

Long term effect of Step Aerobics Training on skin temperature. A pilot study

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ABSTRACT

The purpose of this study was to evaluate the effects of a Step Aerobics Training (SAT) on the skin temperature (Tsk) in different regions (ROI) of the anterior body surface. The study included 15 healthy volunteers of the Bialystok University of Technology (BUT) without any previous experience in SAT training. Two sets of thermograms were recorded before and immediately after exercise at the first and last sessions of a 30-weeks SAT program with a progressive intensity.

The results indicate a generalized drop in body temperature immediately after exercise with ΔT_{sk} values of -2.45°C registered immediately after the first training and lower drops ($\Delta T_{sk} = -1.69^{\circ}\text{C}$) after the 30 weeks of SAT. The regions with lower

values of post- vs pre-exercise Tsk were the thighs both in the first session and in the last session of the 30-weeks SAT program. The results show non-significant variations for asymmetries between the values of the contralateral ROIs in every moment of the data collection.

We concluded that a 30-week SAT program resulted in significant drop of mean Tsk of evaluated body parts (ROI), being the thermal effects related with the areas more activated in the sport practice. From the thermal asymmetries perspective, the training program carried out did not generate any injury risk for the participants.

Keywords: Thermography, Step Aerobics Training, Skin temperature, Exercise

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INTRODUCTION

Physical activity (PA) is one of the fundamental means of improving people's physical and mental health. It has major beneficial effects on most non-communicable diseases and the general health of the population worldwide. SAT is one of the most popular collective forms of PA and fitness is recommended for improving cardiorespiratory efficiency and muscular strength and may also be recommended to improve bone health and accelerate fat burning [1,2].

PA results in increased metabolic heat production, which triggers the body's thermoregulatory mechanisms of excessive heat elimination. The thermal regulatory and hemodynamic processes are controlled by two mechanisms: skin vasoconstriction, induced by the blood flow demand to active muscles, and skin vasodilation required by thermoregulation to increase warm blood flow and heat conduction to the skin [3, 4]. The most effective mechanism for the elimination of the heat produced is sweating, because evaporation absorbs the greatest amount of heat.

Step Aerobics Training (SAT) is one of the most popular collective forms of fitness in health centers worldwide. Invented by Gin Miller in 1986 in Atlanta (USA), SAT combines step-on and step-off movements with marching, dancing and jumping exercises. During SAT, participants are stepping on and off an adjustable height platform in a pattern determined by choreography [5].

The physiological effects of SAT are reasonably well established in terms of cardiovascular activity [6], muscular fitness, changes in body composition and bone health after mechanical load and musculoskeletal injuries [1,2,7]. The long-term changes in skin temperature during SAT with resistance exercise for abdomen and upper limbs with rotational movements line on the back on the step, however, have not yet been described.

Thermography is a non-invasive method used to register body gradients and thermal patterns [8, 9]. Subsequently, infrared thermography transformed into a powerful investigative tool with many applications: mechanical, electrical, military, building and medical. Based on its non-invasiveness, infrared thermography (IRT) has been defined as the scientific analysis of data from non-contact thermal imaging devices [10-18]. Thermal imaging cameras detect radiation in the invisible, infrared range of the electromagnetic spectrum and produce images of that radiation, called thermograms. This method provides real-time visual images with measurements of surface temperatures over a wide area.

It is well known that sports activity induces a complex thermoregulation process wherein heat is given off by the skin [19]. Few studies using IRT have been devoted to sports performance diagnostics [20-24] or sports pathology diagnostics [10, 11, 25] and the evaluation of the efficiency level of various physical exercises. These studies have been performed during gymnastics [26], strength training [27], running [22], cycling [28], swimming [29], and football, handball and basketball [30-32]. However, there is a lack of studies on the long-term evolution of skin temperature after SAT, and the impact of SAT on the thermoregulatory system.

