Applications of Infrared Thermography in Sports. A Review

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REVISIÓN / REVIEW

APPLICATIONS OF INFRARED THERMOGRAPHY IN SPORTS.A REVIEW

APLICACIONES DE LA TERMOGRAFÍA INFRARROJA EN EL DEPORTE. UNA REVISIÓN

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ABSTRACT

Infrared thermography (IRT) records the radiant heat of a body, which is emitted in the range of the electromagnetic spectrum that human vision is not able to identify. The thermal response depends on a number of specific physiological adjustments as body homeostasis and athlete's health, which allow us to establishing interesting applications in sport. The aim of this study was to review the literature on IRT applications in sports, and to propose the optimal characteristics of the register in terms of the subject, the environmental conditions and the camera used. We conclude that the main contribution of IRT in the field of sport is to help identify signs of injury before it occurs, allowing us to act proactively along the training process

KEY WORDS: Thermography, thermoregulation, skin temperature, physical evaluation.

RESUMEN

La termografía infrarroja (TI) registra el calor irradiado de un cuerpo, que es emitido en un rango del espectro electromagnético que la visión humana no es capaz de identificar. La respuesta térmica depende de una serie de ajustes fisiológicos específicos como la homeostasis corporal y salud del deportista, lo cual permite establecer interesantes aplicaciones en el deporte. El objetivo de este trabajo ha sido revisar la literatura en torno a las aplicaciones de la TI en el ámbito del deporte, y proponer las características óptimas del registro en relación al evaluado, las condiciones ambientales y la cámara utilizada. Concluimos que la principal contribución de la TI en el ámbito del deporte es ayudar a identificar signos de lesión antes de que la lesión se produzca, permitiéndonos actuar de manera preventiva durante el proceso de entrenamiento.

PALABRAS CLAVE: Termografía; termorregulación; temperatura de la piel; evaluación física.

1. INTRODUCTION

Applications based on new technologies are constantly emerging from the world of sport. Many of them allow us to evaluate the needs of the athlete, which is used by coaches to try to maximize the performance of the athlete. An example of this are the technologies that help prevent possible injuries or that allow us to accelerate the recovery of the athletes once the injury has occurred. Given the current high level of demand in professional sports, technological innovation is particularly relevant; as examples it could be consideredthe usage ofheart rate monitors [(1)], refrigerated clothes [(2)] or Tensiomyography (3).

Infrared thermography (IRT) is a technique that allows visualization of the heat radiated from the body through registration of infrared emission, which is in a spectrum that the human eye is unable to identify [(4,5)]. This technique is now used extensively in various areas [(6)] as the oil and gas industry, aviation, civil and military construction or veterinary [(7)]. In humans, those applications are mainly focused in the medical field as thermography allows assessment of physiological responses associated to skin temperature, helping in the identification of a number of problems related to different types of pain syndromes [(8)], heart interventions[(9)], vascular deficiencies [(9,10)], neurological [(9,11)] or even in studies related to diagnosis and monitoring of cancer[(12)].

The work of Albert et al. (1964) [(13)] is considered the first in which thermography is used to evaluate a musculoskeletal disorder. Later, in the study of Clark et al. (1977) [(14)]we found the first reference of thermal monitoring in different environments (20°C vs 10°C) with exercise performed in treadmill. However, due to technological difficulties, the quality of the equipment, the cost and the speed for data analysis, this technique has not proliferated in the world of sport. However, the recent technological advances in this sector have allowed the construction of more reliable, economical, manageable equipment with almost immediate software for the analysis of the data, improving the possibility of using this technique in several sportfields: as sports medicine[4,15,16,17,18], physical therapy [19], sport performance [20], research [21,22,23,24,25] and even events management.

Several studies [11,12,18,25] have concluded that thermography is a technology of great validity. They are regarded as positive points [4,15] being a low-cost technique, noninvasive, fast and safe, without emitting radiation, highly reproducible, without physical contact with the evaluated, and enabling track real-time temperature of the subject, building a general and/or local thermal profile through the division of the body into what are called regions of interest (ROI). Consequently, daily use of thermography in sports allows rapid assessment of quantitative and qualitative manner, in addition to monitoring the thermal response of the athlete, which in turn may provide us withrelevant information not only for increasing theathletes'performance but also for their health.

Given that certain physiological disorders may influence the local exchange thermal response [26] or [4,8,11,15], the use of thermography in sports can help prevent muscle, joint or tendon injuries since, in case of overuse or overtraining the local temperature of the affected areas may be increased, compared to other similar or to the contralateral body region [18]. Infrared thermography can detect thermal asymmetry that could lead to injury, with its consequent impact on performance and health of athletes, team planning and even, considering professional sport or high performance, the benefits for the athlete or club.

