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F Literature Search
G Funds Collection

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abstract

Background The study aim was to evaluate the effect of a 6-week modified workout routine using the modified circuit weight training on selected anthropometric measures, components of physical fitness and physiological indices in competitive basketball players.

Material/Methods The study involved 30 basketball players (mean age: 23.4 ±1.8 years). Modified circuit weight training sessions were repeated 3 times a week. Each training session was subdivided into 3 circuits: strength conditioning, exercises to enhance functional fitness and a circuit of sport-specific exercises.

Results Statistically significant differences in values of circumferences and skinfolds were found between pre-test and post-test values, with no statistically significant changes in body mass and total body water. A statistically significant improvement was observed in motor ability tests, except for the barbell bench press test ($p = 0.096$). Statistically significant differences were also found in the values of physiological indices.

Conclusions The 6-week training using modified circuit weight method induced positive adaptations in most of the diagnosed anthropometric indicators, components of physical fitness and physiological parameters. This supports the notion of the comprehensive effect of such training on human body and suggests its usefulness for both athletes involved in specific sports and in health-oriented training of amateur athletes.

Key words circuit training, physical fitness, physiology, basketball

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INTRODUCTION

Circuit training is known to promote comprehensive development of motor abilities in athletes across various sports. Such universality helps develop both anaerobic and aerobic energy systems. These effects can be achieved through manipulation of the duration of the rests between exercise bouts, the number of repetitions and the level of external resistance used in individual exercises. This training stimulates the cardiorespiratory system and muscle metabolism. With the varied exercises and possibility to adjust the level of difficulty, this training can be employed in working with athletes, both young and elderly people [1, 2]. The great advantage of circuit training lies in opportunities for improving various components of physical fitness and focusing on the most specific to a given sport. Monteiro et al. [3] found that additional modifications to circuit training using mixed exercises (i.e. a combination of resistance training and aerobic conditioning) improves the maximal oxygen uptake (VO_{2max}). Brentano et al. [4] used strength training and circuit training in a group of postmenopausal women and documented a 22% increase in VO_{2max} compared to pre-test values. Gettman et al. [5] argued that although circuit resistance training is likely to improve VO_{2max}, it has a major effect on the increase in muscle strength and somatic body composition of athletes. The research on efficient methods to improve human physical fitness has paved the way for sport practitioners to develop multiple variants of circuit training, including modified circuit weight training [6]. Although most movements in basketball focus on strength and speed, some forms of activities, such as defensive tasks or tackling for the ball and position near the backboard seriously tax the muscular system. Therefore, training in this sport should contain various activities oriented at improvement in muscular strength [7, 8].

The study aim was to evaluate the effect of a 6-week modified circuit workout routine using the modified circuit weight training on selected anthropometric measures, components of physical fitness and physiological indices in competitive basketball players.

MATERIAL AND METHODS

The study examined 30 male basketball players from the Korona sports club in Kraków, Poland (mean age: $\bar{x}$ = 23.40 ±1.80 years, mean body mass $\bar{x}$ = 84.39 ±7.69 kg, and mean body height $\bar{x}$ = 188.80 ±5.80 cm. The inclusion criteria were continuous training for 3 to 5 years prior to the test, no medical contraindications to physical exercise, no previous involvement in professional sports at the elite level (no champion level and no Class I athletes).

The experiment was approved by the Bioethics Committee at the Regional Medical Chamber in Kraków, Poland (No. 77/KBL/OIL/2010). All the athletes who were qualified for the tests were informed about the purpose and procedures used during the experiment and signed a written consent for participation in the study.

Modified circuit weight training sessions were repeated 3 times a week (on Mondays, Wednesdays and Fridays) for 6 weeks. Table 1 presents general assumptions for the workout routine based on the modified circuit weight training.

Table 1. General assumptions for the workout routine based on modified circuit weight training

Number of circuits	3 x 3
Number of exercises in a circuit	5
Number of repetitions or duration of the set	15/30 (45) s
Percentage of maximum weight	50%
Exercise intensity	Fast
Rests between circuits	1 to 3 min.

