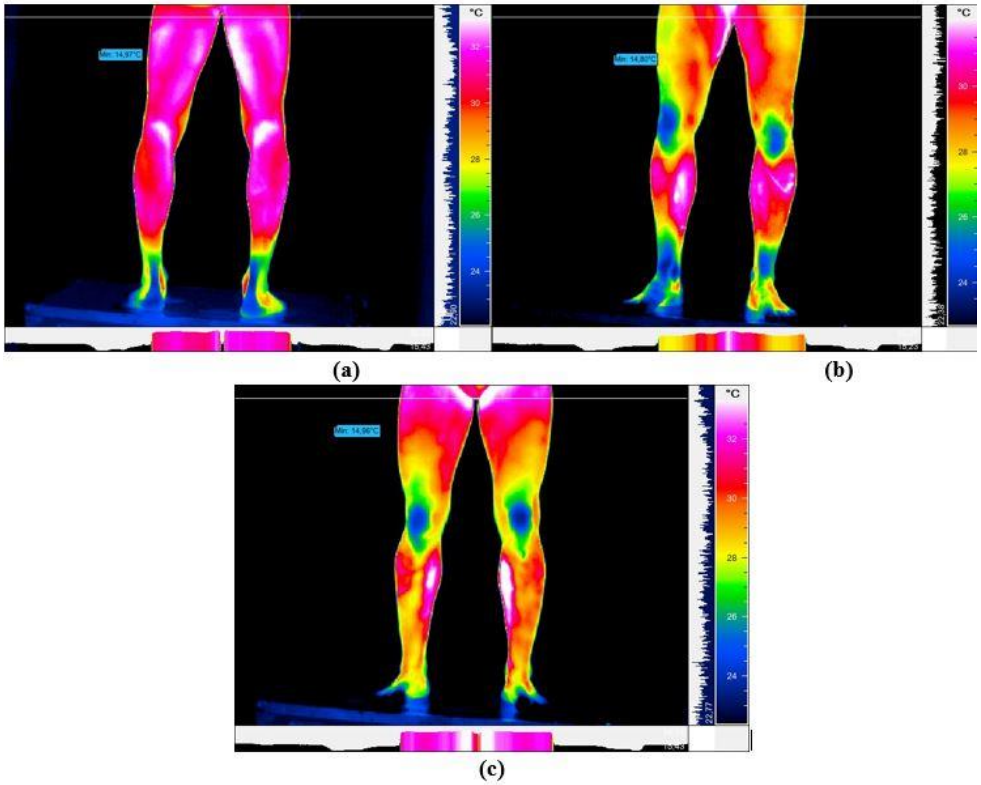

Figure 1. Subjects with known problems a) Player 1's posterior thermography. Inflammation and heat increase can be seen on the right hamstring. b) Player 2's posterior thermography shows that a heat difference can be spotted on the right calf. c) Player 3's anterior thermography shows heat increase on the left calf.

As the problems of players known, physiotherapists rested football players for 1 day. After resting for a day, football players were observed again and the results in Figure 2 were obtained. At the results, it is observed that inflammation and heat level is decreased on all players. Additionally, heat imbalance was not detected. All players told that they felt better.

