THERMOGRAPHIC DIAGNOSTICS IN SPORTS

Jozef **ŽIVČÁK**[1], Mário **JANČOŠEK**[2]

1. Department of Biomedical Engineering and Measurement, Faculty of Mechanical Engineering, Technical university of Košice, Slovakia
2. Department of Sports Kinanthropology, Faculty of Sports, University of Prešov, Slovakia

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- muscular overload,
- movement,
- diagnostics.

Abstract:
The present paper deals with the diagnostics technique of thermal vision in sports. Modern training of athletes means intense training sessions lasting several hours per day over a long-time period. High intensity of training places abnormal demands on various body parts depending on the type of sport. This induces cellular response, response of the body organs or physiological systems. The locomotor system is taxed to its fullest anatomical and physiological capacity. Excessive loading and overloading may induce inflammatory response of acute, subacute or chronic nature. Most medical diagnostic methods developed over the last years have found their place in sports medicine as well. Experts prefer especially non-invasive diagnostic methods, mainly those that provide information visually – sonography and thermal vision.

INTRODUCTION

Thermal vision (or thermography) refers to a diagnostic technique that visualizes and measures the skin temperature. It is a non-contact and non-invasive temperature measurement. During exercise human body emits infrared radiation observable by thermal vision.

Thermal vision assists athletes (professional, performance and recreational ones) in diagnosing overloading, in monitoring healing process after sustaining an injury, in choosing therapeutic intervention, rehabilitation and future training and competition [1,2].

Thermographic diagnostic technique used in medicine can aid to ascertain the phase of inflammation (healing), or the specific type of damage. The thermographic examination itself cannot give exact diagnosis. The diagnosis can be established only via anamnesis, clinical examinations, etc. To determine which tissue, or a part of body organ is damaged experts make use of sonography, X-ray, magnetic resonance imaging, etc. [3,4].

The visualization of temperature variations in subcutaneous body parts (muscles, tendons, insertions, joints, blood vessels, and other internal organs) requires prior to examination to uncover (undress) the specific body part for 15 minutes.

1. THE PRINCIPLE OF THERMAL VISION

Thermal vision is a modern imaging method. The principle of this diagnostic technique lies in recording different temperatures and image of isothermal temperature areas on the body surface. These areas originate independent of pigmentation, which leads to spontaneous emission of infrared radiation.

Infrared radiation is detected by a special camera without body contact. The camera transfers the electric signal on the photographic paper (thermogram). Black and white areas manifest various temperatures of the observed body surface. The white areas are warm and the black ones are cold. A variety of pathological processes changes the emission of infrared radiation from the skin or body organs. The ideal object of thermography is inflammations and tumors indicated by increase in temperature in the site of abscess.

Infrared imaging of the temperatures of body surface is nowadays technically and methodologically elaborated, which allows for recording even the smallest deviations despite the fact that body temperature is exposed to regulating actions in different regulatory circuits [5,6,7].

Under standard conditions there is evident constancy of the temperature pattern, being intraindividually as constant as a fingerprint, despite the fact that the absoulte values of average and maximal temperatures may vary due to the functional regulation status of the patient during the examination. In healthy individuals, the smooth axial thermal gradient is on the periphery with symmetrical distribution of temperature on both sides. Every deviation from the symmetric temperature pattern and each variation in temperature is based on a functional and facultatively pathological origin. To obtain a thermographic record that can be easily interpreted and reproduced standard conditions required for examination and elaborated by the European Association of Thermology have to be met.

2. THERMOGRAPHIC DIAGNOSIS OF MUSCULAR OVERLODING DURING SPORTS TRAINING

Thermal vision records variations in body temperature especially in soft tissue, which is best indicative of inflammatory processes that can be induced either by mechanical stimuli, or by overloading, or also by bacterial, viral, fungal, or microbial infections.

Thermal vision has been found to be utilizable not only in internal medicine, but also in branches of medicine dealing with the musculoskeletal system such as sports medicine, orthopedics, surgery and rheumatology in order to diagnose pathological states, injuries or other processes.