PURPOSE

The aims of this study were to analyze the evolution of changes in skin temperature (Tsk) of selected body areas (Regions of Interest – ROI) in the anterior part of the body on persons practicing a 30-weeks SAT program, to verify whether the side-to-side skin temperature difference (ΔT_{sk}) remain symmetrical after the training program, and to standardize the method of evaluation. We hypothesized that a 30-weeks long SAT have different effects on the Tsk of the considered ROI depending of their implication of the corresponding muscles on the SAT and that side-to-side ΔT_{sk} remains symmetrical.

MATERIALS AND METHODS

The study was conducted at the Bialystok University of Technology (BUT) in Bialystok, Poland and was approved by the local Bioethics Committee (R-1-0002/359/2007). The research was performed on 15 healthy volunteers (5 male and 10 female), who were full-time BUT students who wanted to participate in the study. Inclusion criteria were good general health status, which would allow students to participate in the training program, and not being familiar to SAT training, e.g. they have not practiced it in the past. Before training, all subjects were informed about the training protocol and gave their informed consent regarding study procedures. They were also examined by a medical doctor prior to beginning the exercises. The characteristics of the group at the beginning of the study are presented in Table 1.

Data collection and training sessions were held at the air-conditioned BUT Sports Hall with a constant temperature of $21.7 \pm 0.7^\circ\text{C}$, and humidity of $50 \pm 5\%$ measured with a weather station (ETI 810-155 Digital Thermo-Hygrometer, ETI, Great Britain.), and under artificial light of constant intensity.

Table 1. Anthropometric characteristics of participants at the beginning of the study

Gender	Statistic s	Age [year]	Height [cm]	Weight [kg]	BMI [kg/m ²]	WC [cm]	SBP [mm Hg]	DBP [mm Hg]	VC [ml]
Female (n=10)	X	20.2	1.78	75.38	23.77	84.30	125.90	75.50	5240
	SD	0.38	0.05	9.44	2.83	6.65	4.85	5.43	616.74
	Min	20.0	1.70	64.00	19.75	74.00	113.00	64.00	4200
	Max	21.0	1.84	84.00	23.61	98.00	131.00	82.00	6500
Male (n=5)	X	21.0	1.88	76.24	23.63	88.20	126.00	79.80	5740
	SD	0.0	0.05	5.58	2.39	4.52	5.57	6.44	817.72
	Min	21.0	1.78	65.10	20.23	79.00	120.00	67.00	4500
	Max	21.0	1.93	79.10	25.51	94.00	136.00	88.00	6800

N = number of subjects; x = average; SD = standard deviation; BMI = Body Mass Index.; WC = Waist circumference; SBP = systolic blood pressure; DBP = diastolic blood pressure; VC = vital capacity of lungs

SAT was conducted by the same certified instructor for 30 weeks. The SAT program consisted on warm-up section 10 min, a main part of 40 min including steps with alternating movement of the arms and core exercises on the step, and a cold-down part of 10 minutes with stretching and low intensity exercises. Licensed “workout music” was used in a 118–132 beats per minute range. The intensity of SAT during the sessions was controlled by the tempo of the music, the height of the platform and by

introducing more advanced movements in the choreography. The intensity of exercises increased over time in the way shown in Table 2. The first sessions included only low impact exercises (mainly always with one leg on the floor and without jumps) and the last sessions included high impact exercises (e.g. with many jumps). The students were requested to work within the RPE values shown in Table 2 equal to the Borg scale of perceived exertion [33].

