The deoxygenation and the blood volume signals in the flexor carpi ulnaris and radialis muscles obtained during the execution of the Mirallas's test of Judo to Judo athletes.

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ABSTRACT

The technique of execution of any movement in Judo is extremely important The coaches want tests and tools easy to use and cheaper, to evaluate the progress of a judoist in the tatame. In this paper is presented a test developed by Mirallas, which has his name "Test of Mirallas" to evaluate the maximal power capacity of the judoist. The near infrared spectroscopy (NIRS) signals were obtained to have a measurement of the metabolic work of the flexor carpi ulnaris and radialis muscles, during the execution of the ippon-seoi-nage movement, allowing this measurements to assess by NIRS the maximal oxygen uptake. Also were obtained tympanic, skin forehead, and biceps brachii temperatures during the test time and recovery phase to study the effects of ambient conditions and the post-exercise oxygen consumption. The deoxygenation and blood volume signals obtained gave different results, demonstrating the hypothesis of the coaches that some judoist do the execution of the ippon-seoi-nage movement correctly and the rest didn't. The heart rate frequency obtained in the group of judoist was between 190-207 bpm, and in the minute five of post-exercise was 114-137 bpm; the time employed in the Mirallas's test were from 7'14"s to 13'49"s, and the total of movements were from 199 to 409. The data obtained in the skin forehead, and skin biceps brachii confirms previous works that the oxygen consumption remains after exercise in the muscle studied. According to the results, the test developed by Mirallas is a good tool to evaluate the performance of judoist any time, giving better results compared with standard tests.

1. INTRODUCTION

One of the most difficult part in exercise physiology[4,20] is to develop and to validate an specific test for each sport. The development of an specific test requires a good knowledge of this sport and to leave from the laboratory of physiology. On the other hand, coaches want to have results of the progress of their athletes during the whole periods of training. Also they want specific tests easy to use, to use cheaper tools to obtain data from the test, and do it in the place where they are practicing their sports.

The technique of execution of any movement in Judo[1,19] is extremely important. The test developped by Mirallas has the stipulations cited in the previous paragraph. The movement used is the ippon-seoi-nage where the arms and hands are essential just at the beginning of the movement. Videographic techniques used by a coach cannot detect which muscle[1,2,4,19,20] is or isn't working when the judoist starts the movement. Only using near-infrared spectroscopy technology can be assessed the work of the muscle.

A coach can measure the maximal oxygen uptake[11] non-invasively using the near-infrared spectroscopy technology which allow to assess the tissue oxygenation to evaluate the change of muscle

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oxyhemoglobin+oxymyoglobin (HbO_2/MbO_2) saturation during an exercise in a muscle[6,9,10,11,14] specific. The technique of near-infrared spectroscopy allow to coaches to detect how is working an specific muscle relating the results to VO2max[11].

To assess the temperature regulation during exercise and their evolution in the five minutes of post-exercise the tympanic, skin forehead, and skin biceps brachii temperatures have been obtained. This study was designed to assess how the judoist are affected in their thermoregulation[4,5,8,12,14,15,20] by the ambient conditions in an indoor activity, and to determine the relationship between the changes in the deoxygenation and blood volume signals in the muscle studied and the post-exercise oxygen consumption[7,13,14]. Also it is an indirect measurement of the metabolic work of the muscle[2,4,10,15,20] which activity can be studied by the heat generated during the exercise time.

2. MATERIAL

For this study it was used a Polar electro heart rate recorder, three skin thermometers, a RunMan unit, an infrared tympanic thermometer Ototemp-3000, a four channel digital recorder CTF9004 Ellab A/S, a Kipp&Zonen two pen chart recorder, a Toshiba Satellite T1850C computer and the software developped in Turbo C and hardware necessary for the test of Mirallas.

A group of eleven volunteer judoists from a private club were selected to participate in this study. They are nine males and two females with the following judo levels: brown belt (n=4), 1st. dan (n=1), 2nd. dan (n=5), 3rd. dan (n=1), age from 14-30 years, weight from 54-91kg and height from 1.51-1.78m.