2.1 EXPERIMENTAL MEASUREMENT

At the Department of Biomedical Engineering and Measurement (SjF TUKE) experts dealt with variations in body temperature during exercise training using thermal vision. The purpose of the study was to determine whether it is possible to measure post-exercise changes in the temperature of the skin covering muscles in order to assess the thermodynamic cost of the working muscles. Lower-body skin temperature was measured during exercise.

2.2 METHODS OF EXPERIMENTAL MEASUREMENT

The measurement was conducted in a laboratory setting L14. The laboratory was windowless, this means that the effect of both sunshine-induced heat and sunshine reflection from objects located in the laboratory was eliminated. The measurement room was selected in such a way as to secure environmental conditions similar to clinical setting and to allow for the comparison of thermograms. The patients exercised on a stationary bicycle (bicycle ergometer) and an elliptical trainer. Thermograms were recorded prior to exercise and after exercise as well as at identical intervals during exercise. The measurement was taken after the patient interrupted exercise, assumed a prescribed position and a thermogram was recorded. The length of the individual exercise intervals on a stationary bicycle depended on the physical and mental status of the patient, on the objective diagnosis and patient's subjective feelings.

To illustrate the methods and measurement procedures, procession and analysis of thermograms recorded during these measurements a 28 year old person with a 29.6 BMI was selected. Fig. 1 shows typical thermograms in healthy individuals after exercise.

The position required to collect the reference thermograms was indicated 30 cm away from the exercise machine and 2.6 meters from the camera lens. All persons participating in the study were subjected to measurement under identical measurement criteria such as temperature and air humidity.

The thermogram was recorded during exercise by the exercising person assuming the prescribed body position (by stepping down from the exercise machine, which disabled imaging) every 20 seconds and the thermogram of legs was recorded from in front of the examined person.

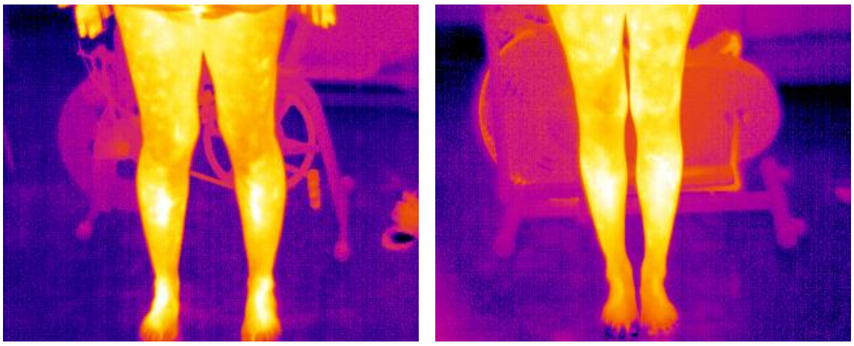

Fig. 1. Post-exercise thermograms a) stationary bicycle, b) elliptical trainer

The collected data might have been affected by exercise interruptions required for correct collection of thermograms.

3. DISCUSSION

The aim of the conducted research was to analyze the thermal distribution during exercise determined via diagnostic thermography.

The following figures (2 to 8) show maximal temperature T_{max}, average temperature T_{ave} percentage contribution of temperatures above 32 °C in right leg (RL) and left leg (LL) prior to and after exercise performed on two types of rehabilitation machines, bicycle ergometer (BE) and elliptical trainer (ET). The sample consisted of 5 healthy individuals referred to as group AB.

Fig. 2 shows maximal temperature T_{max} at the marked site located on the RL. Each person exercised on both machines. The values of maximal temperatures ranged from 31.8 to 34.7 °C.