Table 2. Details of Step Aerobics Training used

Weeks	Week of SAT				
	1–7	8–10	11–20	21–25	26–30
Height of step [cm]	15	20	20	25	25
Speed of bits [BPM]	118–129	118–129	132	132	132
Steps	Low impact	Low impact	Low impact	Low impact	Hi–Low impact
Intensity	Beginners	Beginners	Intermediate	Advanced	Advanced
Borg scale	8–10	10–12	12–14	13–15	14–16
% HRmax (% of maximum heart rate)	40%–50%	50%–60%	60%–70%	65%–75%	70%–80%

A thermographic camera (CEDIP Titanium 560, Cedip Infrared Systems, France) with a real integrated resolution of 640 x 512 pixels (temperature ranges -20°C to $+3000^{\circ}\text{C}$, NETD $<25\text{mK}$, and spectral response $3.6\text{--}5.1\ \mu\text{m}$) was used for thermal image acquisition following the TISEM recommendations [34]. Images were taken with an emissivity of 0.98. For verification purposes, a remote infrared thermometer CEM DT–8819 (Poland) was also used.

Thermographic images were taken before and immediately after exercise in an air-conditioned nearby room with a constant temperature ($21.7\pm 0.7^{\circ}\text{C}$), humidity ($50\pm 5\%$) after an acclimatization period of 10 minutes to the room conditions. Measurements were taken at the distance

of 10 from the subject. The time necessary for collecting all of the 15 thermograms in single series was around 3 minutes. Two series of thermograms were taken in the anterior body of the subject (Fig. 1). The first series of thermograms were taken at the beginning of the academic year (October) and the second series was taken after 30 weeks of SAT exercises (June).

For evaluation purposes eight ROI were defined in the anterior of the body: Arm left (L arm), Arm right (R arm), Shoulder left (L shoulder), Shoulder right (R shoulder), Chest, Abdomen, Thigh left (L thigh), Thigh right (R thigh) were chosen according to the anatomical parts of the human body (Tab. 3). The back part of the body was excluded because many exercises of the SAT program used

the back for being performed (i.e. sit-ups with rotation movements) and the calves were excluded because the exercises were done with socks. For shoulders, arms and thighs, measurements were

taken symmetrically on the left and right side to provide additional evaluation of Tsk asymmetries on both sides of the body, relating to certain muscles or muscles groups.

Table 3. Regions of Interest (ROI) and corresponding muscles or groups of muscles (L= Left; R=right; m.=muscle)

ROI	Muscles, their parts or groups	Integrated ROI
Arm	m. biceps brachii	L and R arms
Shoulders	m. Deltoideus	L and R shoulders
Chest	m. pectoralis, major et minor	Chest
Abdomen	m. rectus abdominis	Abdomen
Thigh	m. quadriceps femoris m. rectus femoris m. Sartorius	L and R Thighs

