

Supplementary material

Reference Article Title: **Effect of exercise on athletes performing in fencing uniforms: methodology and preliminary results of the use of infrared thermography to detect the thermal behaviour of fencers**

Authors: Giulia Lamberti, Francesco Leccese, Giacomo Salvadori and Fabio Fantozzi

Affiliation: Dept. of Energy, Systems, Territory and Constructions Engineering (DESTeC), School of Engineering, University of Pisa, Largo Lucio Lazzarino, 56122 Pisa (Italy)

Featured Application: This investigation has a potential application in the field of sport science, in order to improve the performance of fencing athletes.

Abstract: In recent times, infrared thermography has been often applied to sport science, in order to evaluate athletes' performance in relation to their thermal behaviour. As there is a lack of studies for the sport of fencing, this paper aims to provide preliminary results showing the thermal behaviour of fencers of different competitive level and to provide a methodology for its assessment. In particular, thermal images were acquired before, during and after the training, as well as the metabolic rate and the Rate of Perceived Exertion (RPE), for eight fencers with different competitive level (International/National/Veteran). Results showed that in moderate environments there was any correlation between the environmental parameters and temperature trend on athletes' bodies, while competitive level and thermal behaviour were connected. The presence of thermal asymmetries was also detected. In general, from these preliminary results, professional athletes presented the same temperature trend. Therefore, further studies should be carried out in order to investigate these findings on a larger sample of elite athletes, as their thermal response may be important for improving their performance.

Keywords: Infrared thermography; Thermal imaging; Fencing uniforms; Athletes' thermal behaviour.

Appendix

Data collection of the mean temperature differences recorded on the single body parts and of the thermal asymmetries occurring during fencing

Thermal images were acquired after the definition of the ROIs shown in Figure S1. Since the front and the back part of the athletes' bodies presented the same temperature trend, only the data concerning the front part were reported.

First, the mean temperature differences recorded on the ROIs of all the athletes participating in this investigation are shown.

Table S1 shows the temperature variations on the single body parts, corresponding to the ROIs shown in Figure S1, for all the athletes participating in this investigation.

Figures S2, S3, and S4 show the comparison between the temperature variation of Veteran, National and International athletes, respectively.

Then, since thermal asymmetries may occur in fencing due to the laterality of the athletes, Table S2 shows the comparison between the dominant and non-dominant part and the trunk of the athletes for Veteran, National and International fencers.

Figures S5, S6, and S7 show that in general, the temperature of the dominant part tends to increase faster and decrease lower than the non-dominant part.

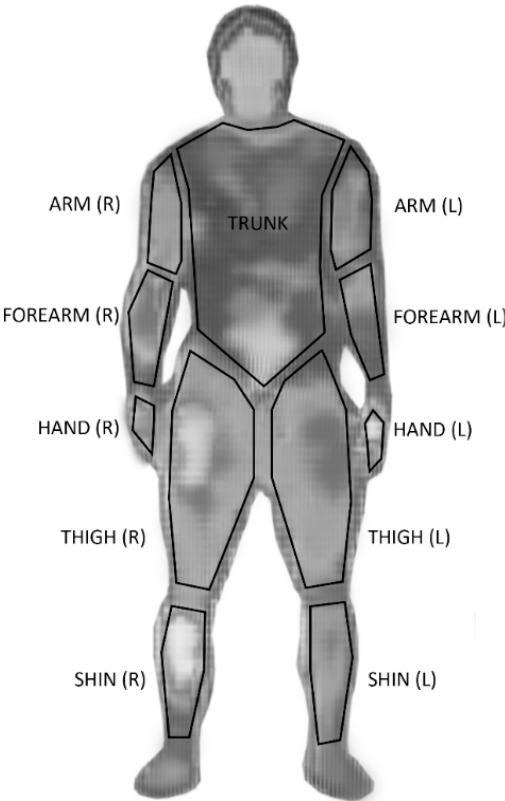


Figure S1. Definition of the ROIs for the single body parts.

Table S1. Temperature variations on the body parts, corresponding to the ROIs described in Figure S1, for each athlete.