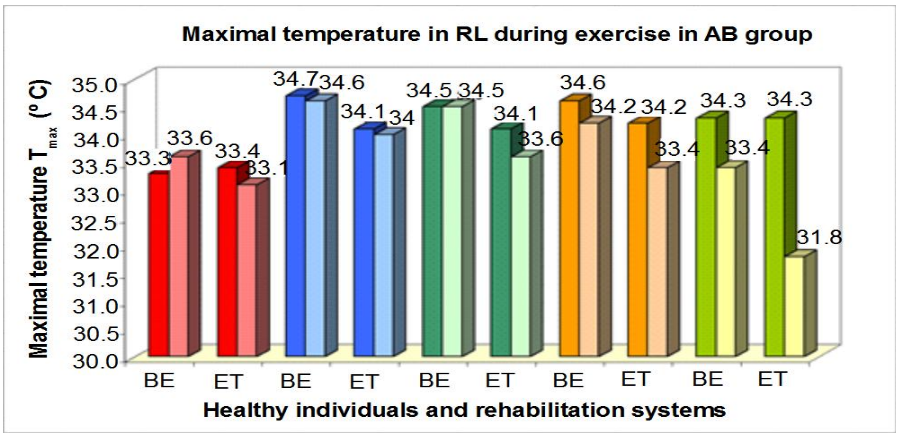

Fig. 2. Maximal temperature T_{max} at the marked site of the right leg in healthy individuals
Description: person no. 1 – red color, person no. 2 – blue color, person no. 3 – dark green color, person no. 4 – orange color, person no. 5 – light green color. Before and after exercising on bicycle ergometer – BE and elliptical trainer – ET.

The greatest difference between temperatures (decrease in temperature) was observed in the last person (light green color) with a difference of 0.9 °C and 1.3 °C in ET. The decrease in temperature was also found in person no. 2 (blue color), where the temperature before and after exercise differed (decreased) by 1.9 °C.

No difference was observed in person no. 1 during exercise performed on ET as the temperature remained unchanged, 34.5 °C. Minimal difference between temperatures was observed in person no. 2 (blue color) on BE and ET and person no. 3 on BE.

Fig. 3 shows maximal temperature T_{max} of the LL. What should be noted is the difference between maximal temperatures of the RL and LL. In exercise performed on BE by person no. 1, the maximal temperature of RL increased by 0.3 °C, while maximal temperature of LL increased by 1.3 °C. In person no. 2, during exercise on BE the T_{max} of LL decreased by 1.9 °C. In most cases (8 persons), the temperature decreased. The decrease in temperature of LL was observed in 7 persons. The temperature increased especially when using bicycle ergometer and decreased when using the elliptical trainer.

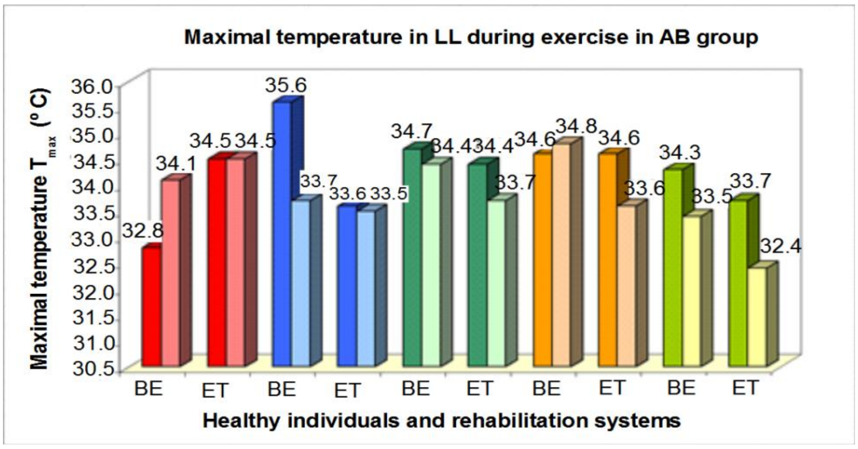

Fig. 3. Maximal temperature T_{max} at the marked site of the left leg in healthy individuals

Description: person no. 1 – red color, person no. 2 – blue color, person no. 3 – dark green color, person no. 4 – orange color, person no. 5 – light green color. Before and after exercising on bicycle ergometer – BE and elliptical trainer – ET

Fig. 4 and 5 show average value of temperature T_{ave} at the marked site of the right and leg before and after exercise.