The wide range ofapplicationsof this new technique in sports provides, for example, a greater amount of information on the athletes'state, which is a key factor to plan a highly personalized training.

The athlete should be the main beneficiary of the new technologies, which, can be used to meet all the needs arising from the high-level sport. When applied properly by professionals, infrared thermography may be successfully used in different areas of sport. Consequently, this study aims to conduct a review of the literature on several applications of thermography in the field of sport, and propose the optimal characteristics of the record in relation to the avaluated athlete, the environmental conditions and the camera used.

2. MÉTHODOLOGY

During March 2012, we searched the PubMed and Scielo database with the keywords "exercise", "medicine", "physiotherapy" combined with "thermography", "infrared rays", "thermal imaging" "thermology", "IR Imaging", "infrared", "thermometry", "ThermoVision", "infrared photography" and "medical infrared imaging." Studies that have a bearing on the use of thermography in the exercise and done in humans were selected. Based on that content it was possible to analyze the possibilities of use of thermography in the field of sport, as well as a critical analysis of its limitations as it is detailed below.

3.TERMOGRAFIA EN MEDICINA DEL DEPORTE

Using thermography can be assessed the overall health of the athlete allowing to detect signs of skin cancer [27], breast cancer [12], thyroid problems [9] even though those alterations will require a more accurate diagnosis by a specialized medical team. A fever state, characterized by records greater than 37.5°C[28] records also can be perceived by the IRT preventing the athlete train outside ideal health levels.

Injuries are one of the main problems of athletes and mayhavean acute or chronic origin. Consideringsoccer as an example, the incidence of injury during European Championship 2008 [29] was 41.6 injuries/1000 hours of activity. Of these injuries, 73% were caused by trauma and 27% overload. Diagnosis, treatment, recovery and rehabilitation of the injury mean a great economic cost. So much so, that according to a Spanish work on the professional soccer League, every first division club spentan average of more than € 7.5 million per season only in regard to the payments duringsick leavedays, and without taking into account indirect costs [30].

Anymean to prevent athlete's injury should to be strongly considered. IRT is a tool of enormous potential, both for athletes and the whole team of professionals working with them, who can receivequick and objectiveinformation on their physical condition and possible evidences of injury or overload, that could impair its performance [8]. That is one of the main virtues that support the use of thermography in sports.

With a periodic thermographic monitoring of the athlete it can be created a specific thermal profile of both the subject and the sport discipline or the team; that is, a "map" with normal thermal characteristics of each ROI such as the frontal and posterior legs of a soccer player. Thus, any abnormal temperature rise in both legs orone specific region [4,9], or that takes place continuosly or more intense than normal in an athletecan be related to an inflammatory process[15]. This situation may occur as a result of: a load of training above the assimilative capacity of the athlete, being able to produce a risk of damageby overload; or inappropriate development of recovery patterns, as may be a balanced nutrition, hours of rest or specific physiotherapy treatments. In any case, it will be necessary to evaluate the cause of the thermal alteration before an injury occurs.

Considering the concept of anatomical proportionality, the thermal response between two contralateral body parts is expected to be symmetrical [9]. Thermal monitoring comparing bilateral body parts indicates that differences up to 0.25°C[31]; 0.4°C[32]; 0.5°C[33,34], or 0.62°C[35] are considered as acceptable. However, difference above this valuesmay indicate that the ROI with a higher or lower temperature, contrasted with his usual thermal profile settings, might have some inflammatory problem (hyperthermia) (4,15,17,32) or degenerative (hypothermia) (4,9,15,17,32).

Chronic lesionslinked to degenerative alterations are common in athletes, for example, cases of Achilles tendon tendinitis in jumpers; abductor syndrome insoccer players; recurrent epicondylitis in tenis players, better known as tennis elbow; or the typical shoulder bursitis in swimmers. These lesions may cause changes in skin temperature, so that thermography, with special sensitivity to identify these patterns, can aid in monitoring their treatment and development process (17). Figure 1 shows an example of this situation, in which an athlete has a temperature difference between the right knee 1.4°C warmer than the left knee, and the right medial leg 1.5°Chotter than the contralateral side.