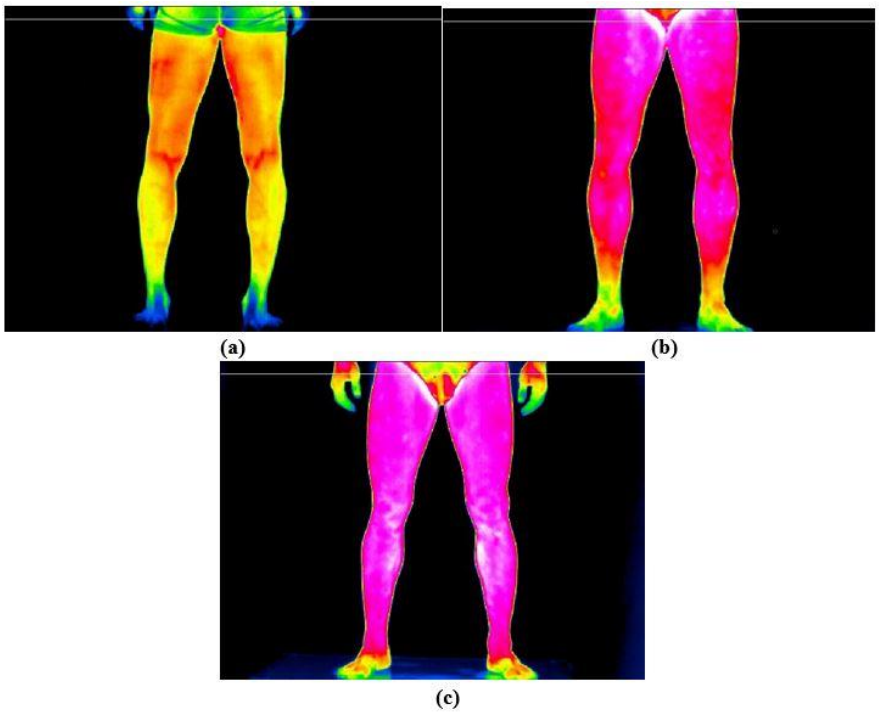

Figure 2. Subjects after resting a day a) Player 1's posterior thermography. Inflammation and heat decreased on the right hamstring. b) Player 2's posterior thermography shows that a heat difference was göne on the right calf. c) Player 3's anterior thermography shows heat was decreased on the left calf.

2.2. Image Processing

In the first step of the image processing algorithm, the RGB values of the thermographic color palette are determined so that the upper and lower values of colors were discovered (Figure 3).

Figure 3. Lower and upper RGB values are extracted from the color palette

In the next step, areas with higher degrees thresholded according to the RGB values obtained from the color palette. In most image processing applications containing thresholding according to the color space, HSV color space is used. HSV usage on such applications aims to eliminate the effect of brightness and ambient lighting on image (Ali et al., 2013). The reason for the usage of RGB color space in this study is the images are already unaffected by the light because the infrared sensor is digitalizing the images irrelevant to the light but relevant to the radiating heat. In Figure 4 an example to the threshold and creating a binary mask is shown.

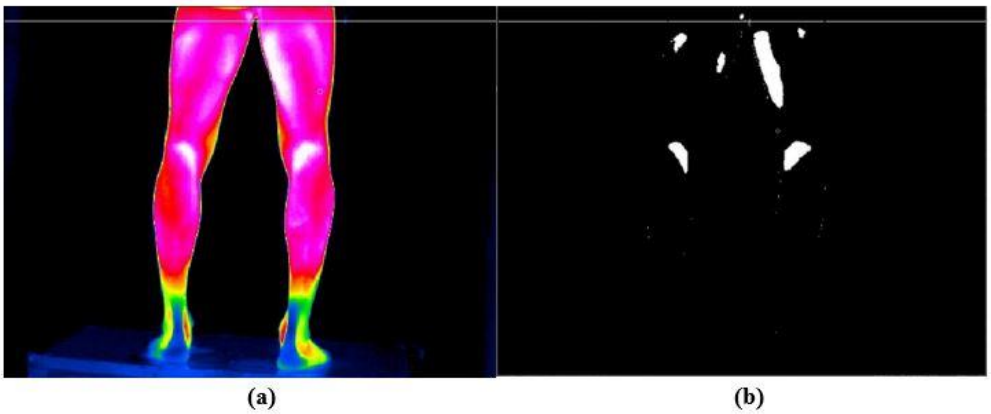

Figure 4. a) Original image, b) Thresholded image (mask) according to lower and upper RGB values

Later the pixels of the warmer areas (Fig. 4b) were extracted from the original image (Fig. 4a). After that, the original image converted to grayscale, and the extracted colored pixels were blended to display warm areas colored so that the physiotherapist can examine the areas easier and diagnose the problem (Fig. 5).

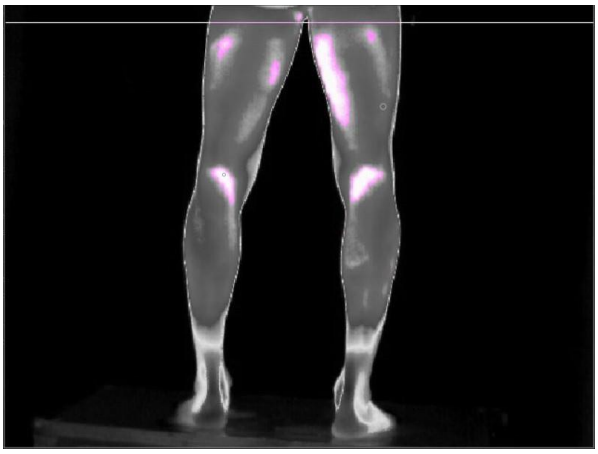

Figure 5. Blended final image with heated areas colored and displayed clearly

After obtaining the final image, the results for all players are shown and discussed in the next section.