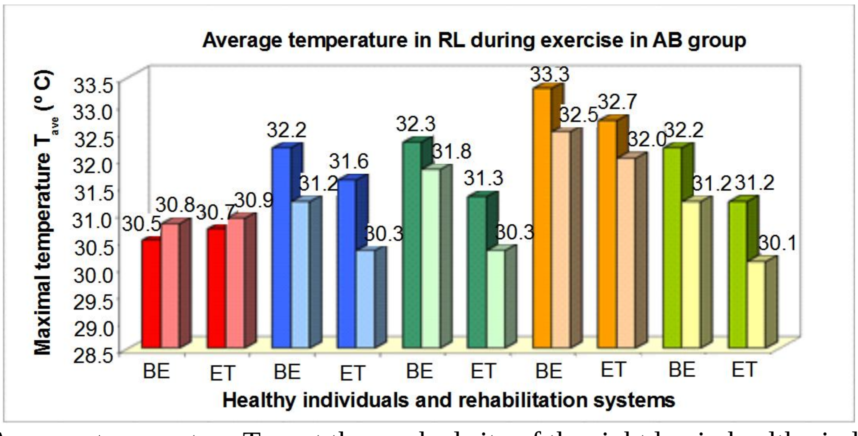

Fig. 4. Average temperature T_{ave} at the marked site of the right leg in healthy individuals
Description: person no. 1 – red color, person no. 2 – blue color, person no. 3 – dark green color, person no. 4 – orange color, person no. 5 – light green color. Before and after exercising on bicycle ergometer – BE and elliptical trainer – ET

Fig. 4 shows average temperature of the right leg in five healthy individuals. The temperature values ranged from 30.1 to 33.3 °C.

The most significant changes in average temperature (decrease in temperature) were observed in person no. 2 (blue color) and the last person. In person no. 2 during the bicycle ergometer exercise, T_{ave} decreased by 1 °C and during the elliptical trainer exercise by 1.3 °C. In the last person (light green color) T_{ave} during the bicycle ergometer exercise decreased by 1 °C as well and during the elliptical trainer exercise by 1.1 °C.

Moderate changes were observed in person no. 1 (red color). In this person, the T_{ave} during BE exercise increased by 0.3 °C and in ET exercise by 0.2 °C. This means that the temperature decreased in 8 individuals and increased in 2 only.

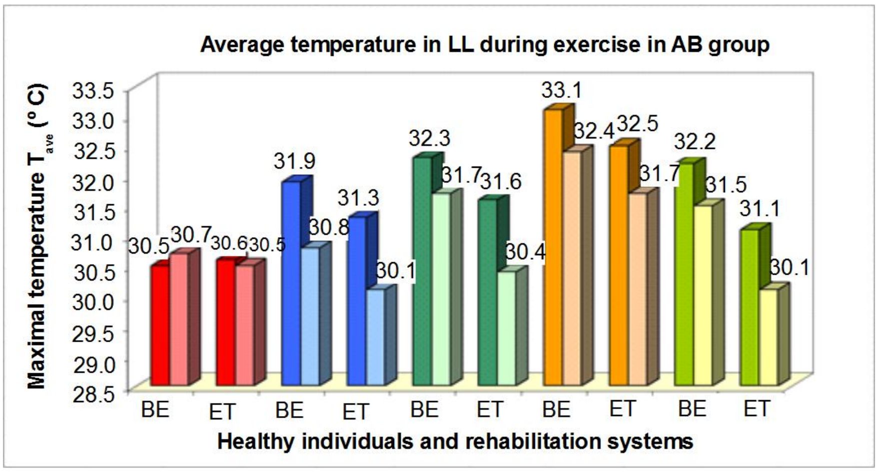

Fig. 5. Average temperature T_{ave} at the marked site of the left leg in healthy individuals
Description: person no. 1 – red color, person no. 2 – blue color, person no. 3 – dark green color, person no. 4 – orange color, person no. 5 – light green color. Before and after exercising on bicycle ergometer – BE and elliptical trainer – ET