		Arm		Forearm		Hand		Trunk	Thigh		Shin	
		(R)	(L)	(R)	(L)	(R)	(L)		(R)	(L)	(R)	(L)
ID 1	ΔT_{12}	5.6	3.4	5.9	5.0	2.5	2.1	4.8	3.9	3.7	1.7	2.8
	ΔT_{23}	8.0	8.9	7.8	8.6	3.7	3.4	9.0	8.5	8.3	7.8	8.4
ID 2	ΔT_{12}	8.5	9.3	6.0	11.4	3.0	2.0	13.4	8.6	10.3	9.9	10.6
	ΔT_{23}	5.2	6.1	5.5	3.0	2.5	1.1	4.2	5.6	5.7	4.4	3.4
ID 3	ΔT_{12}	-11.8	-10.9	-8.3	-9.7	-4.5	-5.5	-12.4	-12.1	-13.2	-11.5	-11.8
	ΔT_{23}	10.3	9.2	8.0	7.8	3.4	2.3	9.7	9.6	9.5	9.2	9.7
ID 4	ΔT_{12}	0.6	-1.7	-0.6	-1.3	-3.9	-5.5	2.2	-0.8	-1.3	-1.5	-2.4
	ΔT_{23}	4.7	6.3	4.9	3.5	4.6	6.2	5.4	6.2	6.3	5.8	5.6
ID 5	ΔT_{12}	-15.0	-14.0	-14.1	-11.2	-9.0	-10.0	-14.3	-14.5	-14.0	-11.5	-11.5
	ΔT_{23}	4.9	2.7	4.4	1.6	7.0	7.0	4.8	6.0	5.5	4.5	5.0
ID 6	ΔT_{12}	10.5	7.5	9.0	7.0	4.2	2.2	8.8	6.5	6.5	2.1	1.6
	ΔT_{23}	-16.5	-15.5	-19.0	-17.0	-5.0	-1.5	-16.0	-14.0	-13.5	-10.5	-10.0
ID 7	ΔT_{12}	-3.6	-4.0	-4.2	-4.2	-3.2	-2.0	-2.3	-3.8	-4.1	-3.3	-0.3
	ΔT_{23}	11.3	11.0	11.0	10.6	7.8	6.0	11.5	10.9	10.9	13.0	10.6
ID 8	ΔT_{12}	15.0	15.5	17.0	16.5	4.8	3.9	15.7	17.5	17.5	16.5	16.5
	ΔT_{23}	5.0	3.5	4.5	3.0	2.4	2.1	3.3	4.0	3.5	5.5	4.0

