FINAL REPORT

RESEARCH PROJECT: *Application of thermography for the establishment of the lower limb thermal profile of Elite Masters Athletes and the influence of athletic competition on their skin temperature.*

Authorship: *Professor: Manuel Sillero Quintana*[1].
Associate Professor: Jakub Grzegorz Adamczyk[2]
Student: Sacha Karabás[1]

[1]*Physical Activity and Sports Sciences Faculty (INEF). Technical University of Madrid. Sports Department.*
[2] *Józef Piłsudski University of Physical Education in Warsaw | AWF · Department of Theory of Sport.*

Introduction

Infrared thermography (IRT) is a technique capable of recording the body temperature that radiates our skin, through a magnetic spectrum that human vision is not able to detect. That irradiated temperature is determined by specific physiological factors and by the health of each subject. The applications of the IRT in the sports are more recent than in the field of industry or in the medical field. However, the applications have increased a lot in recent years, because many research groups have emerged.

From the 19th to the 24th of March in Madrid, the data collection took place during "12th European Masters Athletics Championships Indoor" (EMACi), celebrated at the Gallur indoor track. Research was carried out with cooperation of Faculty of Physical Activity and Sports Sciences of the Polytechnic University of Madrid (INEF) and Józef Piłsudski University of Physical Education in Warsaw (AWF).

In this work it was studied and analysed the variability of skin temperature in function of warming-up and competition during EMACi. The aim of the study was to define the thermal profile of the European Masters Athletes and looking for possible differences depending on the specific variables of each subject (eg. gender, event, age).

The data collection was carried out with a FLIR T540 thermal imaging camera with a resolution of 320 x 240 (76 800 pixels), which has a sensitivity <30 mK at 30 ° C temperature, recording frequencies between 7.5 and 14.0 μm, with an accuracy of ± 2 ° C (± 3.6 °F) or ± 2% of reading. This camera was provided by the Thermography Unit of the Physical Activity and Sports Analysis Laboratory, belonging to the Faculty of Physical Activity and Sports Sciences of the Polytechnic University of Madrid (INEF).

A portable weather station (Oregon BAR386, Oregon Scientific, USA) was also used to measure temperature and humidity, a roll to maintain the characteristics of the bottom temperature of the thermograms during data collection for all subjects that formed the sample (Figure 1).

Study sample

Study sample was composed of 143 European Masters Athletes (101 men and 42 women), aged 49.99 ± 27 years, with a minimum age of 31 years and a maximum age of 77 years. The athletes had an athletic experience of 16.25 ± 46.75 years with a minimum

experience of 1 year and a maximum of 63 years. The athletes trained in this season an average of 8,12 ± 11 hours / week, with a minimum of 3 hours and a maximum of 14 hours.

The data collection was carried out inside the installation, in the warning up zone of the installations of the indoor track of Gallur (Figure 1). In this space an ambient temperature of 17.77 ± 2.37° C was recorded, with a minimum of 15.4° C and a maximum of 19.4° C. An ambient humidity of 38.11 ± 19.89%, with a minimum humidity of 34% and a maximum humidity of 58%.

Figure 1. Research standing at warm-up area.

The outside temperature was also recorded during the data collection being the outside temperature was 8.17 ±10.83 °C, with a minimum registered outside temperature of 1 °C and a maximum registered outside temperature of 19 ° C.

Methods

Data Collection

In order to participate in the study, all subjects had to previously complete and sign an informed consent in which they were explained how the study was to be developed, the requirements necessary to participate in it. In addition, they signed the authorization to use their data for academic and research purposes while maintaining their anonymity.

After having fulfilled the requirement to inform the subjects of the development of the study, and sign the consent, participation in the study began. First a sheet with the subject's data was filled in, where it was annotated the number of thermograms corresponding to the data collection protocol.

During the data collection, six images of the lower limb of the athletes were recorded (3 in anterior view and 3 in posterior view of the lower limb of each subject: 2 photographs before the warm-up, 2 photographs after the warm-up and 2 more photographs at the end of the competition) (Figure 2).