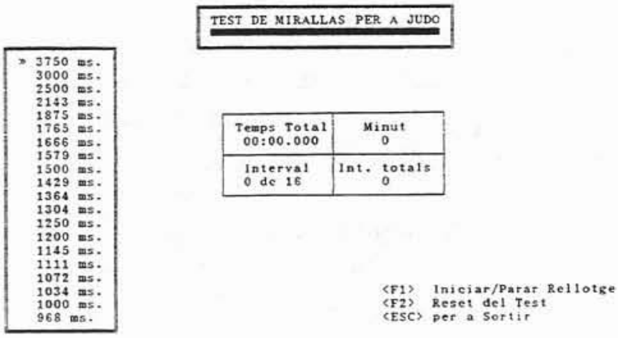
3. METHOD

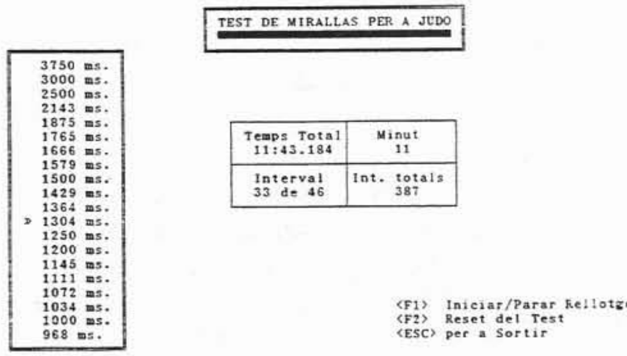
The RunMan probe was placed in the flexor carpi ulnaris and radialis in the left arm. The skin temperature sensors were placed in the biceps brachii of each arm and in the forehead. The tympanic temperature was obtained before and at the end of the test. The belt of the polar recorder was placed in the right place according the specifications of the manufacturer. A general view of the execution of the test and the situation of the material can see in the figures 5 and 6.

3.1 Protocol

The test consists in the partial execution of the ippon-seoi-nage movement. The judoist executes this movement at the time than a beep sound from a speaker which is generated by the computer. Each minute has an amount of intervals and in each interval is when the speaker is turned on. In the next minute the amount of repetitions of the movement is increased and the time between intervals is less than previous one. The judoist executes this judo technique each time that the beep signal turn-on continuously until exhaustion. Before to start the test it has been obtained the basal values of heart rate frequency, skin forehead (skFT), skin biceps brachii right (skBBrT), skin biceps brachii left (skBBlT), tympanic (TT) temperatures, calibrated the near-infrared spectroscopy unit and recorded the basal deoxygenation and blood volume signals. No fluid was intake during and after the test[17].

The figures 1 and 2 show the timing system of the test in the screen computer.

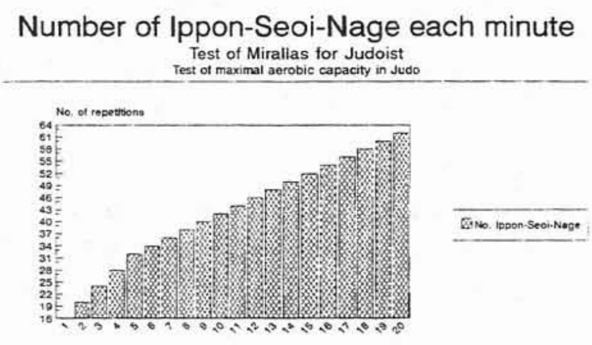


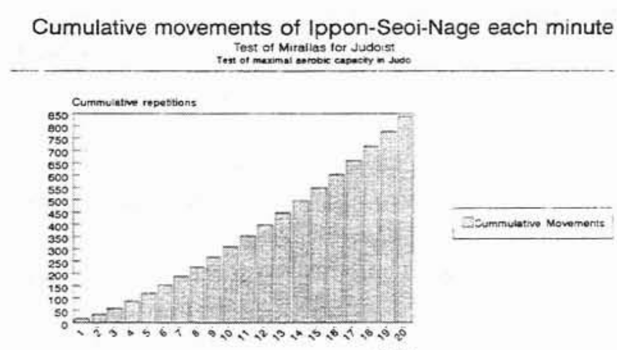


Figures 1 and 2. The timing test and how is recorded in the screen computer.

The figure 1 show the screen before to start. On the left side of the screen you can see a column with twenty minutes. Each data in the column represents a minute where the speaker is turned-on at the miliseconds marked by the arrow. In the middle of the screen you can see a rectangle divided in four parts. The upper left part counts the total time employed by the judoist during his test; the lower left part counts the number of movements to do in this interval; the upper right part gives the minute of the test; and the lower right part gives the cumulative repetitions of the movement. In the right side and bottom of the screen are the command keys, start/stop, reset and leave the program. The figure 2 show a practical application.

The figure 3 show the number of repetitions of the ippon-seoi-nage movement to be done by judoist each minute. The figure 4 show the number of cumulative repetitions of the ippon-seoi-nage movement at the end of each minute.





Figures 3 and 4. Number and Cumulative ippon-seoi-nage movements respectively .

3.2 Near-infrared spectroscopy

To assess the changes in the skeletal muscle oxygenation during exercise has been used a commercial unit (RunMan, NIM Inc. Philadelphia) to obtain the signals of deoxygenation/reoxygenation and blood volume. The probe of the Runman device was placed in the flexor carpi ulnaris and radialis muscles on the left arm of the judoist.