3. Results and Discussion

After image processing algorithm all images are masked successfully and explained detailed in this section for every player.

3.1. Player 1

The player 1 had a grade I hamstring problem. The hamstring problem causes inflammation and increase the heat on muscle. While observing this problem inflammation area size and temperature of the area are considered. As can be seen in Figure 6a there is some heat increase. However, in Figure 6b it can be seen clearly where the increase is, and which muscles are affected.

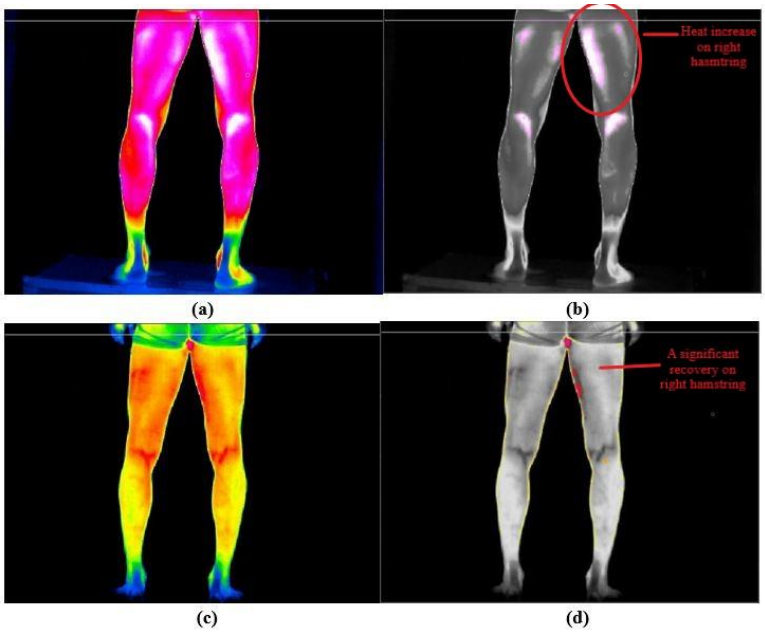

Figure 6. Algorithm result for Player 1 before the treatment and resting (upper row). The results after the treatment and resting (lower row)

In the figure it is seen on the right inner hamstring of the player there is an inflammation. After seeing this result physiotherapists applied the necessary treatment to the exact area. Also, they have pointed out that the result is successful according to their medical examinations. After the treatment, the player rested and observed again (Figure 6c, d). In the figure, it is showed that the resting and treatment success and the heat on the right inner hamstring became normal. Just a small area was observed. So, the player was able to recover after minor treatment. The results showed that if that player kept exercising the injury would become more critical and the player could miss about 20 days of playing and exercising.

3.2. Player 2

The player 2 had tendinitis of the Achilles problem. This problem causes inflammation and increases the heat on the posterior ankle and anterior inner calf. While observing this problem inflammation area size and temperature of the area are considered. As can

be seen in Figure 7a there is some heat increase on both legs. However, in Figure 7b it is observed exactly which leg has the problem and where the increase is, also which muscles are affected. The problem on the right leg is observed as the heat increase on the right inner calf of the player. The reason of the heat increase on the left leg is when the player felt pain on the right leg the player started avoiding forcing the right leg and used his left leg more. This caused a reflected heat on the left leg.

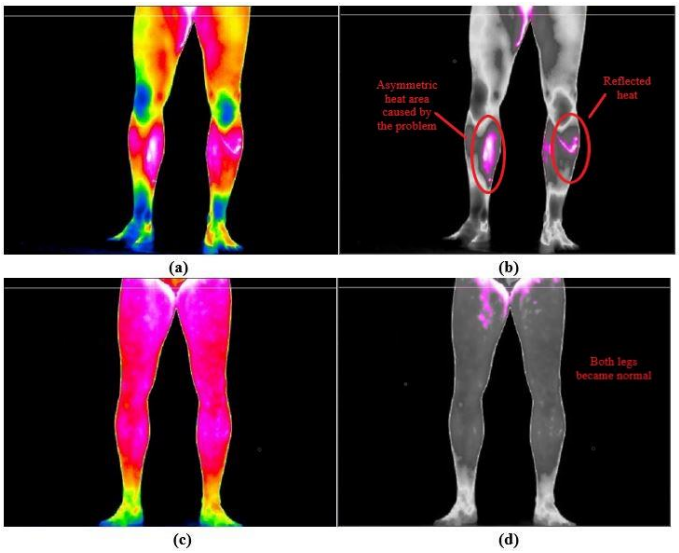

Figure 7. Algorithm result for Player 2 before the treatment and resting (upper row). The results after the treatment and resting (lower row)

