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Original Article (short paper)

Do muscular strength and jump power tests reflect the effectiveness of training programs for basketball athletes?

José H. Mazon[1], Ada C. Gastaldi[1], Natanael T. A. de Sousa[1], Rinaldo R. J. Guirro[1], Victor B. Ribeiro[1], Tábata P. Facioli[1], Stella V. Philbois[1], Hugo C. D. Souza[1]

[1]*Universidade de São Paulo, USP, Exercise Physiology Laboratory, Department of Rehabilitation and Functional Performance, Ribeirão Preto Medical School, Riberião Preto, SP, Brazil*

Abstract — Aims: Muscular strength (MS) and jump power (JP) tests are used to assess athletic ability and measure the effectiveness of training programs. However, their use in various sport modalities needs to be investigated further. This study aimed to explore the changes in MS and JP during three different moments of a macrocycle training session and verify the validity of the tests used to predict the effectiveness of basketball training programs. **Methods:** During macrocycle training (three different moments), sixteen basketball players were evaluated for MS (measured using isokinetic dynamometry at the speed of 60°/s) during concentric contraction of knee flexor and extensor muscles and JP, using countermovement vertical jump (CMVJ) on a force platform. **Results:** Peak torque and maximal work values for knee extension and flexion showed no differences, during the three moments analyzed. Additionally, no changes were observed for CMVJ. **Conclusions:** Our results suggest that the effectiveness of basketball training programs does not seem to be related to the performance achieved by athletes on the tests used. Moreover, the lack of changes in MS and JP values during the macrocycle could be related to the training structure used; volume, intensity, density and workload specificity.

Keywords: team sport; performance; measurement

Introduction

Basketball is an intermittent sport modality with a significant anaerobic metabolism demand. In fact, this metabolic demand is necessary for supporting the performance of moderate and high-intensity movements and periods of active and passive recovery[1,2]. Additionally, some specific attributes of basketball, such as changes in direction, acceleration, speed and jump ability, are closely related to muscle power[3]. Thus, the neuromuscular status of the athlete, which includes strength and power abilities, as well as the different uses of these during participation in a game, may have an effect on the athletic performance of this sport modality[4, 5].

In the context, the efficacy of the programs and methods utilized in basketball training is assessed through the athletes performance, using various physical tests[6, 7]. However, it is fundamentally important that each test is selected according to the specific characteristics of the sport training modality. Many ongoing studies are focused on elucidation of these critical issues. In basketball athletes, evaluation of muscular strength (MS) and jump power (JP) abilities has been used to monitor fatigue and performance, as well as identify muscle imbalances and asymmetries[7-9]. However, the relationship between MS and JP values and the athletes' performance in basketball is not fully understood and needs further investigation. Moreover, the protocols used to evaluate basketball skills, measure abilities of power and strength in many different ways, which makes it difficult for choosing the most adequate one[3].

In fact, little is known about the applicability of the results obtained from certain physical tests used to assess specific athletic performance in team sports. Furthermore, it has been shown that maximal strength and jump power abilities are not used very often during a basketball game[10]. Therefore, this study aimed to explore the changes in MS and JP, during three different moments of a macrocycle training session and verify the validity of the tests used to predict the effectiveness of basketball training programs. We hypothesize that there will be changes in strength and power jump of athletes during macrocycle training and the tests selected to evaluate these physical abilities will be able to identify possible alterations promoted by this specific basketball training program.

Methods

Participants

16 male basketball players (mean ± SD: age, 18.3 ± 0.7 years; height, 188 ± 9.98 cm; weight, 85.6 ± 12.1 kg; training history, 3 ± 0.9 y), who were registered in the state championship, participated in the study. The exclusion criteria were as follows: a) showing musculoskeletal injuries that would prevent the athlete from performing the tests used; b) not participate in training and competitions.