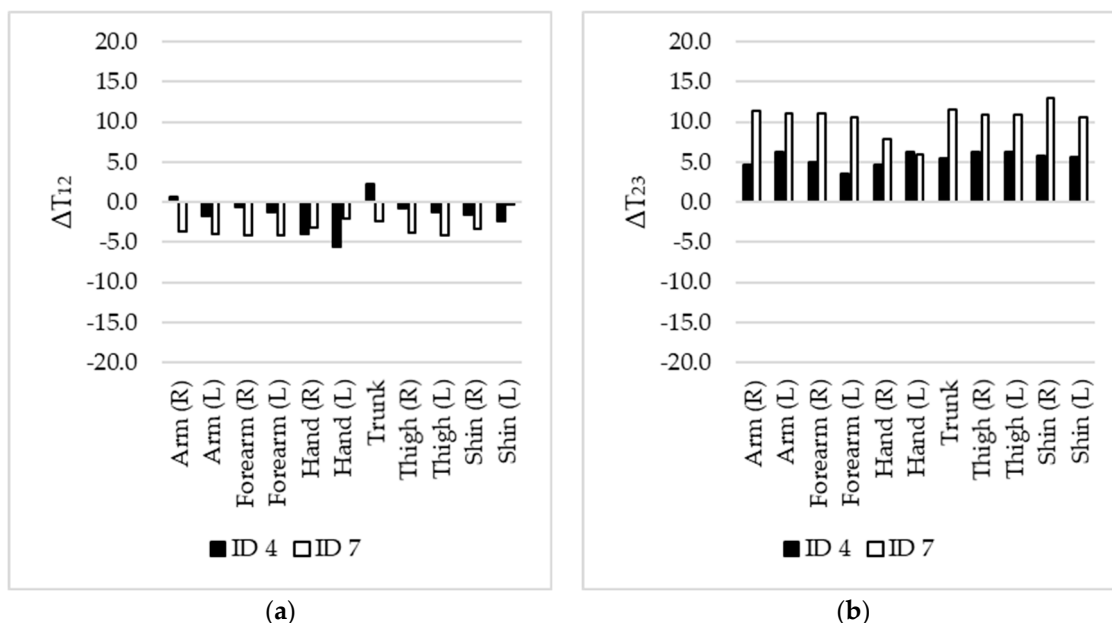


Figure S2. Temperature variations on the body parts corresponding to the ROIs described in Figure 1 for Veteran athletes for ΔT_{12} (a) and ΔT_{23} (b). It can be noticed that both athletes presented a first decrease and a later increase of temperature, even if the younger Veteran fencer (ID 7) showed higher ΔT than the older one (ID 4), as expected.

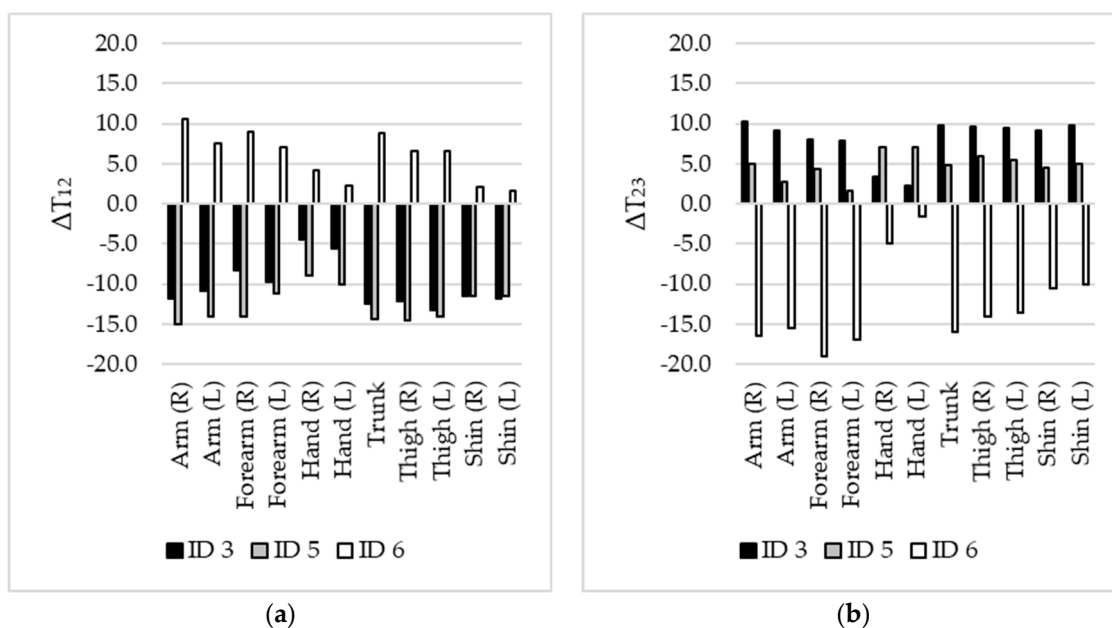


Figure S3. Temperature variations on the body parts corresponding to the ROIs described in Figure 1 for National athletes for ΔT_{12} (a) and ΔT_{23} (b). It can be observed that the most common trend consisted of a first decrease and a later increase in temperature. Only ID 6 showed the opposite trend, probably because the thermal image after training was recorded when the air temperature in the fencing hall was low. In general, values of ΔT resulted much higher than the ones of the Veteran athletes, showing the good fitness level of these athletes.