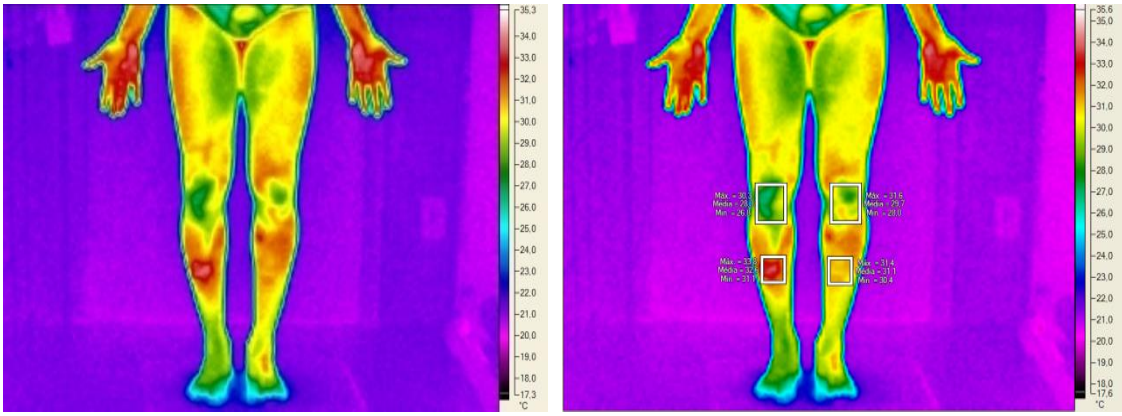

Figure 1: Thermograms indicating thermal assymetries in the knee and anterior leg.*(Source: Database of the Thermography section of the Federal University of Viçosa – Brazil)*

According to our research and practical experience, we porpose a“level of attention”scale to be considered depending on bilateral temperature differences recorded (Table 1).

Table 1: Level of attention scale in terms of the temperature differences obtained between contralateral ROI or between two different measurements of the a ROI for the same athlete.

TEMPERATURE DIFFERENCE	LEVEL OF ATTENTION
≤0.4°C	Normal
0.5° – 0.7°C	Monitoring
0.8° - 1.0°C	Prevention
1.1° - 1.5°C	Alarm
≥1.6°C	High Severity

Based on the table above indications about the level of attention, it should be borne in mind that a difference ≤0.4°C would be considered normal (32). For levels higher than 0.5°C would be advised: a) verifying if some external factor could influence the result; b) monitoringthe athlete to assess his/herenviromental and training conditions; c) increase the frequency of monitoring. We never recommend taking drastical decisions after the first negative assessment. In the case that the difference is repeated in the second assessment, an appropriate intervention by the physician, physical therapist or trainer would be recommended, and the intervention should last until the differences come back into an acceptable range considering the normal values of the athlete.

With values classified as "prevention" an immediate decrease in training load or even training suspension is recommended as when values are higher than 0.8 to 1.0°C is clearly described the existence of a significant inflammatory process [(4)] or a risk of injury in a ROI even without prior symptoms of pain and it is recommended a medical and/or physiotherapic evaluation of the athlete. The state of "alarm" imposes an immediate suspension of training and a medical and physiotherapy assessment. The status of the“High Severity” indicates a difference that may be pathological or a sign of major injury, as in other cases, coordination with the medical team is essential to determine the actual state of the athlete.

However, to apply propertly the Table 1 ranges of severity, we must always consider the individual thermal profile of the athlete and the sport practiced since the previous injury of athletes or characteristics of the sport practiced can cause imbalances in the thermal baseline profile that are within normal limits for this specific athlete or discipline, and which could lead to apply the criteria incorrectly. For example, if the specificity of sport makes the forearm grip always this 0.4ºC warmer, it may be normal that one day the athlete has a 0.8°C imbalance in the forearms, and would not require any special attention.

When significant temperature differences are observed, it is recommended repeating the assessment after 15 minutes to confirm whether this difference is maintained [(32)]. Another possibility is to spray the area with an alcohol or convection cooling and wait for five minutes to see the thermal response of the area [(32)], this technique is known as dynamic thermography [(36)].

IRT also allows to evaluate the level of metabolic activity when there is a trauma[(15)] or after surgery[(32)]. A regular monitoring during the recovery process allows you to track the evolution of the athlete’s thermal profile prior to his normal condition before the injury. Also, the thermographic monitoring allows to assess whether the medical and physiotherapy intervention evolves as expected. Figure 2shows a case of an athlete before and after injuring his right knee with a ruptured anterior cruciate ligament (ACL). Figure 3 shows photos of a thermal high performance judoka 11 daysafter the operation ACL (A) and after 24 days (B), where you can see the apparent thermal recovery process of the athlete.