Each training session was further subdivided into three modified circuit weight training:

- strength conditioning circuit (using barbells, dumbbells and kettlebells),
- functional fitness circuit (plyometric and coordination exercises),
- sport-specific exercise circuit (exercises that engage muscle groups that are most frequently used during sports competition (Table 2).

Table 2. Exercises included into the workout routine

Strength Conditioning Circuit	Functional Fitness Circuit	Sport-Specific Circuit
Overhead squat	Footwork using speed ladders	Chest press with rubbers attached to a ladder
Narrow grip chest pull-ups	Transition from the standing position to the push-up position followed by a tuck jump (burpees)	Lunges with moving the medicine ball from over the head
Lying alternate dumbbell press on an exercise ball	A-skips with dumbbells held in hands	Push-ups on a Bosu Ball [a] and return to the standing position while alternate lifting the Bosu Ball over the head and chest press
Kettlebell [b] swing in from the sumo position [c]	Jumping over a hurdle combined with moving under a hurdle	Pull-ups on a hanging rope with trunk rotations
Russian twists with a disc weight held with both hands	Squats followed by single-leg jumps on a plyo-box [d]	Side stepping between the discs

[a] Bosu Ball – training device made of a rubber half-ball attached to a rigid platform.
[b] Kettlebell – a weight with the centre of mass extended beyond the handle. In most cases, kettlebells are made as cast--iron balls with a handle.
[c] Sumo position - initial position for exercises, characterized by feet wide apart.
[d] Plyo-box - training device used to develop explosive strength (plyometrics).

Five to ten minutes of warm-up routine was administered before the main part of the training session and each session was completed with stretching exercises (10 to 15 minutes). Twice a week, on free days, the athletes participated in sessions to improve technique.

The basketball players were subjected to anthropometric measurements, examination of selected components of physical and special fitness and measurements of physiological indices.

The following anthropometric measurements were performed:

1. Body mass: measurements using TANITA BC-582 with accuracy of 0.01 kg.
2. Body composition:
    - lean body mass [kg];
    - percentage of body fat [% FAT];
    - percentage of total body water [%].

The measurements were performed using the TANITA BC-582 scales.

3. Circumferences:

- second shoulder's circumference (at rest and flexed);
- first forearm's circumference;
- chest circumference after maximal inhalation and exhalation;
- first thigh circumference (at rest and flexed).

Circumferences were measured with an anthropometric tape with accuracy of 1 mm [9].

4. Measurements of three skinfolds [mm] (on the rear surface of the arm, below the inferior angle of the scapula, oblique skinfold on the abdomen). Measurements were performed using harpender skinfold caliper [10].

Components of physical fitness were diagnosed by means of the following test batteries:

1. Motor fitness based on the Eurofit Fitness Test Battery [11]:

- "Plate Tapping" – speed of hand movements;
- "Flamingo Balance Test" – balance;
- "Sit-Ups in 30 seconds" – strength endurance of abdominal muscles and hip flexors;
- "Bent Arm Hang" – strength endurance of upper limbs muscles and shoulder girdle;
- "Handgrip Strength Test" – static arm strength. Test performed using the SAEHAN 5030KIT hydraulic dynamometer;
- "Standing Long Jump" – explosive strength of lower limbs muscles (power);
- "10x5 m Shuttle Test" – agility;
- "Sit-and-Reach Test – flexibility.

2. Cooper's test: the test of 12-minute run, first presented by Cooper [14]. The point of the test is to run as far as possible within 12 minutes. The test was used to evaluate endurance of over one hundred US Air Force soldiers. Following the test, Cooper observed a high level of correlation between the results (0.897) obtained for the maximal oxygen uptake VO_{2max} in soldiers and those obtained in a laboratory environment. The high correlation provided the evidence that the Cooper test can be successfully used to evaluate maximal oxygen uptake (VO_{2max}), which is considered a good indicator of aerobic capacity. Cooper's test was performed using a treadmill at the University of Physical Education in Kraków, Poland. The results were evaluated based on the table proposed by Cooper [12] and used by other researchers including Grant et al. [13] and McNaughton et al. [14].

