Changes in metabolic and motor performance variables induced by training in handball players

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ABSTRACT

Measurement of physical fitness is a common and appropriate practice in sports competition. The information obtained from testing will allow adjustments of the training program to meet an individual's specific fitness needs. The purpose of this study was to analyze the changes in metabolic and motor performance variables in handball players during a training program following a model proposed by Verkhoshanski[7] and adapted by Oliveira[8]. Eleven handball players, from 20 to 32 years old, body weight 89.5 ± 10.4 kg (70.2 and 105.1 kg), height of 184.4 ± 6.7 cm (171.8 and 198 cm) participated in this study. All participants were members of "UniFil/Londrina" Handball Team of Londrina, Paraná. The subjects were tested and retested after developing a 16-week training program, prior to the start of the National League Championship. Data were analyzed using t-test for repeated measures ($p < 0.05$). The results showed very important adaptations with an increase in velocity strength (7.8%, $p < 0.05$), explosive strength (8.1%, $p < 0.05$) and agility (6.4%, $p < 0.05$). Moreover, the training program allowed for some metabolic adaptations, such as anaerobic power (30.5 and 37.5%, $p < 0.05$), and the total time the players could stand at the Yo-yo test, respectively. Aerobic power, measured by $\dot{V}O_2max$, also increased (8.1%, $p < 0.05$). The results suggest that the program proposed was able to create positive motor capacities responses that were observed in the lasting training posterior effect.

Keywords: Physical performance. Training program. Sport.

INTRODUCTION

Handball is a sport that presents physical efforts characteristics of high intensity and of short duration, with emphasis in the motor capacities of velocity and strength, especially the explosive strength and velocity strength.

The mentioned training motor capacities is an important component of the physical performance, therefore, more attention should be dedicated to the development of specific physical conditioning (specific physical preparation) of handball players. Thus, handball as other collective sports, involves a sequence of activities that demand the anaerobic metabolism in a determining manner.

Thereby, Astrand and Rodahl[1]; Wilmore and Costill[2] reported that the variables that determine the physical performance in high response of intermittent sports depend on the energy production, especially on the anaerobic system and the muscle capacity of using energy. Rannou *et al.*[3]; Eleno, Barela and Kokubun[4], showed that the handball game demands a high development of the anaerobic power (via metabolic one), since it influences the performance of the velocity and strength capacities. According to this way of thinking, Verkhoshanski[5], reports that the increase of the moving velocity, reassured by the increase of the athlete's energetic potential, that is, by the body capacity to produce an ever growing amount of energy in the time unit, can be efficiently obtained only through the special physical preparation means.

Thereby, it is observed that modern sports, specifically handball, demand from the physical trainers a well elaborated plan, especially in order to have the athletes reach optimum performance levels and receive an assistance of the dynamics development of the physical performance during a macro cycle training. On the other hand, it has been observed that the planning of the physical preparation has been elaborated based on methodologies considered inadequate to the high performance handball features.

According to Martins, Feitoza and Silva[6], the training periodicity has not been fulfilling in some aspects the demands and needs of the modern sports. One must take into consideration that the competitions are longer, the competitors are of a high technical level and athletes are better prepared among others, hence, modern sports face the constant need of updating the processes of athletes' preparation.

Thus, the periodicity model proposed by Verkhoshanski[7], seems to be adequate to handball's characteristics, once it consists of the application of concentrated loads of strength in step A, serving as pre requisite, joined by specific metabolic stimulations (velocity and technique) in step B, creating foundation to the improving of the performance specific capacities. According to Oliveira[8], in step B, a phenomenon followed by the concentrated loads of strength, called training lasting posterior effect (EPDT/TLPE), occurs, which allows the athlete reach performance levels not possible by the traditional model of periodicity. Thus, this step favors the specific technical-tactical training, besides velocity, in optimum performance levels.

Therefore, this study had as its aim to analyze the changes of the motor and metabolic capacities that act in the physical performance of handball players during a training macro cycle, submitted to a preparation program based on the periodicity model proposed by Verkhoshanski[7] and adapted by Oliveira[8].