The probe illuminates the underlying tissue with a penetration depth about 1-3cm, measuring the reflected light at two specific wavelengths at 760 and 850 nm. The difference in absorption between the oxygenated and the deoxygenated form of Hb and Mb are exploited due to the principle of near-infrared spectroscopy based on the observation that the light absorption characteristics of hemoglobin (Hb) and myoglobin (Mb) in the near infrared region (700-1000nm), where the changes depends on the relative O_2 saturation. RunMan uses two wavelengths at 760nm and 850nm, the difference in light intensity between 760 and 850nm (D760-850) will provide a relative measure of the O_2 saturation and the sum of two wavelengths (S760+850) will provide a relative measure of blood volume changes.

Tissue oxygenation which can be defined as the relative saturation of oxyhemoglobin and oxymyoglobin depends on the balance between O_2 delivery. The changes in tissue O_2 saturation can be determined non-invasively by monitoring changes in the absorption of light in the near-infrared region[6,9,11,14,16].

3.3 Temperatures

Thermoregulation[5,15,18] plays an important role in the performances of the athlete and also is an important parameter during the exercise[5,8,12,14,15,17] and in the post-exercise oxygen consumption[7,13,14], being important for the safety of the athletes and for their performance. During exercise, metabolic heat produced by the exercising muscles is transported by the circulating blood to the surface of the body where it is released to the environment, either by radiation and convection or by evaporation of sweat[2,8,10,12,13,14,17,18].

To assess the brain temperature non-invasively, it has been used an infrared tympanic thermometer (Ototemp-3000, Exergen Co., Newton, MA). The brain has an extremely thermal significance because the increase of temperature can result in irreparable cell damage and can lead to the dangerous syndrome of heatstroke. The tympanic membrane is proximal to the hypothalamus and as it is perfused by the same blood supply as the hypothalamus, reflecting the same temperature as the hypothalamus.

The temperature of the skin is normally lower than that of internal tissue. The skin is not an accurate measurement for core temperature because of ambient-environment dependency. However the skin temperature could be a parameter to assess the work of a muscle, and to assess the post-exercise oxygen consumption, playing an important role for promoting heat dissipation from central circulation during heat load[2,4,5,7,10,12,13,14,15,18,20].

The tympanic temperature was recorded before to start and at stop of the test. The skin forehead and biceps brachi temperatures were recorded before, during and after exercise each one minute.

The figure 5 is a picture during the execution of the test. The figure 6 is a picture when the judoist is prepared for this test. You can see how the skin temperature sensors are placed and also the near-infrared spectroscopy probe is placed in the flexor muscle in the left arm.