Again, physiotherapists started the necessary treatment and the player rested for one day. After the treatment, the player rested and observed again (Figure 7c, d). In the figure, it is showed that the resting and treatment success and the heat on the right inner calf became normal also the reflected heat was gone. So again, the player was able to recover after minor treatment. The results showed that this minor treatment saved the player. Because of this injury went worse this player could have up to 50 days of treatment.

3.3. Player 3

Player 3 had a scar under his right foot. In Figure 8 (a, b), a heat increase is observed on the left calf. The reason of this is the reflected heat explained in player 2's case. Because of the pain on his right foot, an imbalance on the player's movement occurred, and pressed on his foots imbalanced. This case shows the importance of reflected heat and infrared thermography because in normal treatment just the scar would be treated, and the leg would be missed. However, thanks to infrared thermography and our algorithm, physiotherapists started treatment on the leg too and the player rested for a day.

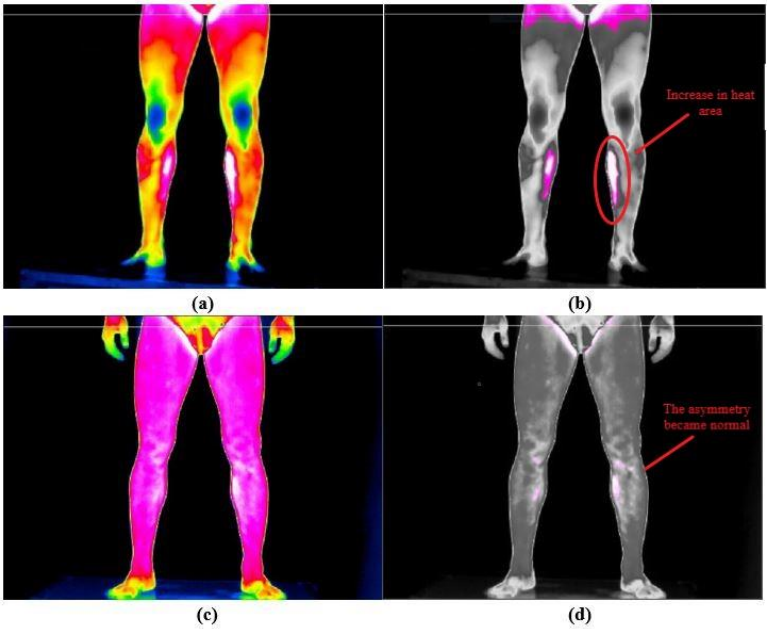

Figure 8. Algorithm result for Player 3 before the treatment and resting (upper row). The results after the treatment and resting (lower row)

After the treatment, the player rested and observed again (Figure 8c, d). In the figure, it is showed that the resting and treatment success and the heat on the right inner calf became normal also the reflected heat was gone. As result, the player was able to recover after minor treatment. The results showed that if that player kept exercising or the muscle problem on legs missed the injury would become more critical and the player could miss up to 30 days of playing and exercising.

4. Conclusions and Recommendations

The results showed the importance of infrared thermography and image processing for diagnostics support clearly. If our algorithm did not apply the players' problems could turn into severe injuries. This could cause them to miss matches and exercises, treatment costs would increase, and the team's success would decrease. Another importance of this study is the algorithm and the results are proved by professional medical staff. The paper's contributions to literature are; there are not many studies on infrared thermography on sports medicine especially on professional football players, as known this study is one of the first multidisciplinary studies carried on professional football players with infrared thermography and image processing which merges sports medicine and engineering. This paper proved that image processing for diagnostic support for detecting injuries has great importance for physiotherapists and football clubs.

In future studies, we are aiming to implement more image processing algorithms, machine learning, and artificial intelligence methods such as traditional machine learning algorithms or deep learning to increase the success and maybe in the future these algorithms will transcend the limits of human capabilities and maybe will prevent all injuries caused by overusing and extreme training. We believe that this paper will be a source of inspiration for other studies.

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