The participants were screened in the Exercise Physiology Laboratory, Department of Rehabilitation and Functional Performance, Ribeirão Preto Medical School, University of São Paulo, Brazil. The study protocol followed the code of ethics of the World Medical Association (Declaration of Helsinki), published in the British Medical Journal (1964) and was approved by the Human Research Ethics Committee of "Hospital das Clinicas" of the Ribeirão Preto Medical School, University of São Paulo, Brazil. All participants signed an informed consent form prior to the start of the study (Protocol: 162.079/2013)

Procedures

The duration of the macrocycle training was 34 weeks and the composition of the microcycle training was established as shown in Table 1. The technical-tactical training intensity was quantified in arbitrary units, using the method proposed by Edwards[12]. This is a (heart-rate-based method that integrates the total volume of the training session with the total intensity of the exercise session, relative to five intensity zones (Fig 1). The strength and power training protocols are shown in Tables 2 and 3. Table 2 shows the distribution of the resistance training load, performed in the fitness center, as training volume (number of sessions a week, number of combinations and repetitions for each exercise) and intensity (% of maximal repetition), during the 34 weeks of the macrocycle.

Table 1. Composition of training microcycles

Microcycles	Total number of days	Number of sessions	Technical-tactical sessions	Physical training sessions	Total duration (min)	Physical evaluations	Official games
1	2	4	3	1	360	---	---
2	6	11	5	---	---	6	---
3	6	10	8	3	900	---	---
4	6	11	8	3	990	---	---
5	6	10	7	3	900	---	---
6	6	10	7	3	900	---	1
7	6	10	7	3	900	---	---
8	6	9	6	2	810	---	2
9	6	11	8	5	990	---	---
10	6	10	7	5	900	---	1
11	6	10	7	3	900	---	1
12	6	10	7	3	900	---	1
13	6	10	7	3	900	---	1
14	6	10	7	3	900	---	1
15	5	9	6	2	810	---	2
16	5	9	4	---	---	6	---
17	6	11	8	3	990	---	---
18	6	10	7	3	900	---	1
19	6	11	8	5	990	---	---
20	6	10	7	5	900	---	---
21	7	9	6	2	810	---	2
22	4	6	3	2	540	---	2
23	6	10	7	5	900	---	---
24	6	11	8	5	990	---	---
25	6	10	7	3	900	---	1
26	6	10	7	3	900	---	1
27	6	10	7	3	900	---	1
28	6	10	7	3	900	---	1
29	5	10	7	3	900	---	1
30	6	10	5	---	---	6	---
31	6	11	8	3	990	---	---
32	6	10	7	2	900	---	1
33	4	6	4	1	540	---	1
34	4	6	---	---	---	---	---

Fig. 1 Magnitude of technical-tactical training load in arbitrary units. Values are presented as mean ± SD.