3. Barbell bench press (lying position, flat bench) with the weight equal to the body weight: strength endurance of the upper limbs and the shoulder girdle. The participant adopted the lying position on a bench so that their feet were put firmly on the ground. The barbell was held with the palms

facing down, wider than the shoulder width. Next, the barbell was lowered to the chest and pressed to the initial position (repetitions that used the full range of the arm motion were counted).

4. Overhead squat with a barbell with weight equal to the body weight: strength endurance of lower limbs. After positioning of the barbell near the trapezius and deltoid muscles, a subject performed squats so that the thighs were at least horizontal to the ground. The repetitions that used the full range of motion were counted.

5. The defence test proposed by Ulatowski [15] to evaluate basketball players' special fitness. The participants performed the test on the volleyball court. Flags were placed in key points (A, B, C, D, E, F, G, H, I) to mark the lines of the court. The participants stood on the start line in point A, the back facing the direction of the run. As soon as they heard the word "start", they ran backwards to point B. From B to C, the participants used side-to-side step consistent with the defensive technique. The next sections were covered in the following manner: C-D: backwards; D-E: sideways; E-F: backwards; F-G: sideways; G-H: backwards, H-I: sideways.

The following physiological parameters were measured:

1. Heart rate (HR): the heart rate was recorded during a training session to determine the maximal and the mean heart rate. POLAR heart rate monitors F-55 and FT-4 we used.

2. Blood lactate: measurements of lactate levels in capillary blood were performed during training sessions:

   - pre-exercise (before training sessions),
   - post-exercise (3 minutes after completion of the main part of the training session),
   - during recovery (20 minutes after completion of the main part of the training session).

Lactate Scout analyzer was used for the measurements.

Anthropometric measurements and motor fitness tests were made 7 days before starting a 6-week training cycle (pre-test) and 7 days after completion of the cycle (post-test). Physiological examinations (body response to physical effort) were scheduled for the first and last days of the training cycle.

Consistency of the variables with normal distribution was evaluated using the Shapiro-Wilk test. Basic measures of descriptive statistics were calculated: arithmetic means ($\bar{x}$), standard deviations (SD), medians (Me). Results were considered statistically significant if the probability level of the test was lower than the predetermined level α=0.5 The intragroup differences between the pre-test and post-test results used the Students t-test for dependent variables (when distribution of results did not differ much from normal distribution) or the Wilcoxon test (if distribution deviated from normal).

RESULTS

The data collected in Table 3 indicated that statistically significant differences in circumferences and skinfolds were found in basketball players between pre-test and post-test results. Body fat percentage decreased by 0.50%. No statistically significant differences were observed in body mass (p = 0.779) and percentage body water (p = 0.121).

Table 3. Comparison of the pre-test and post-test values of anthropometric indices