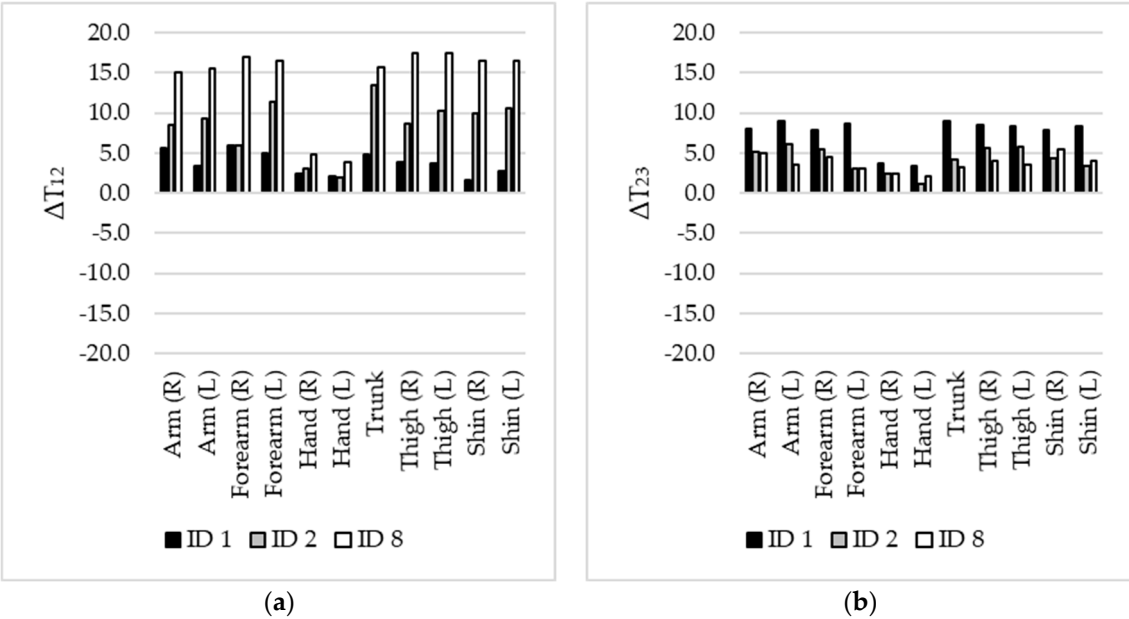


Figure S4. Temperature variations on the body parts corresponding to the ROIs described in Figure 1 for International athletes ΔT_{12} (a) and ΔT_{23} (b). In this figure, it can be seen that international athletes present a constant increase of temperature, even if the extent in the ΔT may vary according to the distribution of the workload during the training. In particular, ID 2 and ID 8 showed ΔT_{23} lower than ΔT_{12} , while ID 1 presented the opposite trend.

Table S2. Temperature variations for the dominant, non-dominant and trunk of each athlete.

ID	ΔT	Dominant part	Non-dominant part	Trunk
1	ΔT_{12}	4.2	3.6	4.8
	ΔT_{23}	8.6	8.7	9.0
2	ΔT_{12}	9.1	7.4	13.4
	ΔT_{23}	4.7	4.2	4.2
3	ΔT_{12}	-10.9	-11.4	-12.4
	ΔT_{23}	9.3	9.1	9.7
4	ΔT_{12}	-2.1	-2.4	2.2
	ΔT_{23}	5.2	4.2	5.4
5	ΔT_{12}	-12.3	-11.5	-14.3
	ΔT_{23}	5.4	4.4	4.8
6	ΔT_{12}	6.5	5.3	8.8
	ΔT_{23}	-13.0	-12.3	-16.0
7	ΔT_{12}	-2.9	-3.6	-2.3
	ΔT_{23}	10.8	9.8	11.5
8	ΔT_{12}	14.2	14.0	15.7
	ΔT_{23}	4.3	3.2	3.3