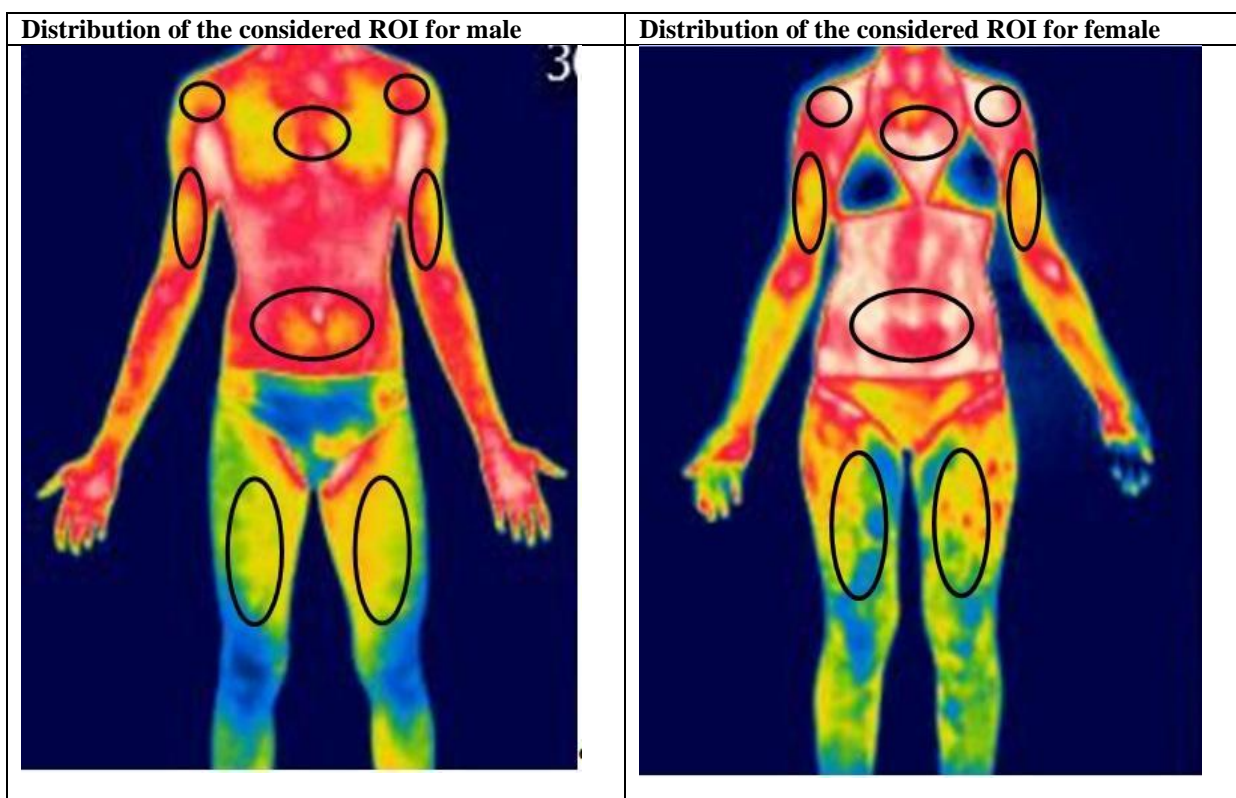


Fig. 1. Distribution of the considered ROI.

Thermographic measurements of Tsk were recorded as real values with an accuracy of three decimal places. Differences of skin temperature (ΔT_{sk}) and symmetries were automatically calculated. A specific software for thermographic image processing (Altair™ 5.80) was used to draw manually the ROI.

RESULTS

Table 4 shows the baseline Tsk values before the 1st SAT session and after the 30-weeks training program.

Differences in Tsk values before starting the SAT sessions were statistically significantly higher ($p < 0.05$) than Tsk values after completing the 30-weeks training program in all of the considered ROIs except for the chest. The higher increments

Statistical analysis was carried out using SPSS 23.0 software (IBM, USA). After confirming the lack of normal distribution of the variables (Shapiro–Wilk test), it was decided to use non-parametrical Wilcoxon signed-rank test, for evaluating differences between two related samples. The statistical significance was set at $\alpha = 0.05$.

were in the arms (1.09 °C and 0.95°C) and thighs (1.04 °C and 1.06°C) and the lower for the shoulders (0.53 °C and 0.52°C) and Abdomen (0.59°C), without significant increment for the chest (0.31°C).

Table 5 shows the post-exercise Tsk values after the 1st SAT session and after 30 months of training.

Table 4. Initial Tsk values before the 1st SAT session and after 30 months of training. (*= p<0.05)

Pre-Exercise	1 st SAT			After 30 weeks			Difference	Z	P
	Mean±SD	Min	Max	Mean±SD	Min	Max			
L arm	31.13±0.92	29.51	32.82	32.22±0.91	30.45	34.25	1.09±0.64	3.408	0.001*
R arm	31.19±1.02	28.37	32.53	32.15±0.78	30.53	33.75	0.95±0.95	3.294	0.001*
L shoulder	32.72±1.31	28.31	33.77	33.25±0.87	31.62	35.00	0.53±1.34	3.408	0.001*
R shoulder	32.73±1.34	28.37	33.96	33.25±0.83	31.57	34.98	0.52±1.35	3.294	0.001*
Chest	32.25±1.09	30.69	34.07	32.56±1.24	30.07	34.43	0.31±0.88	1.193	0.233
Abdomen	31.90±1.78	30.42	33.86	32.50±1.16	30.64	34.22	0.59±0.83	2.215	0.027*
L thigh	30.05±0.94	28.71	31.49	31.10±0.84	29.77	32.52	1.04±0.96	3.068	0.002*
R thigh	29.68±0.92	28.44	31.57	30.73±1.02	29.00	32.63	1.06±1.14	2.840	0.005*