MATERIALS AND METHODS

Sample

The sample of this study, was intentionally selected, and consisted of 11 handball players who daily practiced, were between 20 and 32 years of age, weighted between 70,2 and 105,1 kg with an average of 89,5 ± 10,4 kg, and had height between 171,8 and 198 cm, with an average of 184,4 ± 6,7 cm, filiated to the "UniFil/Londrina" team from Londrina county – PR. The athletes were informed about the study procedures and objectives and signed the agreement term whenever they agreed on participating in the research. This study was approved by the Ethics Committee of the Universidade Filadélfia of Londrina.

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Data collection

All the individuals were submitted to two test routines: the first test routine was conducted in the beginning of the second training macro cycle (on May 07, 08 and 09) and the second on August 27, 28 and 29, 2003, two weeks prior the beginning of the second competition (National League). All tests were conducted in the afternoon. The second test routine followed the same order, starting with a standard warm-up and using the following order for the tests and measurements:

Day 1:

Anthropometrical measurements, Vertical Jump Test and the Arm Wingate Test.

Day 2:

Moving Velocity Test – 40 m run, Yo-Yo Recovery Test level II.

Day 3:

Sextuple Jump Test, Agility Test (square), Two-Way Run Test.

Body types

The Jackson and Pollock protocol was used[9] to estimate the body density and the Siri equation[10] for the calculation of the fat percentage.

Motor tests

Vertical jump test

The explosive strength of the lower limbs of the handball players was indirectly measured through the vertical jump test on a resistive table connected to a digital timer, following protocol proposed by Bosco *et al.*[11].

Only one jump technique was used: jump with countermovement and arm help (CMAJ), having the individual three tries. The best try was the used result.

Arm Wingate

The 30 seconds arm Wingate test was used to measure the anaerobic power of the upper limbs. This test is done in an adapted ergometric bicycle, by JAGUAR, with a 5% load of the body mass. The individuals were told to do the pedaling movement using their arms for 30 s. A computerized system was used to measure the pedaled (with the arms) per minute (rpm), and therefore estimate the performance in some work indexes: absolute maximum power (W) and relative (W/KG), fatigue index (%) and time to reach the maximum power (s).

Moving velocity test – 40 m run

The 40 meters run test was applied to evaluate the moving velocity. The test consists of performing the effort in the highest velocity possible, only decreasing it after the 40 meters run. A photoelectric cell was used to time in seconds the velocity in the 10 and 40 meters. Each athlete had three tries, with a five minute interval between the tries to ATP-CP re-synthesis. The best result among the three tries was used.

Level II Yo-Yo test

The level II recovery Yo-Yo test[12] was used to measure the anaerobic power of the lower limbs of the handball players, through the highest velocity developed and the distance run, which presents maximum, progressive and with intervals characteristic. The test has the objective to make the individual run the furthest as possible, in a back-and-forth system, in a set space of 20 m, where the individual has to move from one side to another with a five second pause, every time he returns to the starting point. The velocity is determined by sound signals. The athlete's arrival has to be at the same time of the sound signal. The test begins with a 11 km/h velocity for 40 m, it increases to 15 km/h for 80 m, after that, the interval between the sound signals diminishes each minute and the individual has to slightly increase the velocity (0,5 km.h per level) to continue to arrive in time to the sides of the corridor. The test ceases when the individual gives u or when he is not capable to follow the rhythm imposed by the test.

Sextuple jump

It consists of six consecutive alternate jumps, to try to reach the furthest distance possible in meters. Each individual had two tries and the best result prevails.

Square test – agility

A test with change direction called "square" was used with the aim to measure the agility of the handball players. The space to be run was marked with four cones, set in a square shape with four meters away from each other. When the individual hears the command: "ON YOUR MARKS, GET SET, GO!", he leaves from one of the cones, runs his fastest diagonally, passing behind the cone and heading paralleling towards another cone passing behind it, and diagonally towards the other cone, finally returning to the starting point. After that, without stopping the run, the individual repeats the same way to end the test. Each individual had two tries. The time register will be in seconds, through a photoelectric cell, being the best time between the two tries considered.

Back-and-forth run test

The aerobic power of the handball players was measured through a back-and-forth run test proposed by Léger *et al.*[13]. In the test the individual moves from one line to another over a 20 m distance, changing the direction according to sound signals from a recorded tape, coming from a player placed between the two marks that set the distance. The sound signal gets progressively faster during the test. The back-and-forth run test begins with a 8,5 km/h velocity and presents an increase of 0,5 km/h each minute. The test finishes when the individual ceases the run or delays two times in relation to the sound signal synchronism for a distance longer than two meters. The last completed step is registered for the calculation of the oxygen maximum consumption.