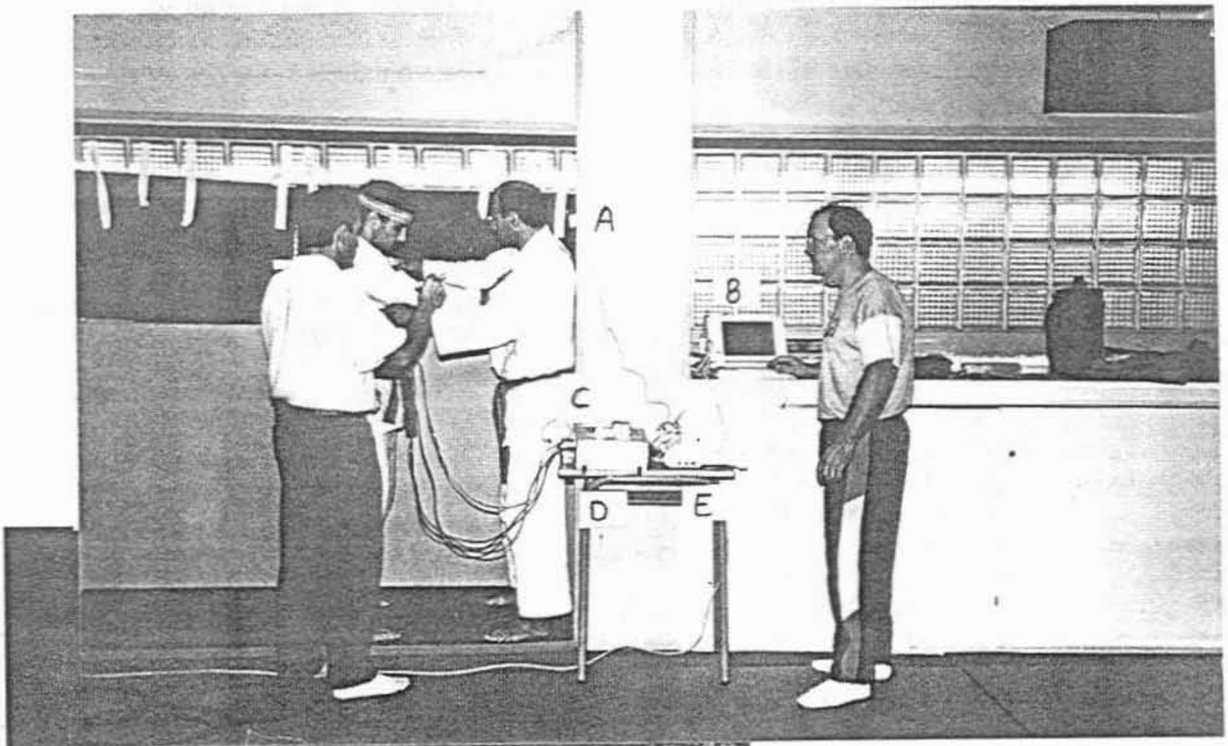


Figure 5. A judoist during the execution the Test of Miralllas.
A.- speaker
B.- computer
C.- RunMan unit
D.- Temeprature recorder
E.- NIRS recorder
Note: The author of the test in the right side of the picture.

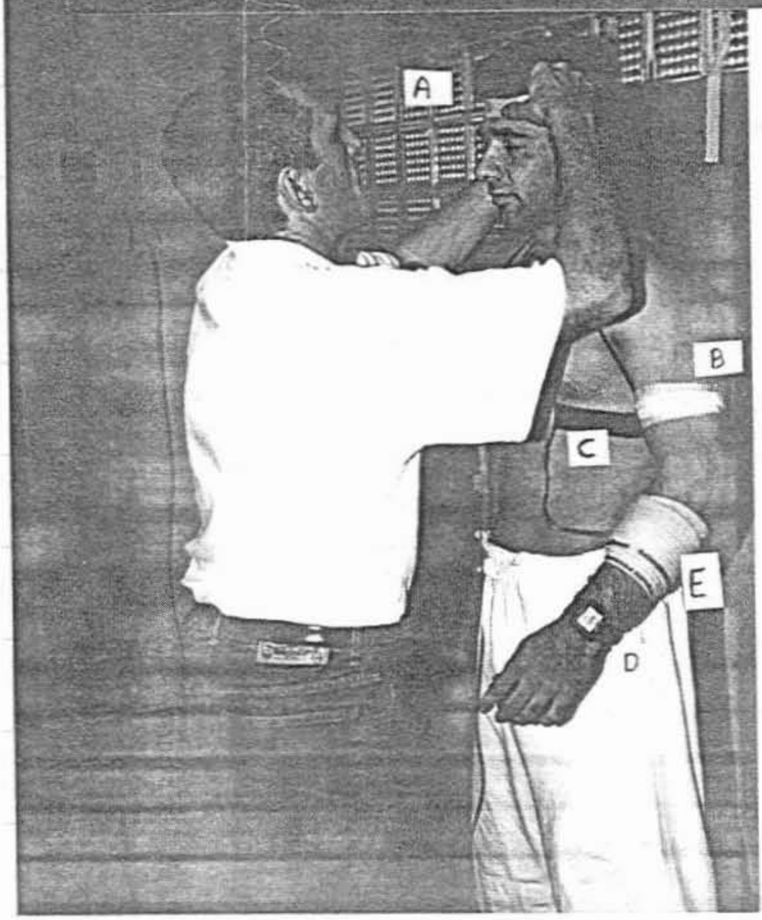


Figure 6. Distribution of the sensor in the body of the judoist.
A.- skin forehead temperature sensor
B.- skin biceps brachii temperature sensor
C.- polar belt for heart rate frequency
D.- polar watch
E.- RunMan probe in the flexor muscles

4. RESULTS

The following table give the main data of the judoist, and the main data obtained in the group studied after the execution of the Mirallas's test.

Table I. Categories of each judoist, age, weight, time employed doing the test, cumulative ippon-seoi-nage movements, maximal heart rate frequency, heart rate during recovery phase at minute 5 and at minute 3, and ambient temperature before and after the test.