Table 5. Final Tsk values the 1st SAT session and after 30 months of training (* p<0.05)

Post-Exercise	1 st SAT			After 30 weeks			Difference	Z	P
	Mean±SD	Min	Max	Mean±SD	Min	Max			
L arm	28.38±1.15	26.06	29.81	30.35±1.18	27.62	31.91	1.97±1.31	3.408	0.001*
R arm	28.34±1.01	26.06	29.90	30.16±0.97	28.04	31.61	1.82±1.4	3.294	0.001*
L shoulders	30.22±1.44	26.73	32.43	31.48±0.96	29.85	33.18	1.25±1.33	3.408	0.001*
R shoulders	30.27±1.42	27.11	33.00	31.12±0.80	29.87	32.53	0.85±1.29	3.294	0.001*
Chest	28.15±1.27	26.54	30.57	29.86±1.05	27.7	31.32	1.71±1.38	3.067	0.002*
Abdomen	28.39±1.11	27.04	30.99	30.04±0.98	27.86	31.35	1.64±1.07	3.410	0.001*
L thigh	29.08±1.22	27.02	30.92	30.56±1.18	28.03	32.39	1.48±1.34	3.352	0.001*
R thigh	29.45±1.12	28.01	31.63	30.55±1.13	27.98	32.18	1.10±1.35	2.410	0.016*

There were a statistically significant increments of Tsk (p<0.05) in all of considered ROIs after completing the 30-weeks SAT considering the values after the first SAT training as reference. The highest increments were in the arms (1.97 °C and 1.82°C), followed by the chest (1.71°C), abdomen

(1.64°C), thighs (1.48°C and 1.10°C) and shoulders (1.25°C and 0.85°C).

Table 6 summarizes the evolution of the Tsk differences post- and pre-exercise (Δ Tsk) comparing the values of the first and the last training session of the 30-weeks SAT program.

Table 6. Evolution of the Δ Tsk (post- vs pre-exercise) on the 1st training session and after 30-week SAT (* p<0.05)

Δ Tsk	First SAT session Mean±SD	After 30-weeks SAT Mean±SD	Difference	Z	P
L arm	-2.75±1.04	-1.87±1.24	0.88	2.700	0.007*
R arm	-2.85±0.98	-1.99±1.24	0.86	2.272	0.023*
L shoulders	-2.49±0.89	-1.78±1.12	0.72	1.505	0.132
R shoulders	-2.46±1.10	-2.14±0.97	0.32	0.909	0.363
Chest	-4.09±0.80	-2.70±1.36	1.39	3.181	0.001*
Abdomen	-3.51±0.68	-2.46±1.11	1.05	3.067	0.002*
L thigh	-0.97±1.61	-0.54±1.54	0.43	0.625	0.632
R thigh	-0.23±0.87	-0.19±1.36	0.05	0.114	0.910

In general, the average drop of Tsk between the initial and the immediately after exercise on the first session was -2.42°C, and for the last session of the 30-weeks SAT program was -1.69°C. The regions with lower values of post- vs pre-exercise Tsk were the thighs both in the first session and in the last session of the 30-weeks SAT program.

All of the considered ROIs showed statistically significant lower thermal effect of SAT training (Δ Tsk) after 30 weeks of SAT (p<0.05). The chest region had the higher variation (-1.39°C)

followed by the abdomen (-1.05°C) and the arms (-0.88°C and 0.86°C), being all of them significant (p<0.05). However, the lower and statistically non-significant (p>.05) variations were found in shoulders (-0.72°C and 0.32°C) and thighs (-0.43 °C and -0.05°C).