So that, more than 800 photographs were edited one by one, selecting manually six regions of interest in each of them using the FLIR tools Software provided the manufacturer of the camera. We can see an example of this analysis in Figure 3. Finally, individual report has been edited and provided to all participants by email (Figure 4).

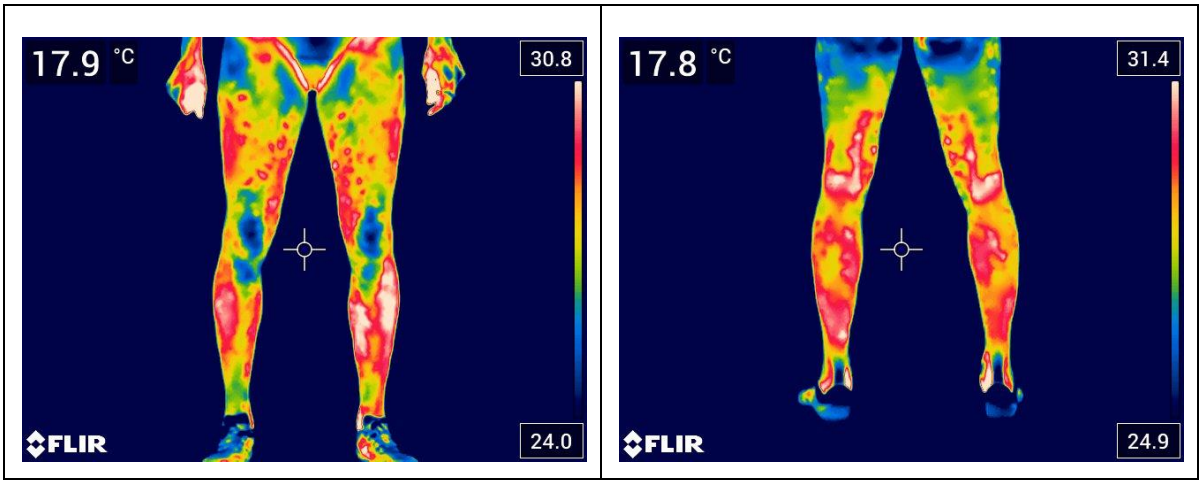


Fig. 2. Examples of the thermal images of the anterior and posterior views before the analysis.