Training program

The program had a monocyclic structure and the training system in blocks proposed by Verkhoshanski[7] and adapted by Oliveira[8] was used.

The macro cycle had a 16 weeks duration, beginning on the second week of May, ending on the fourth week of August, 2003.

11 handball players participated in a training program, five days per week, with training sessions of approximately two hours, to analyze the evolution of the physical performance measured through tests.

The training macro cycle had a preparation structure divided in general and special steps, with two blocks (A and B). The general step consisted of block A, characterized as of concentrated loads of strength, with duration of nine weeks, and was subdivided in three micro steps A1 – 4 weeks, A2 – 3 weeks, and A3 – 2 weeks). After block A, a week rest was given.

The special step consisted of block B, with duration of seven weeks and was subdivided in two micro steps (B1 – 4 weeks and B2 – 3 weeks), with emphasis on the velocity training (acceleration), the velocity resistance, the special resistance and the specific technical-tactical.

Board 1 shows the list of activities developed in each training block.

Data analysis

The data were analyzed through descriptive statistics, being the obtained results at different times of the study grouped in average and standard deviation values, and the differences were compared through student t test for repeated measures. The adopted significance level for all analyses was of $p < 0,05$.

BOARD 1
List of activities developed in each training block

Blocks		Developed activities
BLOCK A	A1 4 weeks	• Exercises in the muscles for resistance strength and strength/hypertrophy; • Circuits for the general and specific muscular strengthening; • Exercises with medicine ball for the upper limbs; • General technical trainings.
	A2 3 weeks	• Multi jump exercises for explosive and rapid strengths; • Traction running exercises on sand and on grass for rapid strength; • Exercises with medicine ball followed by hits to the goal; • Muscle exercises for strength/hypertrophy and maximum strength; • General technical-tactical trainings (without settings).
	A3 2 weeks	• Traction running exercises and still traction followed by technical movements (attack moves) in acceleration; • Exercises in depth jump; • Specific technical-tactical trainings (with settings).
BLOCK B	B1 4 weeks	• Specific technical-tactical trainings (with settings); • Exercises in the muscles (maximum strength) followed by velocity exercises – (contrast); • Special resistance exercises (specific metabolism).
	B2 3 weeks	• Velocity exercises with and without the ball; • Velocity resistance exercises; • Positioned and collective tactical training.

RESULTS

In table 1 the results of the anthropometrical measures and of body mass are presented and the statistics analysis did not show any significant difference to the body mass and the height. However, a significant improvement of the % fat, statistically speaking, can be observed.

TABLE 1
Anthropometrical and of body structure characteristics

	1st evaluation	2nd evaluation
Height (cm)	184,8 ± 7,2 (171,8-198)	184,4 ± 6,7 (172-196,3)
Body mass (kg)	89,9 ± 10,3 (72,3-105,1)	89,5 ± 10,4 (70,2-104)
Body fat (%)	15,8 ± 4,1 (10,5-22,3)	14,1 ± 2,9* (9,9-18,6)

* Statistically significant differences among the evaluations (p < 0,05).

The found values in the actual study for the anthropometrical measures are within the patterns observed in Brazilian handball players[14].

Concerning the results of the motor tests conducted before and after 16 weeks of concentrated loads (tables 2, 3 and 4), it was possible to detect similar behaviors of the motor tests that present a predominant participation of the anaerobic metabolism (vertical jump, sextuple jump, square test, 10 and 40 meters run, arm Wingate and level II Yo-Yo recovery) that try to analyze the motor capacities of explosive strength, rapid strength, agility, velocity and anaerobic power of lower and upper limbs, respectively.

Examining table 2, positive and statistically significant changes for the vertical jump, the sextuple jump and the square test can be seen. An increase in the jump height (8,1%), an increase in the jump distance (7,8%) and a decrease in the time to perform the square test (6,4%) are observed. Therefore, the shown results in table 2 may lead us to the conclusion that important neuromuscular adaptations through the increase in the rapid strength, in the explosive strength and in the agility occurred.