Table 7 contains the values of the asymmetries between contralateral ROIs for the post-exercise Tsk values at the two times of the data collection.

Table 7. Tsk post-exercise asymmetries of contralateral ROIs (left vs. right sides) at the different moments of the data collection. (* $p < 0.05$)

ROI	SAT	Right side			Left side			Difference	Z	p
		Mean± SD	Min	Max	Mean± SD	Min	Max			
Arms	1 SAT	28.34±1.01	26.06	29.90	28.38±1.15	26.06	29.81	0.04±0.41	0.283	0.777
	30SAT	30.16±0.97	28.04	31.61	30.35±0.91	27.622	31.91	0.19±0.66	0.534	0.594
Shoulders	1 SAT	30.27±1.42	27.11	33.00	30.22±1.44	26.73	32.43	-0.05±0.58	0.483	0.356
	30SAT	31.12±0.80	29.87	32.53	31.47±0.96	29.85	33.18	0.35±0.52	0.201	0.594
Thigh	1 SAT	29.45±1.12	28.01	31.63	29.08±1.22	27.02	30.92	-0.37±1.04	0.909	0.363
	30SAT	30.55±1.13	27.98	32.18	30.56±1.18	28.03	32.39	0.02±0.44	0.284	0.776

The results show non-significant variations for asymmetries between the values of the contralateral ROIs in every moment of the data collection.

DISCUSSION

According to our knowledge, this study is the first long-term thermographic examination of people practicing SAT with resistance exercise for abdomen and upper limbs with rotational movements reported in literature.

Our study supports the view that thermographic imaging can be used as a comparative tool for establishing the efficiency of different training methods and the reaction of the Tsk under the influence of physical exercise [35,36]. Changes in Tsk may indicate the degree of loading of the locomotor system, provide information on the efficiency of endogenous heat removal systems during exercise, and provide information on metabolic changes associated with return to homeostasis after exercise. Thermal imaging appears useful as one of methods of monitoring these phenomena [37,38].

Our pre-exercise data indicate that Tsk values were in average 0.76°C higher after the 30-weeks SAT training program. This could be explained in two ways. The first data collection was done in October, when the average ambient temperature is 7.2°C and the second was in June, with an average ambient temperature 16.3°C [39]. It well-known that the ambient temperature may affect the thermographic results [8]. However, the differences of ambient temperatures between data collection moments were not so wide (9°C) and we followed an acclimatization process to reduce the effects of this factors [8,40,47] so that the effects of the ambient temperature should not be considered to explain those differences.

The second explanation would be the long-term effects of exercise and the increment of the physical capacity of the participants. Considering that the participants did not have a good physical condition before starting the program and their experience in practicing SAT was null, the 30-weeks

SAT program would and the progression of the intensity could promote a higher resting metabolism and general activation (muscle stiffness) of the body at the end of the training program, which could reflect on a higher baseline Tsk. Additionally, the higher increments of the temperature in the arms and thighs (around 0.5°C higher than in the shoulders, abdomen and chest) may indicate that this effect could be more intense in the distal areas than in the proximal areas of body.

Considering the Tsk immediately after training throws out an raise in average of 1.48°C after 30-weeks of SAT compared with the baseline values after the first training session. Tanda concluded that a well-trained person would be able to tolerate high core temperature compared with a less trained one [41]. He noted that delayed skin vasodilation did not compromise the blood (and oxygen) supply to active muscles. Similar observations were reported by Chudecka and Lubkowska [15,31] in handball players, who concluded that high physical efficiency is a facilitating factor in the thermoregulatory process, which improves temperature exchange. If we go in deep on the results of the different ROI, we can see that after training the higher differences at the two data collection moments corresponded to the arms and the chest and abdomen. That means that the regions of the trunk and the arms increased their ability to produce heat after the 30-weeks SAT program, maybe due to a greater involvement of these areas after the learning process generated by the experience in the task and to the increment of the intensity carried out along the 30-weeks of training.