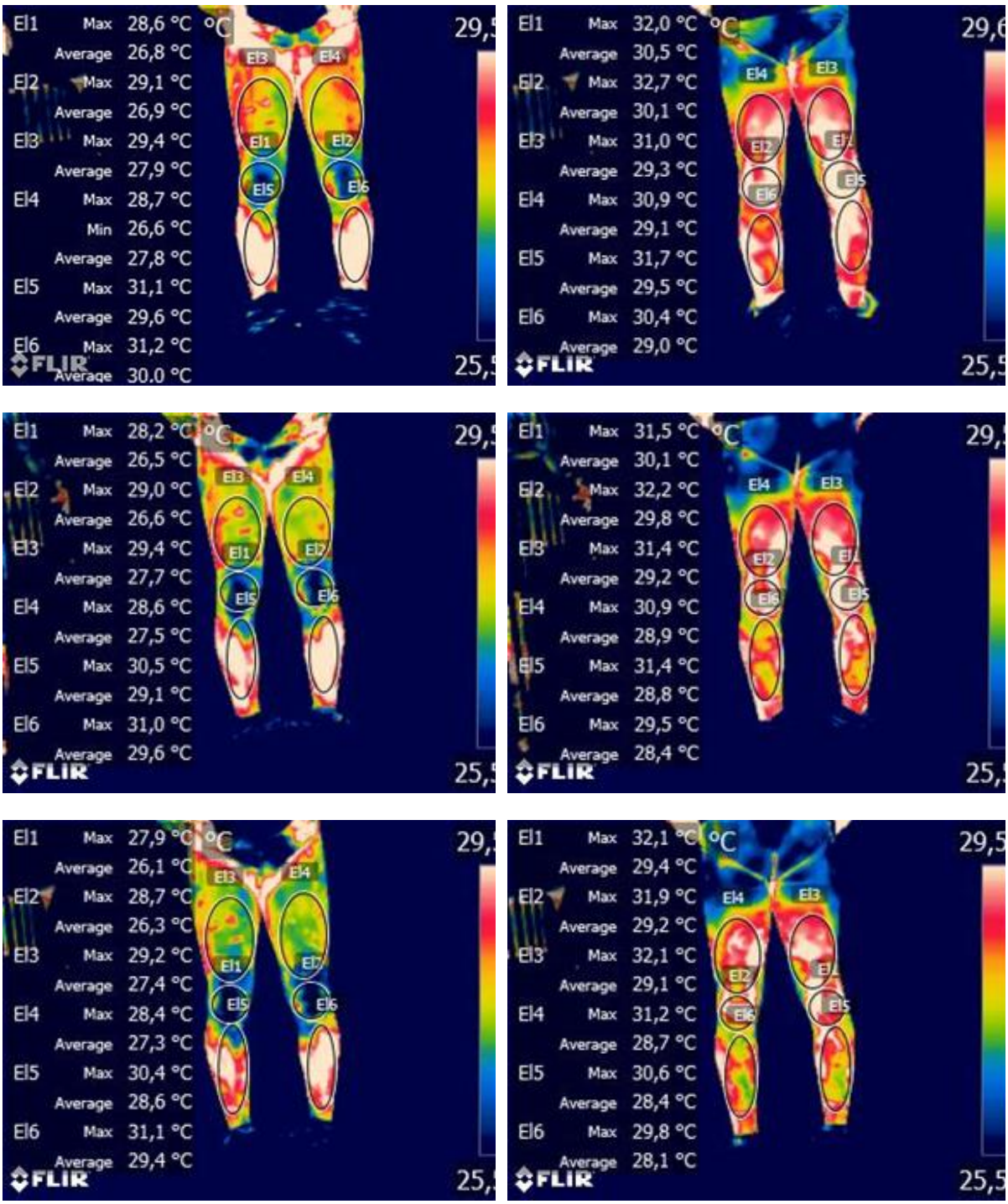


Fig. 3. Thermal images (before warming up, after warming up and after competition respectively) with marked regions of interest (ROI) after the analysis.

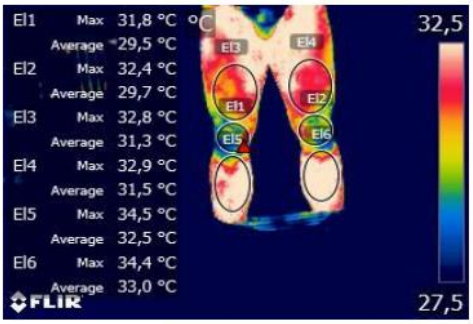
INDIVIDUAL THERMOGRAPHY REPORT

Athlete: DATA PROTECTION | Event: 60 | # Events: 1 | Number: DATA PROTECTION | Age: 37

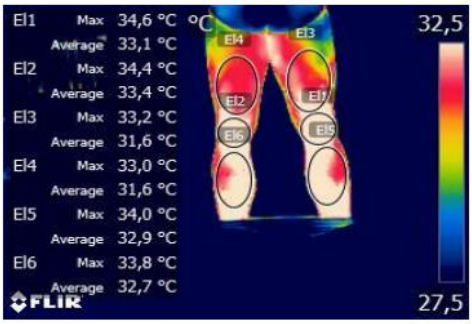
Room Temperature: 18,4 | Humidity: 43 | Remarks:

The thermograms exhibit here have been done by a trained thermographist under the enviromental conditions written above. Many influence factors may affect the results of thermography; the real conditions of the recording did not allowed to ensure the proper aclimatation of the athlete. IMPORTANT: The comments of this report are not a proper diagnose and they have not written by a practitioner. In case of any special thermal partner, we recommend you to comment the results with your medical doctor or physical therapist.