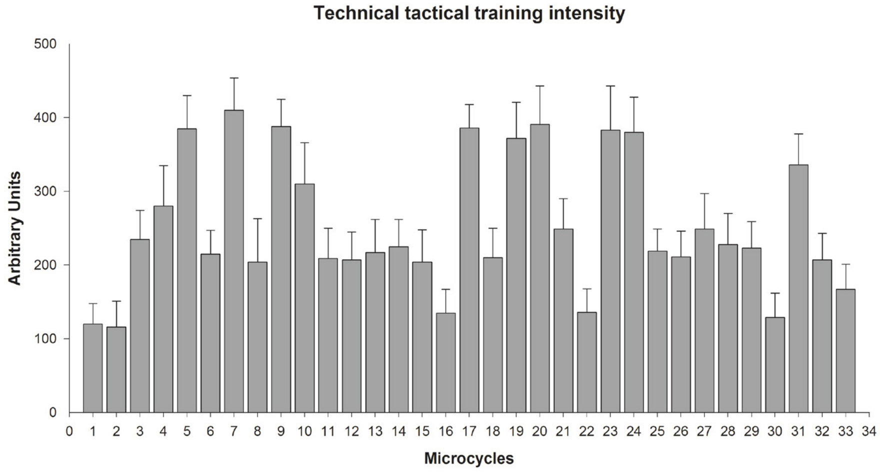


Table 2. Description of strength training

Microcycles	Volume and intensity				Lower limbs exercises and weekly frequency of use							
	Number of sessions	1 Rm (%)	Number of sets	Number of repetitions	Leg extension	Leg curl	Thigh adductor	Leg press	Calf raise	Squat	Deadlifting	Step-up knee
1	1	---	---	---	---	---	---	---	---	---	---	---
2	---	---	---	---	---	---	---	---	---	---	---	---
3	3	60	3	12	3	3	3	---	3	---	---	---
4	3	70	3	10	3	3	---	3	---	3	---	---
5	3	80	4	8	2	2	---	3	---	3	1	1
6	3	80	4	8	1	1	---	3	---	3	2	2
7	3	90	4	6	---	---	---	3	---	3	3	3
8	2	70	3	10	---	---	---	2	---	2	2	2
9	3	60	3	12	1	1	1	2	1	2	2	2
10	3	60	3	12	1	1	1	2	1	2	2	2
11	3	70	3	10	---	---	---	3	---	3	3	3
12	3	70	3	10	1	1	1	2	1	2	2	2
13	3	60	3	12	---	---	---	3	---	3	3	3
14	3	70	3	10	1	1	1	2	1	2	2	2
15	2	60	3	12	---	---	---	2	---	2	2	2
16	---	---	---	---	---	---	---	---	---	---	---	---
17	3	80	4	8	---	---	---	3	---	3	3	3
18	3	90	4	6	---	---	---	3	---	3	3	3
19	3	70	3	10	1	1	1	2	1	2	2	2
20	3	60	3	12	---	---	---	3	---	3	3	3
21	2	70	3	10	---	---	---	2	---	2	2	2
22	2	70	3	10	---	---	---	2	---	2	2	2
23	3	70	3	10	1	1	1	2	1	2	2	2
24	3	60	3	12	---	---	---	3	---	3	3	3
25	3	60	3	12	---	---	---	3	---	3	3	3
26	3	70	3	10	---	---	---	3	---	3	3	3
27	3	60	3	12	1	1	1	2	1	2	2	2
28	3	70	3	10	---	---	---	3	---	3	3	3
29	3	60	3	12	---	---	---	3	---	3	3	3
30	---	---	---	---	---	---	---	---	---	---	---	---
31	3	70	3	10	---	---	---	3	---	3	3	3
32	2	60	3	12	---	---	---	2	---	2	2	2
33	1	60	3	12	---	---	---	1	---	1	1	1
34	---	---	---	----	---	---	---	---	---	---	---	---

Table 3. Speed and Power training

Microcycles	Resisted sprints and plyometric training	Resisted sprints training (session/volume)			Plyometric training (exercises and session/volume)		
	Number of sessions	Number of sets	Duration of set (s)	Interval between sets (min)	Squat jump	Concentric box jump	Depth jump
1	---	---	---	---	---	---	---
2	---	---	---	---	---	---	---
3	---	---	---	---	---	---	---
4	---	---	---	---	---	---	---
5	---	---	---	---	---	---	---
6	---	---	---	---	---	---	---
7	---	---	---	---	---	---	---
8	---	---	---	---	---	---	---
9	2	9	10	1	24	18	18
10	2	9	10	1	30	24	24
11	---	---	---	---	---	---	---
12	---	---	---	---	---	---	---
13	---	---	---	---	---	---	---
14	---	---	---	---	---	---	---
15	---	---	---	---	---	---	---
16	---	---	---	---	---	---	---
17	---	---	---	---	---	---	---
18	---	---	---	---	---	---	---
19	2	9	10	1	24	18	18
20	2	9	10	1	30	24	24
21	---	---	---	---	---	---	---
22	---	---	---	---	---	---	---
23	2	9	10	1	30	24	24
24	2	9	10	1	30	24	24
25	---	---	---	---	---	---	---
26	---	---	---	---	---	---	---
27	---	---	---	---	---	---	---
28	---	---	---	---	---	---	---
29	---	---	---	---	---	---	---
30	---	---	---	---	---	---	---
31	---	---	---	---	---	---	---
32	---	---	---	---	---	---	---
33	---	---	---	---	---	---	---
34	---	---	---	---	---	---	---