This idea is reinforced when the results on the different ROI after training are compared with the results before training. Table 6 showed as the difference between post- and pre-exercise Tsk in our study are more negative the first data collection than after 30 weeks of training. That means the Tsk registered immediately after training was always lower than before training ($\Delta Tsk = -2.45^\circ C$) and the Tsk reduction was lower after the 30 weeks of SAT ($\Delta Tsk = -1.69^\circ C$).

They are very interesting the lower values of ΔTsk in the thigh. This fact should be highlighted because quadriceps is one of the muscles more active

in the SAT [1]. Considering that the other ROIs had greater drops of Tsk immediately after training, the high levels of heat produced by the intense muscular activity of the quadriceps during SAT could have compensated or made inefficient the cooling effect of the sweat on this ROI.

Studies of the thermal response to physical activity have reported both increases and decreases in Tsk immediately exercises [8]. In humans, Clark *et al.* found that Tsk began to fall immediately upon starting a treadmill run and reached steady values within 15 minutes, having fallen some 5°C overall [42]. Merla *et al.* [22] recorded drops in surface temperature of the total body of 15 runners after exercise completion. The temperature values were on average 3–5°C lower than at baseline. Kondo *et al.* concluded that trained subjects are better able to lose heat, and thus to shift through the blood the heat from the muscle to the skin [43]. The physiological explanation could be that an exercise program increases arterial caliber, improves the whole body's vasodilatory function and lowers vasomotor tone.

We consider that the acute effects of warm-up are a descent of Tsk [44]. Additionally, it is assumed that exercise-induced sweating (being a physiological effect of parasympathetic function) for decreasing the body temperature collaborating to the efficiency of the thermoregulatory system [31]. Taking the data before the warm-up and the effects of sweating should be closely related with the reduction on Tsk registered in our work. Furthermore, Kenney and Johnson [45] stated that Tsk over the working muscles decreases both in trained and untrained groups during exhaustive exercises due to the continuous skin vasoconstrictor response due to an increase in catecholamine and vasoconstrictor hormones, as exercise intensity increases.

On that point, our results indicate that the Tsk descent were lower after the 30 weeks of SAT (positive at the difference values in table 6), and this reduction was most relevant in the areas of the arms and trunk (chest and abdomen), which exactly correspond with the wider Tsk differences after training shown in Table 5. This fact points out a kind of adaptation on the trunk and arms areas, probably due to the constant stabilization of the posture [46] and the arm movements, which characterize this kind SAT program [5].

Finally, it should be noted that the Tsk values were not statistically significant different for contralateral ROIs in every moment of the data collection, with values below 0.4°C. The American Medical Association has stated that asymmetry is the most important factor to consider in thermography. The side-to-side differences in healthy subjects are nearly 0°C, considering abnormal side-to-side difference at 1.0°C [6]. Hildebrandt stressed that difference of more than one degree centigrade between sides of the body may indicate a pathophysiological process [8]. Vardasca [40]

showed that, in healthy subjects, the highest temperature symmetry difference was at most 0.4°C±0.3°C in total body views and 0.4°C±0.15°C in regional views. So that, our data support that a 30-weeks SAT program, leaded by a certificated instructor does not generate any injury risk for the participants.

The limitations of our study were the small size sample with different number of male and female participants and the ambient temperature differences at the two moments of the data collection. This makes it impossible to draw general conclusions. Further investigation should evaluate the impact of SAT on other groups of muscles in order to prove the effect of SAT as training method and should be carried out on larger group of participants, preferably with an equal number of male and female participants.

CONCLUSIONS

Our data indicates that a 30-week SAT program resulted in significant drop of mean Tsk of evaluated body parts (ROI), being the thermal effects related with the areas more activated in the sport practice. From the thermal perspective, the training program carried out did not generate any injury risk for the participants.

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