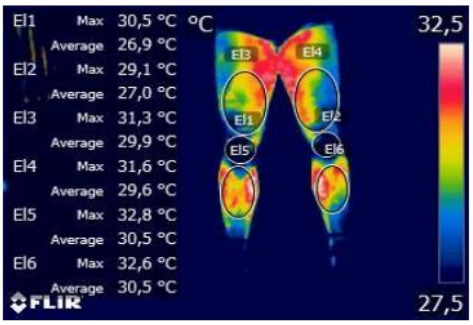
BEFORE WARMING UP ANTERIOR VIEW



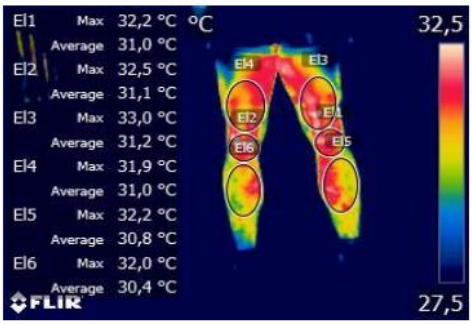
BEFORE WARMING UP POSTERIOR VIEW



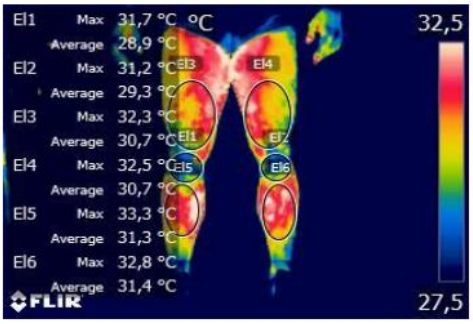
AFTER WARMING UP ANTERIOR VIEW



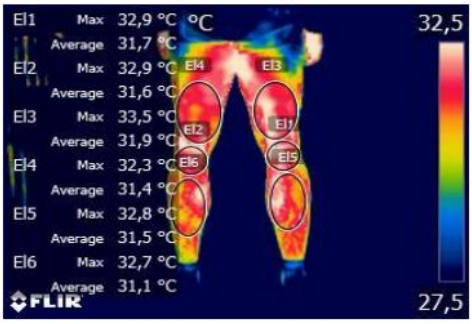
AFTER WARMING UP POSTERIOR VIEW



AFTER COMPETITION ANTERIOR VIEW



AFTER COMPETITION POSTERIOR VIEW



REMARKS ABOUT THE RESULTS

Normal skin temperature reduction after warming-up for blood flow redistribution to the muscles. No specific comments about your thermograms. Thank you very much for participanting in our study.

Fig. 4. Example of individual report.

Results

GENERAL EFFECTS OF WARMING-UP ON SKIN TEMPERATURE

As we expected warm-up caused lowering of skin temperature which suggest initiation of thermoregulation response and dealing with excess heat, which need to be removed from body. Table 1 shows the general results of the Tsk of the ROI of the anterior and posterior face respectively in the lower limbs before and after warming up. The average reduction of the Tsk in the anterior view was -0,99ºC and -0,67ºC in the posterior view.

Table 1. Effect of warm-up in analysed Regions of interest (ROI)

ROI	PRE-Warm-up		POST-Warm-up		Temperature Variation (Post-Pre)	Significance of differences between measurement
	Average (°C)	±SD	Average (°C)	±SD		
Ant. R. Knee	29.73	1.39	28.71	1.27	-1.02	YES
Ant. L. Knee	29.89	1.71	28.90	1.53	-0.99	YES
Ant. R. Thigh	30.87	1.44	29.82	1.24	-1.05	YES
Ant. L. Thigh	30.80	1.16	29.88	1.30	-0.92	YES
Ant. R. Leg	32.22	1.11	31.20	1.08	-1.02	YES
Ant. L. Leg	32.23	1.06	31.30	1.04	-0.93	YES
Post. R. Knee	32.47	1.08	31.53	1.18	-0.94	YES
Post. L. Knee	32.48	1.06	31.57	1.21	-0.91	YES
Post. R. Thigh	31.65	1.15	31.22	1.17	-0.43	YES
Post. L. Thigh	31.66	1.10	31.20	1.19	-0.46	YES
Post. R. Leg	32.09	1.06	31.45	1.16	-0.64	YES
Post. L. Leg	32.04	1.10	31.41	1.17	-0.63	YES

Measurements allowed to distinguish two types of thermal reactions for undertaking exercise (see Figures 5 and 6).