TABLE 2
Changes in the motor variables

	1st evaluation	2nd evaluation
Vertical jump (cm)	45,2 ± 9,4 (23,7-62,2)	49,2 ± 8,1* (33,4-63,7)
Sextuple jump (m)	15,2 ± 1,2 (13,39-17,03)	16,5 ± 1,2* (13,47-18,75)
Agility (s)	19,7 ± 0,9 (17,67-21,04)	18,4 ± 0,5* (17,95-20,50)
Velocity – 10 m (s)	1,77 ± 0,08 (1,61-1,88)	1,65 ± 0,18 (1,59-1,87)
Velocity – 40 m (s)	5,47 ± 0,29 (5,05-6,08)	5,30 ± 0,39 (5,01-5,93)

* Statistically significant differences among the evaluations (p < 0,05).

We may observe a decrease of the necessary time to run the 10 and 40 meters distances in 6,8 and 3,1% respectively for the velocity, which is not statistically significant.

Analyzing table 3 we may assert that there was a positive change, however, not statistically significant for the absolute power (PA) and for the relative power (PR) of 1,9 and 5,9%, respectively. Concerning the time that the handball player took to reach the PA, the results showed statistically significant improvements of 11,2%. Concerning the fatigue index, which is measured by the difference of the maximum power and the minimum power, a decrease of 1,7% after 16 weeks of concentrated loads training was seen.

TABLE 3
Changes in the arm Wingate test

	1st evaluation	2nd evaluation
Absolute power (W)	615,9 ± 104,1 (457,7-786,9)	627,3 ± 120,3 (466,2-808,1)
Relative power (W/kg)	6,63 ± 1,07 (4,89-8,74)	7,02 ± 1,31 (5,12-8,37)
Maximum power time (s)	6,27 ± 1,35 (4,0-8,0)	5,64 ± 1,03* (4,0-7,0)
Fatigue (%)	57,98 ± 4,39 (46,94-62,86)	58,97 ± 3,49 (51,92-63,79)

* Statistically significant differences among the evaluations (p < 0,05).

The results of the variables of the anaerobic power caused by the level II Yo-Yo recovery test, showed statistically significant differences for the distance run, for the still time and for maximum velocity reached in the end of the test (table 4). The distance run and the still time in the test presented expressive increase of 30,5 and 37,5%, respectively, while for the maximum velocity, the increase was of 3,8%.

Table 5 presents the results of the variables of the back-and-forth run test. Statistically significant improvement for all variables

TABLE 4
Changes in the anaerobic power variables measured through the level II Yo-Yo recovery test

	1st evaluation	2nd evaluation
Run distance (m)	429,1 ± 130,3 (200-640)	560,0 ± 148,6* (320-840)
Test time (min)	3,09 ± 1,19 (1,31-5,12)	4,25 ± 1,14* (2,25-6,43)
Maximum velocity (km/h)	19,2 ± 0,7 (18-20)	19,91 ± 0,54* (19-21)

* Statistically significant differences among the evaluations (p < 0,05).

can be observed. The athletes increased the still time and consequently the distance run during the test in 7 and 8,6%, respectively. Concerning the $\dot{V}O_2$max, the average results let us identify statistically significant improvement of 8,1% after 16 weeks of concentrated loads training.

TABLE 5
Changes in the aerobic resistance variables measured through the back-and-forth run test

	1st evaluation	2nd evaluation
Test time (min)	8,48 ± 1,19 (6,3-10,58)	9,07 ± 1,40* (6,0-11,0)
Run distance (m)	1.547,3 ± 277,9 (1020-2060)	1.680,0 ± 294,5* (1120-2060)
Preside $\dot{V}O_2$max (ml/kg/min)	46,5 ± 3,23 (40,8-52,5)	50,6 ± 4,22* (41,8-55,4)

* Statistically significant differences among the evaluations ($p < 0,05$).

DISCUSSION

The specific characteristic of handball demands from players an effective participation in activities that need a good aerobic and anaerobic response[15]. However, some authors report that handball is a sport that demands predominately the motor capacities that depend on the anaerobic metabolism[3-4,16].

Thus, it seems reasonable to affirm that the motor capacities strength and velocity and their ways of manifestation are crucial, since the technical and tactical capacities can be consistently superior when the handball players present high levels of adaptation of the anaerobic metabolism[3].

Thereby, in this study the concentrated loads training methodology proposed by Verkhoshanski[7] and adapted by Oliveira[8] was chosen. Thus, the exercises for the strength training, velocity and its manifestation ways should be used in physical preparation programs of high performance handball players, with the aim to potentiate the anaerobic metabolism adaptations and consequently obtain an optimum performance in the competition.