The exercises used to develop the lower limb strength, as well as their weekly use frequency, are also included in Table 2. The volume and intensity of the resistance training oscillate (3 to 4 sets for each exercise, with load between 60 and 90% of a maximum voluntary contraction - 1RM) due to the microcycle characteristics and also the competition schedule. During the competitive period (microcycle 6-33), exercises that required greater specificity of motor gesture in relation to the game actions were emphasized. As seen in Table 3, the methods used to develop power jump and speed capability. We respected the principles of individuality and training specificity in the plyometry (power jump) and tracking (speed) sessions. The plyometric jumps and tracking were performed in blocks with submaximal and maximal intensities and all series were followed by specific actions with the ball. The volume of the plyometric training sessions was determined by the average number of jumps performed by the athletes during a basketball game (60 to 78 jumps). Twelve sessions of plyometry were performed, all during the competitive period, due to the competition schedule (short preparation period followed by an extended period of competition), as shown in Tables 1 and 3.

MS and JP were measured in three different moments during the macrocycle training (microcyles 2, 16 and 30, which aimed to monitor the adaptations and assimilation to the training loads applied) as follows: 1) measurement of peak torque and maximal work, using isokinetic dynamometry, during concentric contraction of knee flexor and extensor muscles and 2) measurement of JP (lower limbs), using the countermovement vertical jump (CMVJ) performed on a force platform. measure. A 48-hour interval was established between the last training session and the laboratory evaluations. The athletes were instructed to avoid physical activities during this period.

Muscular Strength Evaluation

MS was measured using the gold standard Biodex System 4 Pro® isokinetic dynamometer (Biodex, New York, NY), which has the highest correlation coefficients for reliability, accuracy, and validity[13]. The players performed five maximal isokinetic contractions for measuring peak torque and maximal work at the speed of 60°/s, during concentric contraction of knee flexor and extensor muscles. Prior to the evaluation, the laterality of the participants was determined, following a procedure established in a previous study[14]. The athletes were then seated on the isokinetic dynamometer with the hips in 80º flexion. The axis of the instrument was aligned with the knee joint axis. To minimize extraneous movements of the body during contractions of the thigh muscles, straps were secured across the chest, pelvis, and thigh[15]. The center of resistance was located at the distal 1/3 of the leg, 2 cm above the lateral malleolus of the tibia tarsal joint and then fixed with adjacent straps. The participants were asked to position their arms across their chest. The weight of the limb to be tested was checked by the dynamometer for automatic correction of the parameter values measured to avoid the effect of gravity[14]. The range of motion was between 100º and 10º, corresponding to 90° and it was limited to avoid the effect of passive insufficiency of the hamstring muscles, that is, when an antagonist muscle (hamstring muscles) limits the action of an agonist muscle (quadriceps). Prior to the test, the participants performed three submaximal isokinetic contractions to familiarize themselves with the equipment and its operation, as well as the strength needed according to the selected speed[16]. The lower limb used for starting the test was chosen at random. Visual and audio feedback was provided to the subjects[14, 15].

Jump Power Evaluation

JP was evaluated using a force platform (OR7/6/1000, AMTI, Watertown, MA, USA), which is a high-quality measurement tool developed for jump/power testing[17,18]. Data acquisition and analysis were performed using AMTI NetForce® and BioAnalysis® software (Watertown, MA, USA). The sampling rate was 1000 Hz, and the acquisition time was 8 seconds. Prior to the test, the subjects warmed up, by performing submaximal bilateral jumps on the force platform, followed by three maximal CMVJ series, with rest periods of 30 seconds between series. The athletes were instructed to remain with their hands on their waist and to quickly perform the eccentric phase of each jump (knee angle of approximately 120°) and then jump as high as possible, during the concentric phase. Knees and ankles were to remain extended "upon landing"[19]. During the tests, the participants were verbally encouraged to maximize their jumping abilities.

Statistical analysis

The data were analyzed by the Sigma-Stat® program, version 2.03, and are presented as mean ± standard deviation. The power and strength values were analyzed using the one-way ANOVA and Kruskal-Wallis tests, when applicable. The significance level was set to $p < 0.05$ for all analyses.

Results

Muscular Strength

Table 4 shows the values of peak torque (absolute and relative) and maximal work (absolute and relative) for basketball players during different moments of the training macrocycle, obtained from the isokinetic dynamometer software. No significant differences were observed in any of the parameters analyzed in this study when comparing the three test moments (microcycles 2, 16, and 30).