Figure 5 shows a pattern characterized by a homogenous response of the skin with some localized hyperthermic areas corresponding to the more activated areas after an intense activity. Normally these subjects do not exhibit a high level of sweating.

Figure 6 is an example of a dotted pattern after a moderated and generally aerobic exercise. These hot spots correspond to the location of the perforator vessels that provide warm blood from the muscle to the skin to allows sweating in other to release the excess of heat generated by the muscle activity.

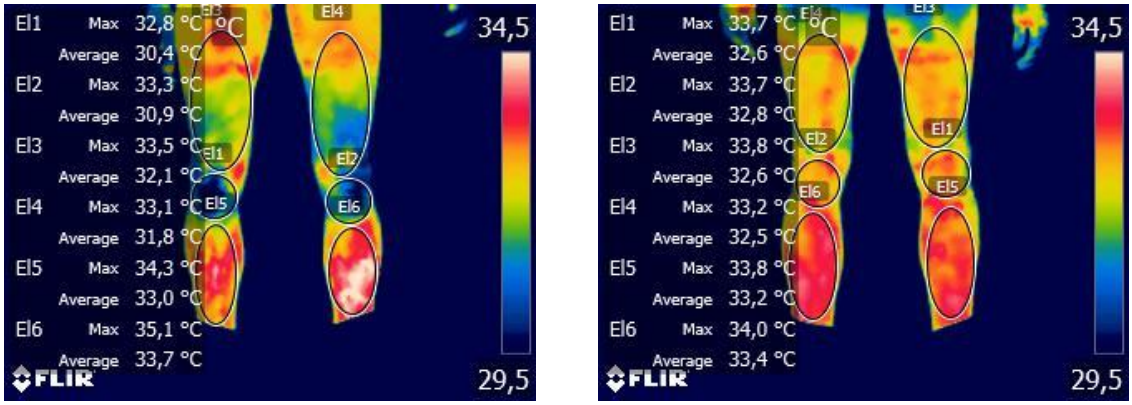


Figure 5. Example of effects of heating on the temperature of the skin – Homogeneous response.

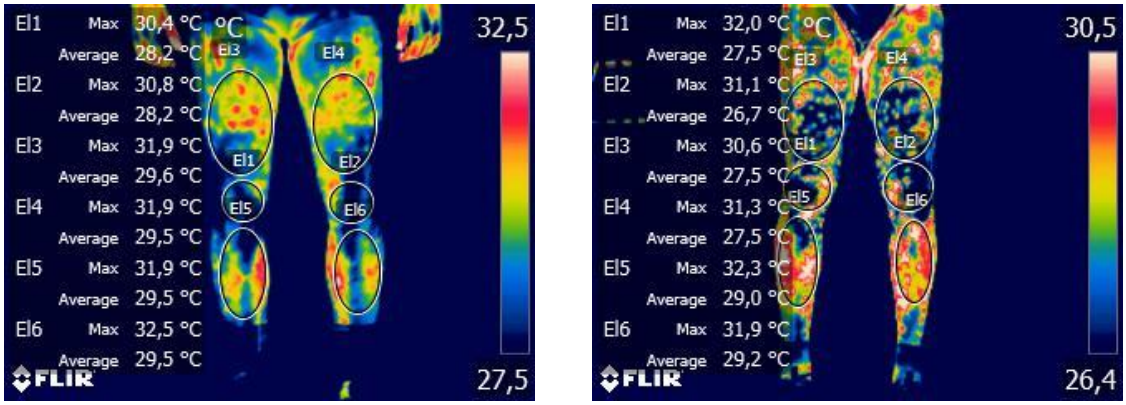


Figure 6. Example of effects of heating on the temperature of the skin – Dalmatian (dotted) response.

General effects of competition on skin temperature

In most of the ROIs, we can observe lowering down of the skin temperature (Tsk) after the competition (Table 2). These reductions were not significant for all the ROIs and were concentrated in the legs (anterior and posterior) and on the posterior knee, where the vessels are closer to the skin without presence of big muscles participating in the running.