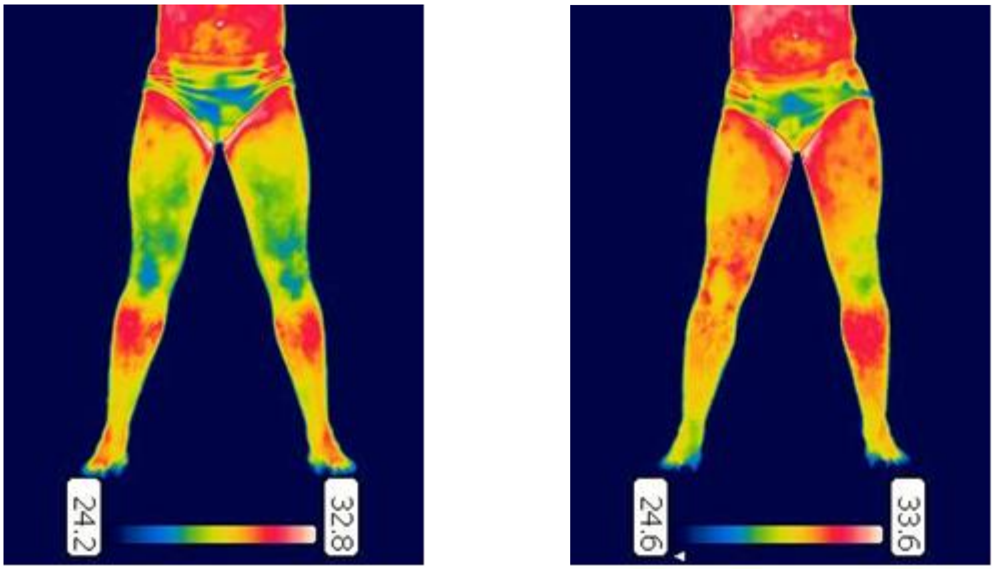

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Figure 2: IRTbefore (A) and after (B) a ACL injury *(Fuente: Base de datos de imágenes del grupo TERMOINEF de la Universidad Politécnica de Madrid)*

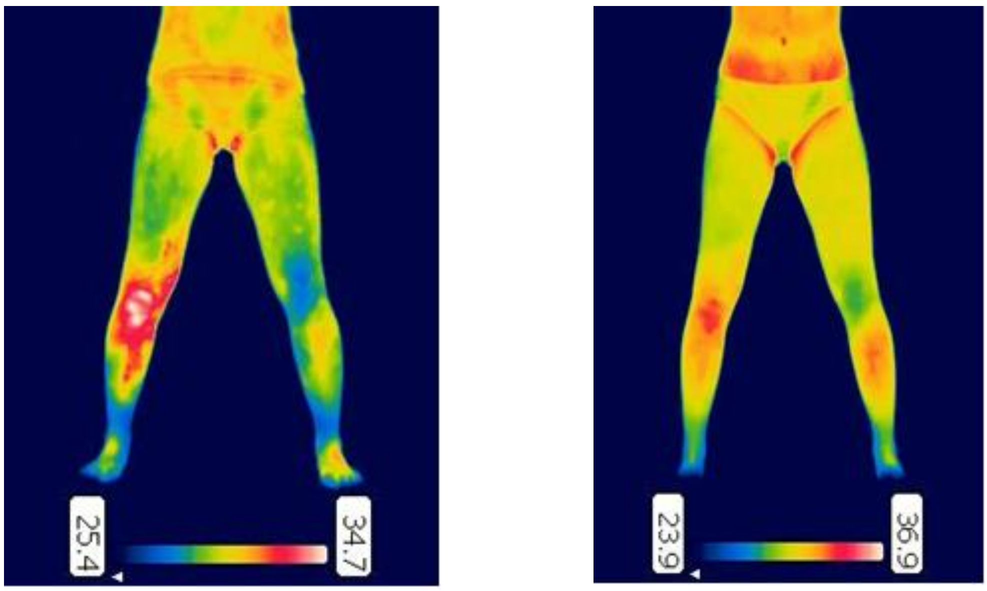

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Figure 3: IRTafter 11 days (A) andafter 24 days(B) from a ACL intervention in a high level judoka. *(Source: Database of images TERMOINEF group of the Technical University of Madrid)*

They have been also reported atypical thermal responses in different pain syndromes cases [8,11], with mio-fascial syndromswith differences between 1-2°C [32]and chronic joint disorders[37] with decreasing temperature suspection presence of a reflex sympathetic dystrophy.