						Heart rate frequency (bpm)			Ambient temperature	
Judoist	belt.	age	weight	Test time	Cumulative rep.	at stop	at min. 3	at min. 5	at start	at stop
JD1	2nd. dan	19	54 kg	8' 04"	231	204	133	126	24.7	22.4
JD2	2nd. dan	22	70 kg	10' 48"	345	190	123	114	23.5	23.9
JD3	2nd. dan	29	68 kg	6' 56"	187	194	123	118	24.9	25.6
JD4	1st. dan	18	67 kg	11' 59"	399	200	123	120	25.0	23.8
JD5	brown	21	66 kg	7' 14"	199	193	130	120	23.1	24.0
JD6	3rd. dan	30	74 kg	12' 12"	409	195	131	129	26.3	26.1
JD7	2nd. dan	25	71 kg	10' 38"	337	193	135	127	25.6	23.8
JD8	brown	15	72 kg	8' 53"	263	196	122	122	24.9	24.8
JD9	brown	19	91 kg	13' 49"	489	206	124	115	25.1	24.7
JD10	2nd. dan	22	74 kg	11' 41"	386	192	131	126	24.3	25.2
JD11	brown	14	54 kg	7' 22"	204	207	134	133	23.8	22.4
$\bar{x}$		21.2	69.1	9' 57"	313	197.2	128	122.7	24.6	22.4
SE		±1.55	±3.03	±42"	±31	±1.8	±1.5	±1.8	±0.28	`±1.89

The figure 7 show part of the results obtained by a polar electro heart rate recorder; these records corresponds to JD2, JD6, JD9, and JD10 respectively.

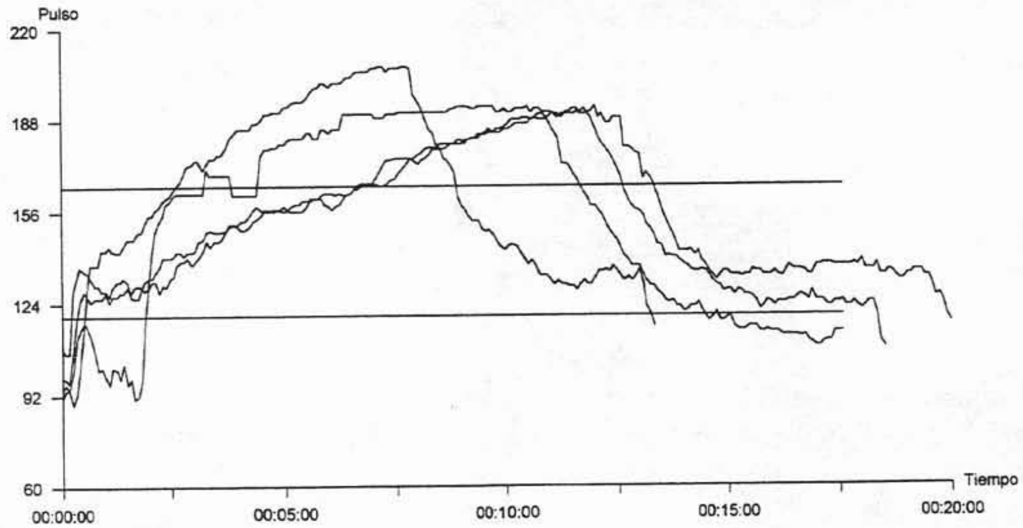


Figure 7. Samples of heart rate frequency recorded by polar electro in four judoist of the group.

The figure 8 show a graphical chart of the group comparing the amount of repetitions of the ippon-seoi-nage movement and the heart rate frequency for each judoist.

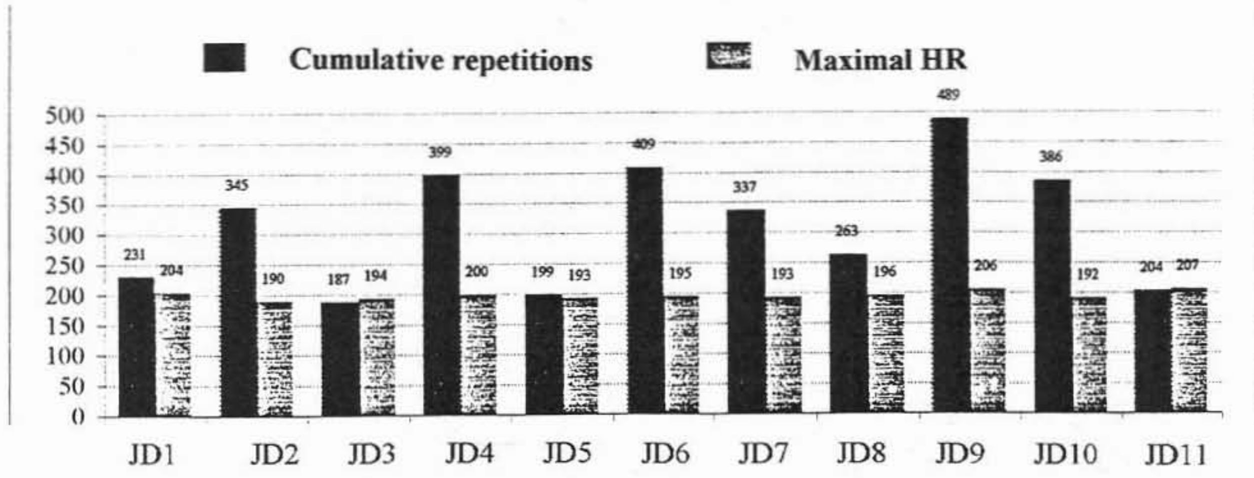


Figure 8. Cumulative repetitions of the ippon-seoi-nage and heart rate frequency in each judoist.