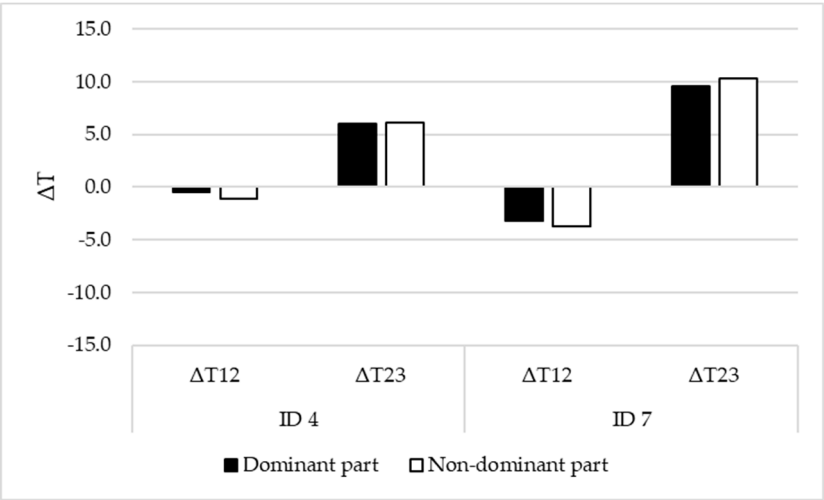


Figure S5. Comparison between the temperature variation of the dominant and non-dominant part of the Veteran athletes.

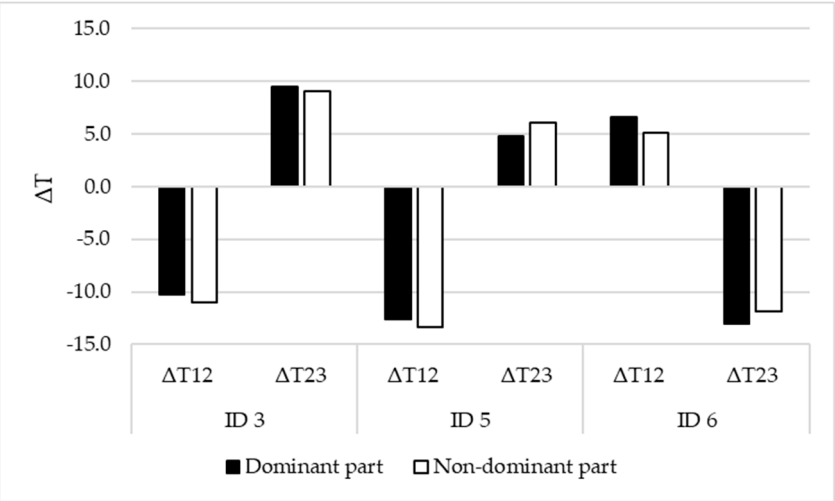


Figure S6. Comparison between the temperature variation of the dominant and non-dominant part of the National athletes.

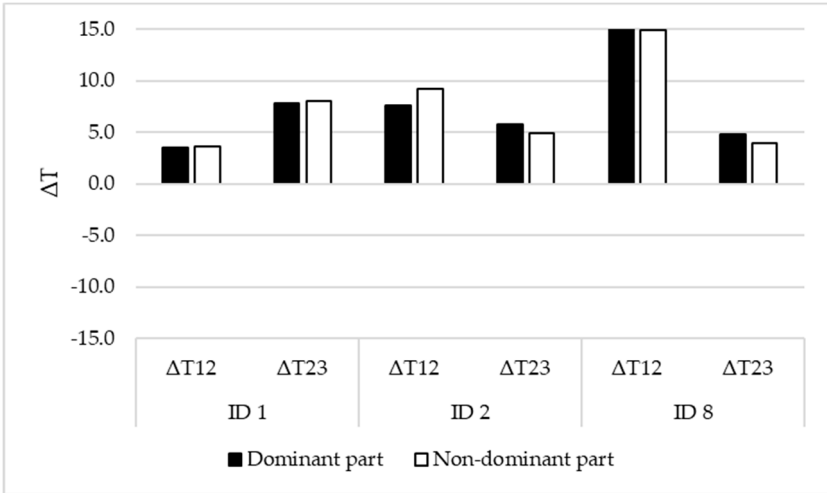


Figure S7. Comparison between the temperature variation of the dominant and non-dominant part of the International athletes.