Specifically, BenEliyahu (1990)[18] points to the possibility of a thermographic monitoring of some problems such as tennis elbow, patella-femoral syndrome, knee injuries, stress fractures, myofascial syndromes, spinal pain, and shoulder injuries foot, and various neuropathies such as carpal tunnel syndrome. All these problems appear frequently in athletes, thus impairing performance. In this way, IRT can help anticipate such problems terminating within a lesioneven before painful symptoms appear[15]. Interestingly, the absence of pain does not discard the existence of an injury [32]. The advantage of this technology is that it can detect injury before the pain is revealed.

thletes competing in long-term tests at ambient conditions of extreme heat (such as triathletes and marathoners) often suffer hyperthermia processes[38] during training or competition, whichcan produce even death under uncontrolled conditions [39]. The use of IRT can help identify this condition immediately and to stablish acute procedures in an attempt to lower the body temperature.

It is worth noting that thermal imbalances by IRT may be a warning sign of injury; however, additional tests are needed to diagnose the existence of a specific organic or metabolic problem [9]. For example, in the case of a muscle tear, we should perform biochemical tests, tomography, ultrasound or other diagnostic techniques by image, in order to surely diagnose and quantify the severity of the injury.

Therefore, the practical use of thermography in the field of sports medicine will have as its main contribution injury prevention [15,16,40,41]. However, it can also help in monitoring the evolution and treatment of an injury and warning about potential problems in the health of athletes. So, it is interesting that physicians directly involved in the treatment of athletes and sports teams consider the use of this technique as an additional tool into the daily work routine with patients.

4. THERMOGRAPHY IN SPORT PHYSIOTHERAPY

Sports physical therapists can also use routinely thermography to help plan its interventions[15,17]. A good example would be cryotherapy treatments (42) in which cold water baths are applied to relax the muscles. Thermography could help monitorize the level of hypothermia reached in a given region and the duration of the treatment, thus avoiding excessive exposure to cold or, conversely, controling if the cooling has not been sufficient to achieve the desired effects.

Figure 4 shows the average temperature of the hand before (a = 32,9ºC) and after (b = 17,6ºC) cryotherapy treatment of 5 minutes, which clearly exhibits the temperature difference and a higher temperatue in the area of the thumb joint after treatment.

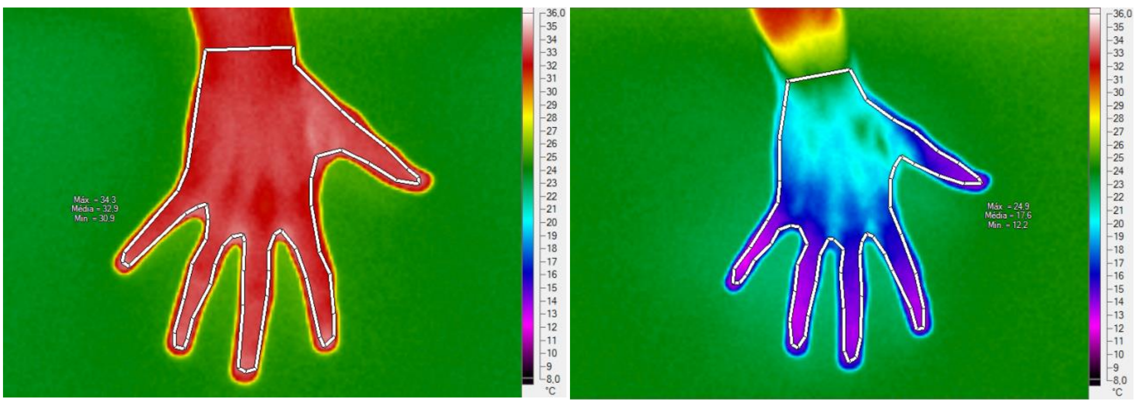

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Figura 4: Thermograms inmediateley before (A) and after (B) aphysiotherapy treatment with cryotherapy.*(Source: Database of the Thermography section of the Federal University of Viçosa – Brazil)*

After a prolonged immobilization due to injury, the temperature of the affected region usually decreases. This phenomenon maybe be identified by the thermal profile of the athlete or by bilateral comparison with the unaffected zone [9]. Monitoring the effect of the physiotherapy intervention will succeed when the temperature progressively affected region draws closer to that of the corresponding bilateral region.

Therefore, IRT is an important practical support tool for physiotherapists, which may help in their interpretation of the treatment given to the athleteand, by extension, to any patient.