Variable	Pre-test	Post-test	Students t-test		
	x̄±SD	x̄±SD	Difference x̄±SD	t	*p*
Body mass [kg]	84.39 ±7,69	84.31 ±7.20	0.08 ±1.51	0.28	0.779
Lean body mass [kg]	71.74 ±6.87	72.21 ±6.77	-0.46 ±0.86	-2.88	0.008
Percentage body fat [%]	12.53 ±1.65	12.03 ±1.67	0.50 ±0.31	8.88	< 0.001
Percentage total body water [%]	63.20 ±2.35	62.96 ±2.02	0.24 ±0.81	1.60	0.121
Second shoulder's circumference, at rest [cm]	33.53 ±3.04	35.03 ±2.52	-1.50 ±1.28	-6.30	< 0.001
Second shoulder's circumference, flexed [cm]	34.84 ±3.05	35.81 ±2.90	-0.97 ±1.41	-3.69	0.001
First forearm's circumference [cm]	29.21 ±1.84	29.60 ±1.67	-0.40 ±0.52	-4.07	< 0.001
Chest circumference - inhalation [cm]	100.90 ±4.07	103.69 ±3.81	-2.79 ±0.90	-16.68	< 0.001
Chest circumference - exhalation [cm]	99.07 ±3.74	101.10 ±3.74	-2.03 ±1.02	-10.77	< 0.001
First thigh circumference, at rest [cm]	59.29 ±2.39	61.64 ±2.59	-2.34 ±1.23	-10.24	< 0.001
First thigh circumference, flexed [cm]	61.05 ±2.19	63.40 ±2.29	-2.34 ±1.28	-9.85	< 0.001
Skinfold: rear surface of the arm [mm]	30.97 ±6.67	28.90 ±5.16	2.07 ±2.53	4.31	< 0.001
Skinfold: below the inferior angle of the scapula [mm]	31.69 ±6.79	29.86 ±5.55	1.83 ±2.85	3.45	0.002
Skinfold: oblique fold on the abdo-men [mm]	30.79 ±6.69	28.72 ±5.64	2.07 ±3.69	3.02	0.005

∝=0.05

A statistically significant improvement in motor ability tests after completion of the 6-week training cycle was noted, except for the barbell bench press test (p = 0.096) (Table 4).

Table 4. Comparison of the results obtained in motor tests with pre- and post-test values

Motor ability test	Pre-test	Post-test	Students t-test		
			difference		
	x̄±SD	x̄±SD	x̄±SD	t	*p*
Plate Tapping [s]	12.60 ±1.40	11.93 ±1.46	0.67 ±0.47	7.71	< 0.001
Flamingo Balance Test [count]	4.28 ±1.41	3.69 ±1.00	0.59 ±0.98	3.21	0.003
Sit-Ups in 30 sec [reps]	19.90 ±3.13	22.72 ±3.10	-2.83 ±1.75	-8.68	< 0.001
Bent Arm Hang [reps]	6.93 ±3.50	7.93 ±3.27	-1.00 ±1.63	-3.31	0.003
Handgrip Strength Test [kg]	48.59 ±4.80	49.76 ±4.65	-1.17 ±1.49	-4.24	< 0.001
Standing Long Jump [cm]	236.72 ±11.16	242.24 ±11.75	-5.52 ±6.85	-4.33	< 0.001
10x5 m Shuttle Test [s]	12.14 ±0.65	12.00 ±0.66	0.13 ±0.19	3.81	0.001
Sit-and-Reach Test [cm]	6.03 ±4.63	8.45 ±4.48	-2.41 ±1.62	-8.05	< 0.001
Cooper's test [m]	2688.97 ±132.20	2779.83 ±122.60	-90.86 ±59.46	-8.23	< 0.001
Barbell bench press [reps]	5.21 ±3.82	4.48 ±2.69	0.72 ±2.27	1.72	0.096
Overhead squat [reps]	12.34 ±5.57	22.14 ±11.97	-9.79 ±7.63	-6.91	< 0.001
Ulatowski defense test [s]	16.31 ±1.98	15.69 ±2.05	0.62 ±0.59	5.61	< 0.001

Table 5 illustrates differences in the heart rate frequency and the level of blood lactate during recovery between pre- and post-test calculated using the Wicoxon test, whereas data in Table 6 shows differences in other indices calculated using the Students t-test for dependent samples. These differences were statistically significant, pointing to more effective adaptations in athlete's body after the complete training cycle.