3.2 Jump Power

JP parameters (flight time, height, and maximal power) of the basketball athletes were obtained with the use of a force platform during three distinct moments of the macrocycle training (microcycles 2, 16, and 30) and are shown in Table 5 The values of jump height achieved by each athlete during the three moments is seen in Figure 2. No differences were observed when the analyzed parameters were compared.

Table 4. Values of peak torque and maximal work of basketball players measured by isokinetic dynamometry at the speed of 60°/s during concentric contraction of knee flexor and extension in three different moments of macrocycle training.

Moments	Microcycle 2	Microcycle 16	Microcycle 30	(P)
Knee extension (Dominant limb)				
Peak Torque (N.m)	279.7 ± 36.5	293.7 ± 31.9	296.0 ± 40.0	0.522
Maximal Work (J)	318.0 ± 46.8	312.3 ± 45.6	325.2 ± 46.8	0.806
Normalized Torque (%)	326.2 ± 36.3	336.5 ± 37.5	330.1 ± 37.2	0.719
Normalized Work (%)	370.8 ± 48.6	357.2 ± 48.0	362.9 ± 42.0	0.760
Knee extension (Nondominant limb)				
Peak Torque (N.m)	268.7 ± 39.6	271.8 ± 33.7	272.6 ± 41.0	0.966
Maximal Work (J)	295.7 ± 51.3	294.2 ± 44.2	291.2 ± 52.0	0.976
Normalized Torque (%)	313.6 ± 39.8	312.8 ± 45.7	305.8 ± 49.5	0.905
Normalized Work (%)	344.0 ± 45.4	337.4 ± 52.4	325.9 ± 54.2	0.695
Knee flexion (Dominant limb)				
Peak Torque (N.m)	138.5 ± 19.7	139.8 ± 21.3	146.9 ± 19.1	0.585
Maximal Work (J)	160.0 ± 25.7	158.6 ± 30.6	164.4 ± 21.6	0.868
Normalized Torque (%)	161.0 ± 14.7	159.9 ± 22.9	164.1 ± 16.4	0.860
Normalized Work (%)	185.9 ± 20.5	180.8 ± 31.0	183.9 ± 22.6	0.879
Knee flexion (Nondominant limb)				
Peak Torque (N.m)	136.3 ± 17.6	138.7 ± 16.7	147.7 ± 14.9	0.253
Maximal Work (J)	152.7 ± 27.0	162.7 ± 27.2	171.5 ± 20.1	0.225
Normalized Torque (%)	159.1 ± 18.8	159.0 ± 20.1	165.5 ± 16.6	0.655
Normalized Work (%)	177.9 ± 27.4	185.2 ± 29.3	191.9 ± 21.3	0.460

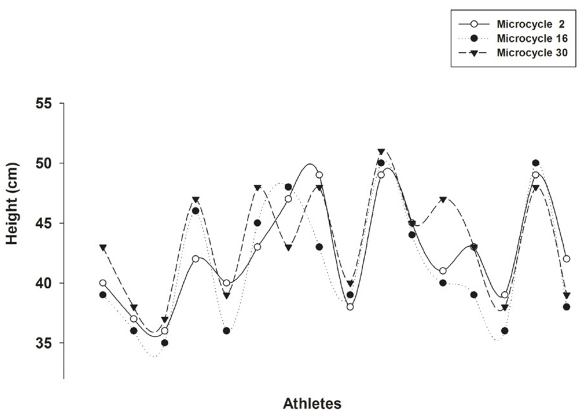
Values are presented as mean ± SD.

Table 5. Characteristics of CMVJ performed by basketball players on a force platform in three different moments of the training macrocycle.

CMVJ Parameters	Microcycle 2	Microcycle 16	Microcycle 30	Valor P
Flight time (s)	0.588 ± 0.02	0.581 ± 0.03	0.594 ± 0.02	0.609
Height (cm)	43 ± 4.27	42 ± 5.12	43 ± 4.47	0.524
Maximal Power (W)	4.302 ± 729	4.268 ± 735	4.536 ± 681	0.629

Values are presented as mean ± SD.