5. THERMOGRAPHY APPLIED TO THE SPORT PERFORMANCE

The coach or physical trainer can use thermography as a tool to assess the impact of the training load and recovery. It is therefore necessary that they use it as routine and regularly as possible for obtaining the evolution of the athlete's thermographic profile.

After a workout is normal to happen an increase in metabolic activity as a compensatory response to recover the body after a catabolic period. That is well documented by gas analysis and it is known as EPOC effect [43]. However, the physiological compensatory response decreases progressively to a return to the athlete baseline[44]. This may take, depending on training load over 3, 12 or even 24 hours, when the athlete would be in complete normality [43]. Not reaching the baseline on the ventilatory parameters of the athlete, may be an indicator that the recovery time was not enough or that the recovery process has not been adequate. In that case, the athlete will require more resting time and it would be necessary to revise the nutrition, sleep patterns, recovery protocols and/orthe relationship volume and intensity of the athlete's training.

After identifying by IRT the athlete is not yet in perfect physical condition, the coach and/or trainer will have to make two decisions: first, to assess whether or not the athlete is prepared for the programmed training session; and second, based on the analysis of possible reasons for the poor recovery indicating the thermal imbalance and trying to solve the problem at its source, take the decision of reducing the intensity of training or resting.

We should consider that acute and chronic thermoregulatory adjustments are extremely complex and with a very high intra-subject component [45] due to specific endogenous responses influencedby a set of factors [46] such as age, gender, body fat percentage, sweat glands characteristics, specific endocrine responses and even circadian rhythms. All these factors make it necessary to thoroughly know every athlete with the aim of establishing accurately the thermal baseline. That will enable a follow up study of a cause (training) and the corresponding effect (thermal curve). In the same way that heart rate variability has been proposed as a method for controling training[1], thermography can also be an alternative for that purpose.

IRT can help understand the thermal response during exercise, considering that each individual suffers from the influence of many factors, including the environment, clothing andthe training load. Some studies have investigated specific situations as the practice of Tai Chi Chuan [47] or pedaling a bike for 100 km in a cold and warm environment [48]as well as monitoring the thermal response in the hands during exercise [49]. Merla et al. (2005) [50]concluded by the IRT that trained subjects had better thermal control over skin than untrained subjects during an treadmill exercise.

Interestingly, recent studies by the research group of thermography TERMOINEF of the Polytechnic University of Madrid, have been able to identify specific thermographic profiles by type of sport. For example, in professional soccer players it is normal that the external tibial region of the dominant leg has a consistently higher skin temperature than the other leg [41]; in the case of judo, the thermal profile is characterized by a higher temperature in the gripping arm [51]. Thermal profiles are crucial to avoid misinterpretation of the thermograms; however, it is necessary to deepen the characterization of these profiles, this point opensa very interesting research line in the field of sport thermography.

The physical trainer will have to be aware of three types of thermal responses: a) the thermal symmetry between the contralateral areas; b) comparing individual thermal values with thebaselines of the individual or collective sport discipline; and c) monitoring the individual thermal values of the ROI'swith a greater training load, as the Achilles tendon in jumpers.

It is well documented that one of the positive effects of aerobic training is increased vascularization [52], which allows us to provide more oxygen to the different muscle regions, being this a very important aspect for bothendurance athletesand any athlete of sports with a high anaerobic component, as it will accelerate the recovery of the athlete. Thermography could be a very interesting method to follow thislong term adaptation to training[10], given that the evolution of the resting local skin temperature along the training process should produce a small temperature rise which may be an indicator of increased capilarization. In the case of physicaly active people with diabetes or vascular problems [9,10] monitoring the skin temperature, mainly in lower limbs, it will have an even greater importance, as it will mean an adaptive improvement of its peripheral vascularization.

The work of Akimov et al. (2009) [53] could identify that thermography has the ability to predict the anaerobic threshold in laboratory conditions; which would mean IRT could be a support tool in indicating the exercise intensity based on the established objectives. Chudecka and Lubkowska (2010) [54]also indicate that thermography can serve as an indicator of fitness.

Therefore, IRTis another tool to support decision-making on the training load for the technical teams responsible for training the athlete. However, in this area they are still exploratory studies when compared to the research already consolidated in the fields of sports medicine and physiotherapy. On the other hand, there are strong indications that this tool can be used routinely in the future to help in the prescription of training and retraining in order to return to competition.