This acute response to the exercise could be due, first, to the vasoconstriction and redirection of blood to working muscles started in the warming up and, second, to the air

convection which occurs during athletic competition. The average reduction of the Tsk in the anterior view was less significant on the anterior view -0,08ºC than on the posterior view -0,17ºC in the posterior view.

Considering some studies referred in literature, these results could be different when the data were collected not immediately after finishing competition but some minutes after finishing competition, in that case the legs good become hotter, due to the recovery of the blood flow on the skin and the increased circulation and body work for recovery after the effort. However, under the conditions of our study, the acute effect of the competition on the studied athletes was a slight reduction on the skin temperature.

It is worth noting that some athletes exhibit and increased temperature immediately after competition. Figure 7 below shows one of that cases.

Table 2. Effect of competition in analysed Regions of interest (ROI)

ROI	PRE-Competition		POST-Competition		Temperature Variation (Post-Pre)	Significance of differences between measurement
	Average (°C)	±SD	Average (°C)	±SD		
Ant. R. Knee	28.85	1.35	28.69	1.34	- 0.16	NO
Ant. L. Knee	28.98	1.54	28.74	1.37	- 0.24	NO
Ant. R. Thigh	29.82	1.39	29.90	1.40	0.08	NO
Ant. L. Thigh	29.87	1.41	30.01	1.36	0.14	NO
Ant. R. Leg	31.29	1.14	31.18	1.17	- 0.11	NO
Ant. L. Leg	31.42	1.12	31.21	1.11	- 0.21	YES
Post. R. Knee	31.65	1.23	31.44	1.20	- 0.21	YES
Post. L. Knee	31.67	1.26	31.43	1.23	- 0.24	YES
Post. R. Thigh	31.18	1.28	31.18	1.27	0.00	NO
Post. L. Thigh	31.18	1.34	31.15	1.27	- 0.03	NO
Post. R. Leg	31.45	1.26	31.19	1.22	- 0.26	YES
Post. L. Leg	31.37	1.30	31.08	1.25	- 0.29	YES

General asymmetries for all regions of interest

Tables 3 and 4 shows the asymmetries (differences between right side and left side) detected in the Tsk of the different considered ROI of the lower limbs at different moments analysed during the study.

Table. 3. Comparison of Tsk asymmetries (anterior view) in the different ROI and in the different moments of study

ANTERIOR VIEW		Right		Left		ASYM	Significance of differences between measurement
MOMENT	**ROI**	Average °C	±SD	Average °C	±SD		
PRE-Warm-up	**Knee**	29.73	1.39	29.89	1.71	-0.16	NO
	Thigh	30.87	1.44	30.80	1.16	0.07	NO
	Leg	32.22	1.11	32.23	1.06	-0.01	NO
PRE-Competition	**Knee**	28.83	1.32	28.98	1.50	-0.15	NO
	Thigh	29.83	1.36	29.89	1.38	-0.05	NO
	Leg	31.28	1.12	31.39	1.09	-0.11	YES
POST-Competition	**Knee**	28.70	1.34	28.75	1.37	-0.05	NO
	Thigh	29.90	1.40	30.01	1.36	-0.11	YES
	Leg	31.18	1.17	31.21	1.11	-0.02	NO

Table 4. Comparison of Tsk asymmetries (posterior view) in the different ROI and in the different moments of study

POSTERIOR VIEW		Right		Left		ASYM	Significance of differences between measurement
MOMENT	**ROI**	Average °C	±SD	Average °C	±SD		
PRE-Warm-up	**Knee**	32.46	1.08	32.48	1.06	-0.02	NO
	Thigh	31.65	1.15	31.67	1.10	-0.02	NO
	Leg	32.09	1.05	32.04	1.09	0.05	NO
PRE-Competition	**Knee**	31.64	1.22	31.67	1.24	-0.03	NO
	Thigh	31.18	1.29	31.19	1.32	0.00	NO
	Leg	31.40	1.27	31.34	1.29	0.05	NO
POST-Competition	**Knee**	31.44	1.20	31.43	1.23	0.00	NO
	Thigh	31.18	1.26	31.15	1.26	0.03	NO
	Leg	31.19	1.22	31.07	1.24	0.11	YES

As it can be observed on that tables, no differences were found in pre warm-up symmetries in mean data for all subjects. If there were some individual contra lateral differences, they would suggest overload or injury and that info was provided to Athletes in their individual report.