Fig. 5 shows a bar chart demonstrating average temperatures before and after exercise on BE and ET in left leg in 5 healthy individuals. As shown in the chart, the values ranged from 30.1 to 33.1 °C. The course in LL is similar to that of RL. The only difference was recorded in patient no. 1, where the temperature decreased by 0.1 °C after rehabilitation exercise performed on elliptical trainer. In person no. 1, the differences between average temperatures before and after exercise were most moderate. Similarly to RL most profound changes were found in patient no. 2, where the temperature decreased by 1.1 °C and by 1.2 °C during BE exercise and ET exercise, respectively. The analysis of the chart shows that the most significant changes with decreasing trend were observed in rehabilitation exercise on elliptical trainer (4 persons).

Fig. 6 and 7 show percentage contribution of temperatures above the selected threshold of 32 °C before and after exercise in 5 healthy individuals at the marked site of the right and left legs.

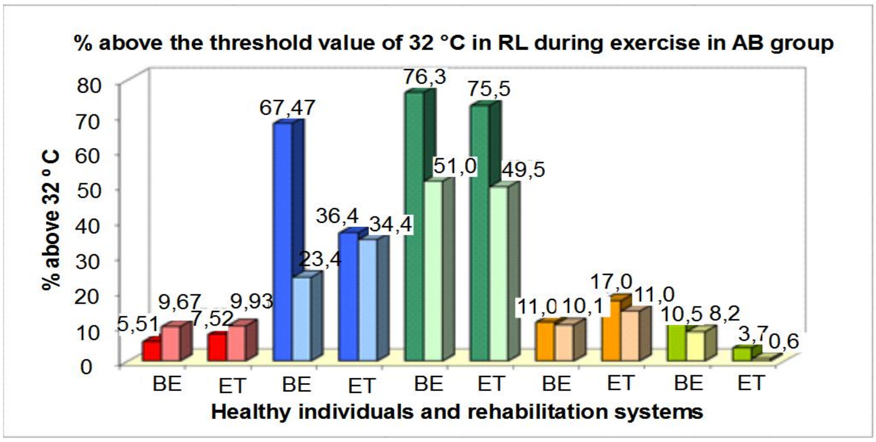

Fig. 6. Percentage contribution of temperatures above the threshold temperature of 32 °C at the marked site of the right and left leg in healthy individuals
Description: person no. 1 – red color, person no. 2 – blue color, person no. 3 – dark green color, person no. 4 – orange color, person no. 5 – light green color. Before and after exercising on bicycle ergometer – BE and elliptical trainer – ET

Fig. 6 shows data on RL. Percentage values indicate the patient with either a warmer, or colder leg and the change in thermal distribution relative to the selected threshold value of 32 °C. The percentage values ranged from 0.6 to 76.3 %. The most profound changes were found in persons no. 2 and 3 (blue and green color). In person no. 2 who underwent rehabilitation on bicycle ergometer the temperature decreased by 43.87 %. In person no. 3, the temperature decreased by 25.22 % and by 23.02 % after performing bicycle ergometer exercise and elliptical trainer exercise, respectively.