Table 5. Comparison of selected physiological indices before and after completion of a 6-week training cycle (Wilcoxon test)

Variable	Pre-test		Post-test		Wilcoxon test	
	x̄±SD	Me	x̄±SD	Me	Z	*p*
Heart rate [bpm]	150.55 ±6.56	152.00	149.55 ±6.56	151.00	-5.38	< 0.001
Lactate level during recovery [mmol/l]	4.34 ±0.80	4.20	4.14 ±0.80	4.00	-5.38	< 0.001

∝=0.05

Table 6. Comparison of selected physiological indices before and after completion of a 6-week training cycle (Students t-test)

Variable	Pre-test	Post-test	Students t-test		
			Difference		
	x̄±SD	x̄±SD	x̄±SD	t	*p*
Maximal heart rate [bpm]	178.03 ±4.53	176.41 ±3.86	1.62 ±0.94	9.27	< 0.001
Energy expenditure [kcal]	651.55 ±63.33	639.41 ±63.30	12.14 ±2.40	27.22	< 0.001
Lactate level, pre-exercise [mmol/l]	2.50 ±1.09	3.28 ±0.98	-0.78 ±0.14	-30.89	< 0.001
Lactate level, post-exercise [mmol/l]	9.35 ±1.25	9.18 ±1.21	0.17 ±0.09	9.79	< 0.001

∝=0.05

DISCUSSION

Similarly to other sports, in basketball it is critical to develop and maintain a high level of physical fitness components. The 6-week training experiment based on modified circuit weight training primarily focused on dynamic, multi-joint exercises based on concentric-eccentric muscular work. A stronger effect of individual exercises on athletes can also be linked to the type of equipment used (kettlebell, Bosu ball, plyo-box). This ensured the comprehensive stimulation of muscular work, ensuring its functional character adjusted to the physical demands of basketball. The whole training regimen was supplemented with static stretching in order to accelerate post-training recovery and promote regaining the full range of motion (ROM). Duncan et al. [16], who examined young people from the UK, found that 6 weeks of circuit training has an effect on reduction in body mass and BMI, whereas Tsutsumi et al. [17] argued that high-intensity resistance training is effective in improving muscle strength and reducing body fat levels. In our study, basketball player's body mass was not significantly changed over the 6-week workout routine. However, the increased body circumference and reduced body fat percentage should be emphasized. This is attributable to a relatively high intensity of the training used in the study. We found improvements in the results of the 12-minute Cooper test, which leads to the conclusion that the maximal oxygen uptake (VO_{2max}) was increased. The 12-minute run test has gained popularity in evaluation of endurance and physical capacity. Rosendal et al. [18] used the Cooper test to evaluate physical capacity of soldiers in response to military training. The results obtained by Alvero-Cruz et al. [19] demonstrated a high degree of reliability and accuracy for the results obtained in the Cooper test in a group of long-distance runners. Bandyopadhyay [20] documented a high correlation (0.93) between the distance covered in the Cooper test and the results of a direct test to evaluate VO_{2max}. Another study that demonstrated high correlations between the Cooper test and VO_{2max} were published in 2013 [21]. The study examined women from the West Bengal region in India, with the results revealing the correlation of 1.00 between the 12-minute run test and the direct measurement of VO_{2max}. These findings were consistent with previous data presented by researchers from different places of the world. The examinations supported the notion that the use of the Cooper test is an effective and accurate tool to evaluate physical capacity and endurance. Furthermore, it is a convenient and inexpensive test of capability to consume oxygen by the body.

A statistically significant improvement was found for the tests that evaluated endurance and strength, except for the barbell bench press, with the arithmetic mean in post-test reduced by 0.72 repetitions. Deteriorated results obtained in this test were probably caused by incomplete recovery in the activated muscles between individual training sessions. Ide et al. [22] found that dynamic muscle work during resistance training requires more time for regeneration. The authors demonstrated that the muscle could be less efficient even up to 96 hours after the training session, which has an unfavorable effect on the work during consecutive motor tasks. Analysis of all the exercises used in the workout routine based on modified circuit weight training reveals that the deltoid muscles, which are additionally engaged during barbell bench press, were substantially loaded [23]. Therefore, it can be presumed that the lack of adequate post-exercise recovery concerned these muscles. Many authors argue that duration of the rest that ensures the recovery of the exhausted muscle is individual for each human [24, 25]. It was also found that reduced muscle strength is one of the symptoms of the onset of overtraining [26]. It is also worth emphasizing that strength conditioning does not only have a direct effect on muscles but it also places a heavy load on the nervous system. Some experts approach strength conditioning as development of the capability of the nervous system [27, 28]. The neuromuscular load also requires adequate time for resting after training stimuli [29, 30]. Lehmann et al. [31] argue that intensive training may impair weaker nervous impulses that activate muscular contraction. This phenomenon represents a market that indicates the level of fatigue or overtraining. However, these findings were not supported by our results, especially in the balance test, which improved after training.