6.TERMOGRAPHY APPLIEDTO RESEARCH IN SPORT

The points presented above are certified by rigorous scientific research. The this section is devoted to the most innovative research lines on thermography that directly affect the life of the athlete.

Thermoregulation studies have used different techniques to assess local or core temperature [55,56]. There are some articles protocols using digital infrared thermometers to measure the tympanic temperature or mercury thermometers for taking in the armpits or the oral cavity temperature, which are difficult to follow in terms of exercise. There are other studies in which a rectal sensor[55.56] or gastrointestinal pill [57]measures internal temperature for a continuous monitoring of the subject during exercise. However, although the latter are very reliable methods are difficult to implement, very uncomfortable and basically restricted to laboratory use.

Thermography has many advantages over previous methods, but the main is that it allows an assessment of the entire body instantly. Given these factors, it is important to study the specific thermoregulatory responses both at rest and during exercise groups like children, women [33] and seniors [24,33], or disabled persons who exercise athigh level[58].

In the case of athletes, it is very interesting to understand in what way the extremes of heat or cold environments influence their thermoregulatory response, helping to establish strategies seeking greater comfort during and after physical activity. Another important line of research corresponds to the impact of dehydration [59] and, consequently, the effect of thedifferente hydration methods used by athletes. It is known that hyperthermia is a major cause of fatigue during exercise [48], so hydration has an important role to avoid that situation [60,61] so that thermography could be a technology for its control.

Studies on the development of garments that provide better thermal response also represent a promising field of research, focusing on the type of clothing to be used, the type of color, material [62], the amount [63] or even the cooling system used [2,64]. A small example is shown in Figure 5 where two shirts, one red (A) and another black (B) were exposed to sunlight for 15 minutes at an ambient temperature of 26°C. It is clear that the black shirt caught more solar energy thus increasing its temperature with a difference of 4°C against the red shirt. In this case, an athlete who was competing in hot environmental conditions wearing a black shirt would have a greater thermal load, thereby requiring more effort in an attempt to cool the body, which would also lead to a further loss of fluid and, consequently, dehydration. This clearly implies that the uniforms of the athletes like marathoners, triathletes or soccer players who do their training and competing in open and hot environmentsshould always opt for light-colored clothing. Consequently, in cold conditions the best choice to help warm the body would be dark-colored shirts.

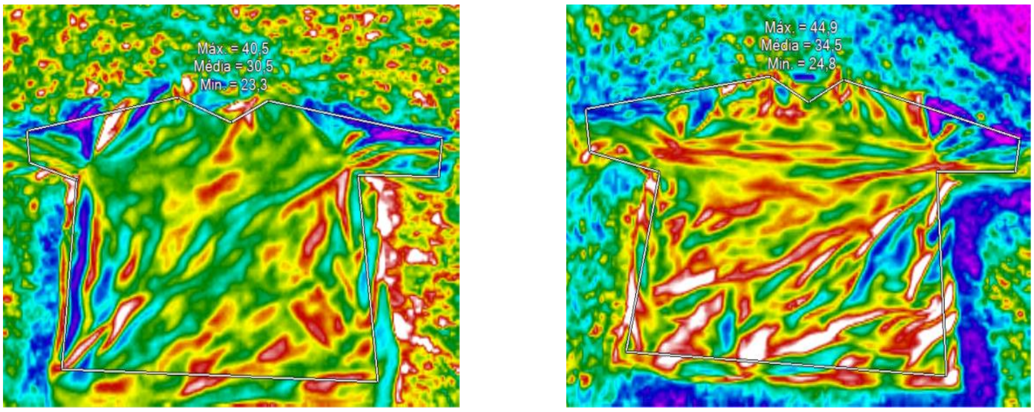

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Figure 5. Thermal response of a red (A) and black (B) T-shirt after 15 minutes of solar exposure.*(Source: Database of the Thermography section of the Federal University of Viçosa – Brazil)*

Researchers have the ability to develop studies which contribute to progress in the applications of thermography in sport, helping to understand how to evaluate different body thermoregulatory responses both in high-level athletes and in amateur athletes and also in people from special population groups.

7.**TERMOGRAPHY APPLIED TO SPORT MANAGEMENT**

At present there are clubs of certain sports such as soccer, basketball, volleyball, or cycling, in which their athletes sign for substantial economic quantities. A very recent example is the purchase of the player Cristiano Ronaldo by Real Madrid, meaning an investment of 94 million Euros. Before signing the contract the athlete usually takes a number of medical tests and functional tests to evaluate whether the player's health is optimal at the time of signing. Tests must be fast and provide information that may indicate an athlete is injured or not. Considering its features, IRT could be incorporated into the screening tests protocol, thus helping to detect thermal imbalances that could be indicative of risk of injury or providing some signs that lead to the medical team to assess more in depth the athlete with specific diagnostic tests before taking the important decision to contract the athlete.