Considering that, the sample was very heterogeneous because it included athletes of both genders and participating in different specialties. Asymmetries that were detected after the competition occurred probably as an effect of specifity of event (eg. take off leg in jumps or leading/fore leg in hurdles) or even by the inclination of the track in the curve.

As an example of this effect, Figure 7 shows the thermograms of a long jumper before and after competition. The hamstrings and the calf of the right knee become hotter than the left knee generating an asymmetry probably generated by the activity of the right leg on the take off. In that case the duration of the competition allows an increment on skin temperature that it does not appear in the general results because the post-competition results were recorded immediately after a single race. The long jumpers perform 3 or 6 jumps in the competition that allows more time for the elevation of the temperatures in the active areas.

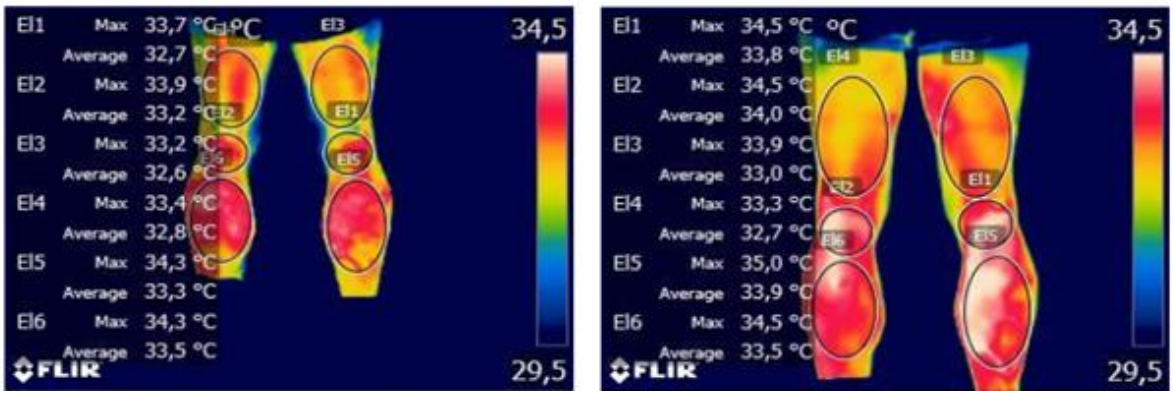


Figure 7. Thermograms of a long jumper (right take off leg). The first thermogram was before competition and the second after competition.

General conclusions of the study

After analysing the results of the study, the main conclusions of the work were the following:

1. The practice of athletic competition affects the temperature of the skin of the European Elite Masters Athletes.

2. After warming-up, the Tsk of the master athletes significantly falls an average of -0,99ºC in the anterior view and -0,67ºC in the posterior view, which suggest correct adaptation to exercise.

3. Immediately after competition, the Tsk of the master athletes slightly decrease -0,08ºC on the anterior view and -0,17ºC on the posterior view. Those reductions were not significant for all the regions of interest.

4. The athlete's thermal profile is characterized by symmetry with slight asymmetries that may correspond to the specificity of the event performed.

Apart from that "scientific" conclusions, the analysis of the individual results showed that the condition of the lower limbs of the athletes participating in the EMACi were quite good; in general, much better than other for people of the same age.

A limited number of participating athletes exhibit some thermal asymmetries that were reported, and they were suggested to show those results to their doctors in order to study their cause and considering the convenience of any treatment for preventing future injuries or any kind of damage in future.

Acknowledgements

We would like to thank the support and facilities that the EMA and the RFEA have given us to carry out this project, especially the president of the EMA (Kurt Kaschke) and the delegate of the RFEA for organizing the competition (Álvaro del Pozo). The study was supported by the Polish Ministry of Science and Higher Education (Grant no. AWF – DS-273).

We would like also to thank the collaboration to all the athletes participating on this study.