The figure 9 show the evolution of the skin biceps brachii temperatures in the left arm (skBBlT) and in the right arm (skBBrT), and the skin forehead temperature (skFT). Also the tympanic temperature (TT) is given at basal time and stop time.

Table II. Values of tympanic (TT) temperatures before to start and the end of the tests of Mirallas., Skin forehead (skFT), skin biceps brachii right (skBBrT), skin biceps brachii left (skBBlT) temperatures at basal, stop and minute five. All temperatures are in Celsius degrees.

	Tympanic TT°C		skin forehead skFT°C			skin biceps brachii right skBBrT°C			skin biceps brachii left skBBlT°C		
Judoist	basal	stop	basal	stop	min. 5	basal	stop	min. 5	basal	stop	min. 5
JD1	36.7	36.4	35.1	35.2	36.5	34.9	35.2	36.2	35.1	36.0	36.9
JD2	36.4	36.8	35.3	36.4	36.9	34.5	35.1	36.9	34.2	35.9	37.0
JD3	36.5	36.7	35.4	36.8	37.0	34.8	35.1	36.4	34.9	34.8	36.1
JD4	36.2	36.7	35.2	35.9	36.0	35.0	35.8	36.6	35.6	36.2	37.0
JD5	37.1	37.5	35.1	35.3	36.4	34.8	35.3	35.9	34.2	34.7	35.0
JD6	36.3	36.3	34.9	35.9	36.7	35.1	35.1	36.4	34.9	36.7	37.5
JD7	35.9	36.4	35.0	35.8	36.5	34.7	33.2	35.6	34.4	31.9	32.3
JD8	36.0	36.4	35.5	36.2	36.1	34.8	37.1	37.4	34.7	34.7	35.6
JD9	35.5	36.0	34.5	37.0	36.6	33.8	34.8	36.4	34.0	35.5	36.8
JD10	36.2	36.8	34.6	36.0	37.0	34.8	35.3	36.8	34.4	36.4	37.3
JD11	35.8	36.8	35.1	35.9	36.5	34.7	34.8	35.5	34.1	34.9	35.8
$\bar{x}$	36.2	36.6	35.0	36.0	36.5	35.7	35.1	36.3	34.5	35.2	36.1
SE	±0.13	±0.11	±0.09	±0.16	±0.09	±0.1	±0.27	±0.17	±0.14	±0.39	±0.44