Given the huge amount of money involved in some high performance sport, injuries are in addition to loss of health and performance of the athlete and/or team, a significant loss of money for the club. In this regard, studies such as Gomez-Carmona (2012) (65) have demonstrated the utility of IRT to reduce the incidence of injury, and thus, the cost involving injuries.

This technique could be also used by insurance companies to certify what happens in many cases: technical or athletes who disregard the symptoms of his own body or the evidence of the test and finally compete, even at knowing the extreme risk they take. In the same way, it could be used by clubs to ensure that the insurance fees were reduced including routine IRT assessments on the injury prevention protocol of thetechnical team.

8. PROPOSAL FOR IMPLEMENTATION OF THERMOGRAPHY IN THE SPORT

There are a number of factors(46,66) that can influence the body's thermoregulatory response. These factors should be recorded on sheets of observation and controlled as far as possible by informing to the evaluated 24 hours prior to the assessment about the testing standards.

There are no specific recommendations for the thermographic recording data in the sport (15), but may take into account the indications proposed by Ring and Ammer (2000) (67) to decrease the margin of error in thermographic data collection in humans, also increasing the reproducibility of testing conditions and the measurement results.

We suggest the implementation of specific areas of thermographic evaluation in sports training facilities. That area must have a minimum size of 10 m^2 (2 x 5 m), and they should be equipped with the following materials:

a) A thermal imaging camera with a resolution equal or superior to 320 (horizontal) x 240 (vertical) pixels, a minimum sensitivity of 65 m°K, a measuring range covering the possibilities of human environment (between 0°and 50°C), a thermal sensitivity of 0.02°C or lower, and standard data outputs to the PC.

b) An air conditioner and a weather station for recording the environment both inside and outside to ensure an environment at 21 - 23°C (9,11,15,17) and a humidity of 35 - 38% (15).

c) A roll-up screen of 1.5 m (width) x 2.5 m (height) or painted wall,preferable dark and with low infrared reflection, to ensure a uniform background temperature.

d) A platform for the evaluated is not in contact with the ground to take the picture.

e) A computer software for analysis of thermal images.

f) Appropriate forms for the data collection and other instruments as anthropometric tools for determining the body composition of the athlete.

It is highly recommended that the assessed adapts to room temperature, standing up with the minimum possible clothes. Usually it is considered enough a minimum time of 10 minutes for establishing a thermal homeostasis (66), but there are works that point to a time of 20 minutes (15,17).

The equipment must be used by a technician with training both in the capture and treatment of thermographic images. Then, images of athletes and reports, especially those with obvious imbalances in temperature, should be forwarded to the appropriated professionals (doctors, physiotherapists and trainers) to interpret the results and perform the interventionthey consider more adequated.

It is also interesting to thermal monitoring, recording training conditions, mainly with regard to the intensity and volume, besides the type and amount of used clothes and hydration. Such information recorded in a database can be especially important for creating profiles and thermal responses depending on each athlete and sport discipline.

9. LIMITATIONS ON THE USE OF IRT

Like any new technology, thermal imaging has a number of limitations that must be taken into account. Some of them are:

a) The studies published today unable to provide a specific thermal profile for each sport.

b) The specificity of the thermal response of each individual makes difficult comparison between subjects.

c) It is important to note that IRT is not a diagnostic tool, but a technique that provides additional information which may be supplemented by other techniques and appropriated diagnostic tools.

d) They must be developed computer softwares for the human thermographic imaging analysis, which are able to analyze images of a fast, reliable and objective way.

e) It is interesting to evaluate whether there are errors in the results considering the thermographic images from two different cameras.

f) There is no specific and established pattern analysis in the area for sports.

g) Most cameras have a margin of error of 2% on the value of reading, and need to improve their accuracy.

Despite these limitations, IRT can be an important tool for application in the field of sport.

10. CONCLUSION

Infrared thermography is a technique that can be applied routinely in physical activity and sport, with particular benefits to the work of doctors, therapists and trainers. This technique provides information on the thermal response and the specific physiological adjustments of the subject that indicates the health and physical condition of the athlete. Its main virtue lies in the detection of imbalances that can lead to injury, thus becoming a key information tool for injury prevention and for the evaluation, monitoring, and customizing the athletes’ training load.

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