Following this way of thinking, Toledo[17] studied the dynamics of the change of the motor capacities in an annual macro cycle, using concentrated loads and reported statistically significant increase for the explosive strength, measured through the stative horizontal jump test between the A1 and A3 micro steps (six weeks). The author mentions that such increase was due to an adaptation improvement of the motor possibilities of the athletes, specially obtained by the change of the functional state and by the inter and intramuscular coordination improvement. Concerning the rapid strength, measured through the sextuple jump test, the author did not find significant improvement, however, a slight change between the A1 and A3 micro steps was observed.

In another study, Moreira[18] applied the methodology of concentrated loads training in adult basketball players and reported increases that varied from 0 to 5% in the moving velocity for the 30 meters run for a 12 weeks period. Toledo on the other hand[17], who studied soccer players and applied the same training methodology of the actual study, reported increases that varied from 2 and 15% for the moving velocity measured through the 30 meters run test in a seven-week period. Concerning the actual study, though, it seems that the concentrated loads of velocity developed with the aim to improve the moving velocity need to be restructured, once the 40 meters run time decrease was statistically not significant. One of the training strategies used for the velocity development, especially in the B2 block, was to have stative running exercises for 5 seconds and after 20/30 seconds of rest, the handball player ran in velocity in the 5 and 20 meters distances. It is believed that such strategy should be reorganized, removing from the training session the stative running exercises, which may allow the EPDT.

Concerning the PA and PR values measured through the arm Wingate test, the results of the actual study report improvement in 16 weeks of concentrated loads training. Rannou *et al.*[3] applied the Wingate test for the lower limbs with the purpose of analyzing the physiological profile of adult handball players and reported that the PA and the PR of the handball players are better than of the athletes who practice sports with resistance predominance. The authors reported that such differences are due to the greater muscular mass and to the neuromuscular adaptations of handball players.

Concerning the variables related to the aerobic resistance, the results showed significant improvement for the maintaining time and for the distance run during the test, besides the oxygen maximum consumption ($\dot{V}O_2$máx). Although the preparation program is basically originated from short duration and high intensity activities (strength and velocity), it was observed that the physical exercises with predominance of anaerobic system and the technical-tactic training with intermittent characteristics, offered important improvement in the aerobic and anaerobic physical conditioning of handball players.

Handball is a sport characterized by intermittent efforts, of varied extension and random periodicity. Thus, it is necessary to apply a test also with intermittent characteristics to detect the physiological adaptations. Therefore, in the actual study the level II Yo-Yo recovery test was used to measure the anaerobic power. We may affirm based on the mentioned test results that the concentrated loads preparation program, which is based on special preparatory exercises of increasing volume and of general preparatory exercises of reduced volume, made the manifestation of the lasting posterior training effect (EPDT/LPTE) possible, as reported by Oliveira[8]. According to Moreira[18], the strength concentrated loads destined to make the morphological restructures possible, are the basic condition for the effective EPDT expression. In the actual study one may observe that the strength concentrated loads and their manifestations occurred predominately during the first weeks of training. It is thereby seen that in the following eight weeks the preparation program gave priority to the use of velocity concentrated loads and their manifestations, with the aim to make EPDT possible. We can affirm through the results of the studied motor capacities that such physiological phenomenon occurred mainly in the motor capacities that depend on aerobic metabolism predominately.

FINAL CONSIDERATIONS

The most remarkable considerations of this study are:

This study confirms that the training program of handball players should have emphasis on exercises that promote adaptation in the anaerobic metabolism;

The concentrated loads training methodology applied for 16 weeks, caused improvement in the motor capacities that predominately depend on the anaerobic metabolism;

The concentrated loads represented training stimuli sufficient to produce statistically significant increases of the aerobic resistance in a 16 weeks period;

The results analysis allows us to affirm the efficiency of the block training system in handball, due to the possibility to explore the adaptation supply, through the use of the concentrated loads.

Although there are few studies in Brazil that adopted the concentrated loads training system, especially in collective sports, it is verified that such model of periodicity adaptively used, may be applied bringing important benefits to the physical response of the athlete. Due to this study limitations (only two evaluations, short time training, lack of evaluation at the end of the competition), it is

suggested that other studies should be developed taking the mentioned limitations into account.

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