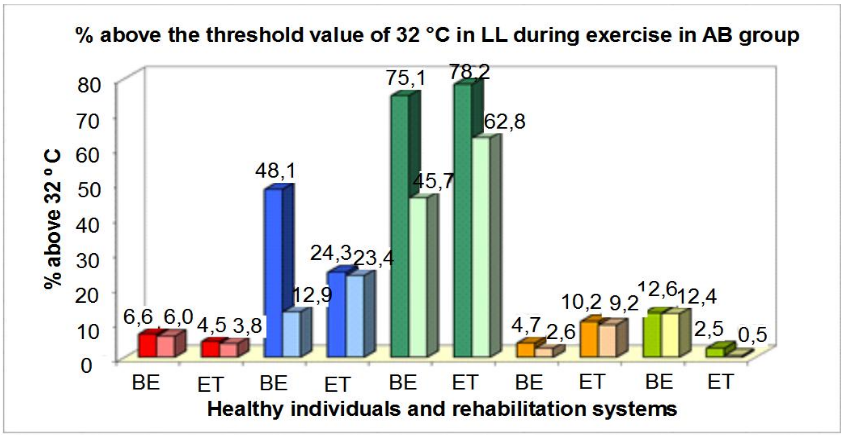

Fig. 7. Percentage contribution of temperatures above the threshold value of 32 °C at the marked site of lower leg in healthy individuals
Description: person no. 1 – red color, person no. 2 – blue color, person no. 3 – dark green color, person no. 4 – orange color, person no. 5 – light green color. Before and after exercising on bicycle ergometer – BE and elliptical trainer – ET

Fig. 7 shows percentage contribution of temperatures above the threshold value of 32 °C at the marked site on left leg in healthy individuals. The data shown by bar charts are similar to those for the right leg. Unlike right leg the percentage contribution of temperatures above 32 °C moderately decreased. The percentage above 32 °C ranged from 0.48 to 78.22 %. Similarly to right lower leg the most significant changes were observed in persons no. 2 and 3.

Fig. 8 shows temperature and humidity in the measurement room before and after exercise in five healthy individuals. The differences between temperature values and humidity values, respectively, fell within normal range, which leads to the assumption that the temperatures in the room did not affect the results of the measurements.

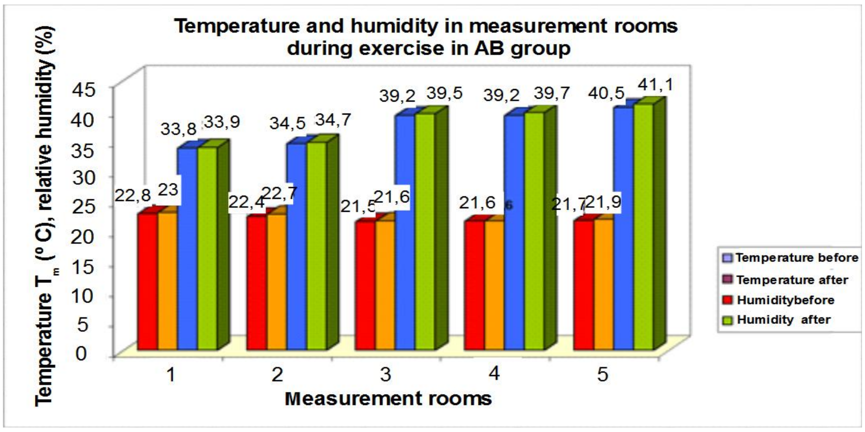

Fig. 8. Temperature and humidity in the measurement room before and after exercise in healthy individuals (AB)

The pilot experimental study presented in this paper forms basis for future research, which will require both experimental determination of correlation between several parameters affecting measurement and the application of statistical methods on a large statistical sample in order to assess the role of thermographic technique in terms of muscular overloading during sports training.

CONCLUSIONS

The assessment of effectiveness determination using thermographic diagnostics with respect to muscular overloading during sports training will be made possible through conduction of future research and experimental studies. First of all, one of the primary tasks will be to compare thermal vision cameras manufactured by different companies (e.g. FLUKE, FLIR, NEC). With respect to the present study, a variety of tasks to be conducted in the future have arisen. These tasks will serve to test the new possibilities of modern thermographic devices within the scope of studied application. This will include determination of correlates among several baseline parameters such as room temperature, room humidity, metabolic processes in human organism, body temperature measured via contact measurement at several standard landmarks resulting in the thermographic output – thermogram. What is crucial is to determine the effect of perspiration on surface temperature, where one of the possibilities is to correlate the outcome thermograms with skin resistance, which will assist in determining the emissivity of the skin.

The thermographic functions can be simultaneously used together with other diagnostic techniques such as plethysmography, EMG, ECG, blood pressure measurement, etc.

The conduction of the study was inspirational also for the field of software procession of collected data, which is to be complemented by functions such as automatic determination of surfaces, tools for measuring distances and surfaces on outcome thermograms, automatic distance analysis of thermographic camera from the subject and the application of photographic filters.

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