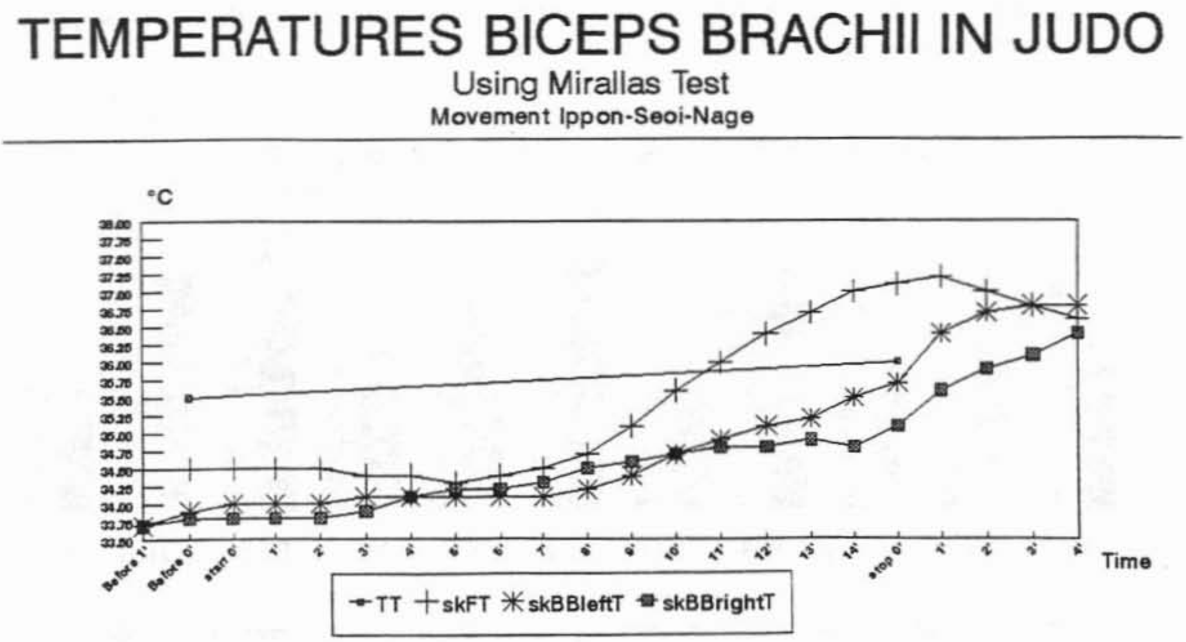


Figure 9. Evolution of skin forehead, biceps brachii temperatures in the judoist JD9.

The tympanic temperature provided by an infrared thermometer demonstrate that all the judoist have a normal evolution after the test. The skin forehead temperature peak is at the end of the exercise starting to decrease during the recovery phase. Both have a normal evolution according to previous studies[14].

The temperatures in the skin biceps brachii right and left (skBBrT, skBBlT) have an analog evolution of the quadriceps which had been found in previous studies[14]. At the beginning of the exercise the initial values of the biceps brachii temperatures are low, starting to increase around the minute five which usually corresponds to sweating time in the judoist, arriving the peak of these temperatures after to stop the exercise.

The figure 10 show changes of deoxygenation/reoxygenation and blood volume during de test in the flexor carpi ulnaris and radialis. It is around the minute five that the signal of deoxygenation starts to increase which also corresponds when the judoist start to sweat, when the judoist stop, the test is finished, then the recovery phase starts.

The amplitude[14] of deoxygenation/reoxygenation signal A_{DRB} from stop to the base line is 40 mm and respect to the lowest point during the recovery phase in the reoxygenation signal, the amplitude A_{DRD} is 55 mm. For the blood volume the amplitude of the signal from stop to base line is A_{BVB} 26 mm, having the blood volume signal the same amplitude A_{BVD} respect to the lowest value in the recovery phase. The half-time of reoxygenation is extremely variable, and also the half-time of the blood volume both in the recovery phase in all the judoist of the group. This variability is due to that each judoist executes the technique of the movement randomly, this incorrect application affects the results obtained in the near-infrared spectroscopy signals. The near-infrared spectroscopy data obtained help the coaches in parameters as metabolic work of the muscle, and time using the muscle for a correct technique .

5. DISCUSSION

The half-time of reoxygenation and blood volume give an important information of the execution of the technique, which is impossible to verify by other systems, like videographic techniques. However they are many different results from each judoist, which corresponds to the correct execution of the technique. In some judoist with good technique the signals obtained by near infrared spectroscopy give an important value of deoxygenation and blood volume signals. The rest with bad execution of the technique gave a poor signals of deoxygenation and blood volume.

The basal levels of tympanic and skin forehead temperatures have similar values and their variation depends of the ambient conditions. During exercise time both temperatures increase, the slope depends of the intensity of the exercise, the performance of the subject, and the ambient conditions. These temperatures after the exercise have a quickly fall in their values, going usually to below basal values. Temperatures in the biceps brachii before exercise are conditioned by the ambient and the judoist's performance. During exercise time, the biceps brachii temperatures initially remain at basal values.