Fig. 2 Height of countermovement vertical jump (CMVJ) performed by each basketball player during different moments of the training macrocycle.



Discussion

In the present study, MS and JP of basketball players were analyzed in three different periods of a macrocycle training (microcycles 2, 16, and 30) The main finding was that MS and the JP values remained unchanged, during the macrocycle. These results were evidenced by the absence of change in the values of peak torque, maximal work, and performance achieved in CMVJ, assessed by a isokinetic dynamometer and force platform.

The plateau or decrease in the maximal performance of athletes is often associated with an imbalance between the workload and the recovery period [20]. In this context, many studies have demonstrated the use of physical tests to control and evaluate the efficiency of sports training programs[5,7,8,21-23]. Strength and power measurements can provide valuable insights into the training state of athletes[21]. In basketball, the performance of high-intensity movements is closely associated with the development of strength, sprint, and agility[24]. In fact, the improvement of these motor skills contribute to efficient basketball movements, with and without the ball, that play an important role in the tactical-technical aspects of the game[25].

However, little is known about training methods and specific adaptations involving basketball athletes and studies that address the use of different periodization models and the performance achieved in physical tests over the course of the macrocycle training, are still incipient. Therefore, for the development of lower limb strength capacity, the present study used resistance training at a bodybuilding gym. The selected exercises (leg press, squat, deadlifting, step-up knee) emphasized the work of the main muscle groups involved in the specific actions of the modality in question. As far as the improvement of the jump power, the method used was the plyometry, with the performance of submaximal and maximum vertical jumps. The training methods used are validated in the literature for increasing MS and JP of lower limbs[22,26-29]. Nevertheless, the training program had no effect on MS and JP of the athletes, when analyzed in different moments of the macrocycle training. Our findings are not consistent with the findings of other studies that have observed increased capacities for muscular strength and jump power in basketball athletes [28, 29]. The main reason for this outcome is not clear, and considering the importance in the selection of specific physical tests to evaluate the performance of athletes, it is possible that the results observed in the present study are related to the lack of specificity of the tests used.

The MS, measured by isokinetic dynamometer (considered gold standard in the evaluation of muscle function), has been used more frequently in the evaluation of the imbalances and asymmetries in basketball athletes[9,16]. Thus, the 1 RM test has been suggested, for example, to assess the performance of dynamic lower limb muscle strength in basketball athletes during half-squat exercise[30].

From the biomechanical point of view, it is necessary to recognize that the jumps performed on the force platform were different from those used in the plyometry sessions and during the technical-tactical training, which could explain the JP results. In fact, a study that investigated the specificity of the tests used to evaluate the jumping power in basketball athletes, concluded that Sargent Jump is highly correlated to the specific movements of this modality. In addition, the manifestation of the maximum vertical jump power does not occur frequently in basketball [10], which also may explain the observed results. Moreover, it is also possible that the lack of changes in the parameters evaluated is related to the structure of the training loads used in the macrocycle in question. However, the values of peak torque, maximal work, and jump power were maintained by the athletes, when the different moments were compared, suggesting, a possible maintenance of the performance of strength and power of the lower limbs of the athletes, during the macrocycle.

Conclusions

Our results suggest that the effectiveness of basketball training programs seems to not be related to the performance achieved by athletes on the strength and power tests included in this study. In turn, it is possible that the absence of change in MS and JP values, during the macrocycle, can be assigned to the structure of the training used, i.e, volume, intensity, density and/or specificity of workloads.

Study Limitations

The study presented limitations mainly regarding the monitoring of other performance markers that would allow establishing correlation with the results obtained. In addition, it was not possible to submit the athletes to different training programs in order to evaluate their effectiveness. Another limitation refers to the size of the sample, which, because it is small, allows us to consider the results found only for the athletes in question.

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Corresponding author

Hugo C. D. Souza, Ph.D.
Department of Rehabilitation and Functional Performance. School of Medicine of Ribeirão Preto, University of São Paulo, 14049-900, Ribeirão Preto, SP, Brazil.
E-mail: hugocds@fmrp.usp.br

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