We demonstrated improvements in strength endurance and power of the lower limbs. Therefore, it can be assumed that integration of weight training and plyometrics into workout routines is very effective in improving athletes' functional motor fitness. The study published by Cronin and Hansen [32] also demonstrated that locomotor speed of rugby players is largely dependent on the use of plyometric exercises. Rahimi and Behpur [33] recommended combination of strength conditioning with plyometrics to achieve optimal improvements in speed and strength of lower limbs. The authors compared various modifications of strength training and found the highest anaerobic power in athletes who were involved in modified circuit weight training combined with the program of static and explosive strength exercises. Furthermore, Blazevich and Jenkins [34] found that strength conditioning does not always lead to improvements in anaerobic power.

Faigenbaum et al. [35] found that classical resistance training could deteriorate flexibility. Therefore, the authors recommended a combination of strength training and stretching or dynamic plyometric exercises. These authors argued that their method could yield an increase in flexibility after a 6-week training cycle by up to 28% compared to the initial levels. Andrejić [36] did not observe any regression in the level of flexibility in examinations of young basketball players who were involved in a 6-week training routine based on strength conditioning and plyometrics. The results of the sit-and-reach test in our study also suggest that the modified circuit weight training does not lead to reduced flexibility.

We used a special test that mimicked the way basketball players move on the court to verify whether the modified circuit weight training has an effect on the participants' special fitness. It is worth emphasizing that the workout routine used in our study was aimed to strengthen and activate muscle groups directly involved in the movement tasks used in basketball. Explosive plyometric exercises have been frequently integrated into the process of physical preparation of basketball players and their usefulness has been supported by motor tests [7]. The results of special work of basketball players in the test can point to the functional usefulness of the proposed workout routine.

Reduction in the mean heart rate, energy expenditure and post-exercise blood lactate levels and lactate levels during recovery demonstrate positive adaptations of athletes' bodies to the demands of the workout routine. Examination of blood lactate levels after 6 weeks of training based on modified circuit weight training methodology showed that the pre-exercise lactate levels increased compared to the initial value. Accumulation of blood lactate may result from the excessive load that the athletes were exposed to. It is remarkable that the blood lactate levels in the weeks where measurements were taken were higher than those accepted as recovery levels. It can be presumed that the athletes who participated in the experiment had to share the training process with regular professional work or learning at school and were unable to recover fully after training sessions.

Our research showed that the 6-week training based on modified circuit weight method in basketball players has an impact on the improvement in somatic parameters and components of physical fitness, and it enhances adaptations to physical exercise. Therefore, this workout routine can be used in athletes who are involved in specific sports and in health-oriented training of amateur athletes. With regard to the holistic effect of the training system on professional athletes, this training should be carefully planned. In order to improve the likelihood of greater achievements in competitive sport, the exercises should be chosen with respect for the demands of a given sport discipline. Our findings suggest the need and usefulness of monitoring athletes in terms of body response to physical exercise. This should help make adequate adjustments to the training process.

CONCLUSIONS

The 6-week training using modified circuit weight method induced positive adaptations in most of the diagnosed anthropometric indicators, components of physical fitness and physiological parameters. This supports the notion of the comprehensive effect of such training on the human body and suggests its usefulness for both athletes involved in specific sports and in health-oriented training of amateur athletes.

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