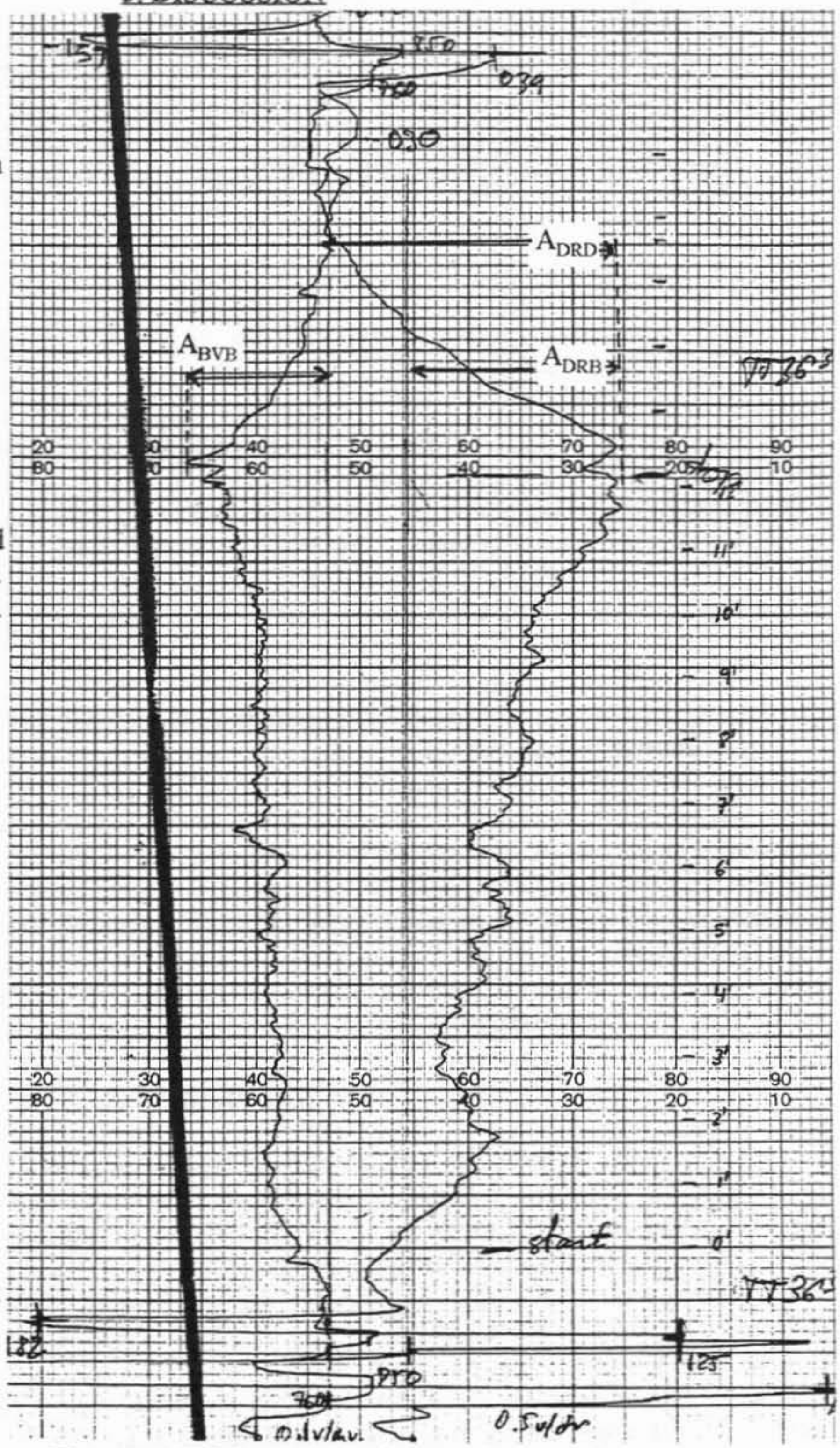


Figure 10. NIRS signals during the test and recovery time

The skin biceps brachii temperatures (skBBrT, skBBlT) start to increase slowly at minute five. It could be due to that the heat from exercising muscles is eliminated by radiation, convection, and by evaporation of sweat. The increase in the temperature values after exercise could be explained by the reduction of convection, evaporation circulation of blood, and also that the bone has a thermal inertia slow reducing the inner bone temperature usually by thermal conduction in the different layers of the muscle tissue. The pattern is similar that the evolution of the quadrices temperature in the studies of post-exercise oxygen consumption[7,13,14].

6. SUMMARY

The two initial objectives have been accomplished. The first one was to assess the oxygen consumption in the flexor carpis ulnaris and radialis which can be correlated to VO2max[9,11]. The other objective was to demonstrate that using a near-infrared spectroscopy device coaches have a good tool easy to be used any time and any moment in the tatame without the necessity to use sophisticated tools only available in laboratories of physiology. Also it has been demonstrated that the test of Judo developped by Mirallas is a great chance respect to the common and standard protocols, protocols that are far away to the reality of the necessities of Judo. In addition a portable near-infrared spectroscopy device can help coaches to demonstrated their judoists, when one of them apply a technique of any judo movement correctly.

The temperatures of biceps brachii obtained during the five minutes of the recovery phase confirms that the oxygen consumption remains in a muscle supporting previous studies that found a delay in the decline of oxygen consumption to resting levels after exercise, this phenomena is partially explainen by the metabolic effects of elevated temperature[7,13,14]. Obtaining the skin temperatures in the biceps brachii show also which biceps brachii muscle of each arm is working more than the other, and when one arm is replacing o helping more the judoist in the execution of the movement.

The same test using a gas analyzer is planned in the future, but in the place where the judoist practice judo. The objective is to eliminate many factors of disturbance which implies to go in a laboratory. This limitation are also in order to improve this test, giving results to coaches that can be compared and validated in any private club of judo.

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