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Young investigator

Research article

LONG TERM EFFECTS OF DIFFERENT TRAINING MODALITIES ON POWER, SPEED, SKILL AND ANAEROBIC CAPACITY IN YOUNG MALE BASKETBALL PLAYERS

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ABSTRACT
The purpose of this study was to identify the effect of 4 months of different training modalities on power, speed, skill and anaerobic capacity in 15-16 year old male basketball players. Thirty five Lithuanian basketball players were randomly assigned into three groups: power endurance group (intermittent exercise, PE, n = 12), general endurance group (continuous exercise, GE, n = 11) and control group (regular basketball training, CG, n = 12). The power endurance model was based in basketball game external structure whereas the general endurance model was based in continuous actions that frequently occur during the basketball game. The training models were used for 16 weeks in sessions conducted 3 times a week during 90 minutes each in the competition period. The following tests were performed: 20 m speed run, Squat jump, Countermovement jump, Running-based Anaerobic Sprint Test (RAST), 2 min. shooting test and the Shuttle ball-dribbling test. A 3×2 repeated measures ANOVA revealed no statistically significant differences in the 20 m speed run, Squat jump and Countermovement jump ($p > 0.05$). On the other hand, RAST showed significant increases in PE, with greater increases during the 5th and 6th runs. The PE training model also produced a significant improvement in the shuttle ball-dribbling test (48.7±1.5 in the pretest, 45.5±1.3 in the posttest, $p \leq 0.05$). Globally, our results suggest that both training modalities were able to maintain initial values of speed and power, however, the anaerobic capacity and skill increased only in the players from the power endurance group. Therefore, the power endurance training (intermittent high intensity exercise) may be more beneficial to prepare junior players according to the game cardiovascular and metabolic specific determinants.

KEY WORDS: Basketball, endurance, training modelling, young players.

INTRODUCTION

The importance of developing good conditioning programs based on the specific physiological demands of each sport is considered a key factor to success (Gillam, 1985; Taylor, 2003; 2004). Basketball requires tremendous endurance, speed, agility, and power (Siegler et al., 2003). At the elite level, research has identified the intermittent high-intensity exercise as predominant and fitness improvements to this activity pattern have further been defined as power endurance (Siegler et al., 2003; Thomas, 2000; Trinič et al., 2001).

In elite basketball games, available time motion analysis research shows that adult athletes performed per game 105 high-intensity bouts (85% maximum heart rate, HR) while covering a distance of 991m (in high-intensity) executing 50-60 changes in speed and direction and 40-60 maximal jumps (Janeira and Maia, 1998; McInnes et al., 1995). Additionally, McInnes et al. (1995) have reported mean heart rates of 169±9 bpm (89±2% from peak HR) and verified that 75% of playing time was spent with a HR response greater than 85% peak HR. On the other hand, Apostolidis et al. (2003) described the physiological characteristics of 30 high-level junior players and concluded that VO_{2max} and anaerobic power values were moderate and the ventilatory threshold was relatively high. These authors also found statistical significant correlations between the mean power output calculated in the Wingate test and several technical tests (control dribble, speed dribble, high intensity shuttle run, shuttle run and dribble). Thus, it seems clear that the physiological requirements of men's senior and junior elite basketball are high, placing considerable demands on the cardiovascular and metabolic response of players to intermittent exercise.

One question that remains unknown in the literature is the structure of training models and their chronic impact in players' physical fitness. In fact, in order to meet the specificity principle of training, it seems that basketball training models should be based on competition physiological determinants (Gillam, 1985; Taylor, 2003; 2004) and, basketball practices should prepare players to respond adequately to these requirements. We did not find any study conducted on this particular topic; however, available time-motion research (McInnes et al., 1995; Taylor, 2003) can lead us to two different approaches in basketball training modelling. In the first, coaches could use a training model based on power endurance (PE) in which players will perform their actions within the basketball game external structure (e.g., 4×15 min. of intermittent exercise), their heart rate indexes (e.g., mean heart rate 160–170 beats per min.) and their recovery (e.g., 3 passive pauses 2×2 min. and 1×15 min.). In the second, coaches could use a training model based on general endurance (GE) in which players will perform continuously the actions that frequently occur during the basketball game meaning, for example, that they will never perform high-intensity drills more than 10-15 seconds, run farther than 20 meters without a change of direction or perform less than 50-60 high-intensity jumps. At the youth level, training models have traditionally focused on increasing general endurance, but no attention has been given to intermittent high-intensity training, an aspect so crucial in basketball (Sampaio et al., 2004; Siegler et al., 2003).

Therefore, it seems clear that the physical fitness of basketball players and, consequently, game performance can be influenced by these two different training approaches and that no literature is available to report these training modalities chronic effects. Thus, the purpose of this study was to identify the effect of 16 weeks of power endurance and general endurance training in power, speed, skill and anaerobic capacity of junior basketball players.

METHODS

Subjects

Thirty five Lithuanian basketball players from 15-16 years of age were randomly assigned into three groups: power endurance group (PE, n = 12), general endurance group (GE, n = 11) and control group (CG, n = 12). All the players had the same experience in sports (PE = 7.1 ± 0.4 years; GE = 7.2 ± 0.9 years; CG = 7.1 ± 0.6 years), were of similar height (PE= 1.82 ± 0.08 m; GE = 1.81 ± 0.05 m; CG = 1.85 ± 0.06 m) and weight (PE = 75.4 ± 6.2 kg; GE = 73.2 ± 5.1 kg; CG = 77.1 ± 8.4 kg). The training models were used for 16 weeks in sessions conducted 3 times a week during 90 minutes each. Approval was obtained from the Internal Review Board for research at the University of Vilnius (Lithuania) and informed consent was given by the players and their parents.

Training models

PE – Power endurance (intermittent exercise)

This training model is based on a basketball game external structure and actual game conditions heart rate values. The basic workload structure was the following: basketball technical and tactical actions during 4×15 min. periods; mean heart rate 160–170 b/min; 3 passive pauses (2×2 min and 1×15 min, Figure 1). In the first part of the training, the main goal was directed to the improvement of ball passing (15 min), the second part to ball dribbling (15 min), and the third part to ball shooting (15 min). Each exercise had the approximate duration of 45 – 55 s with 15 – 25 s pauses and was repeated 6 times. The fourth part of the training was directed to the improvement of team tactics (5x5 full-court game). Short pauses (2x2 min) were used for free-throw shooting and a long pause (15 min) was used by the coach to explain tactical work.

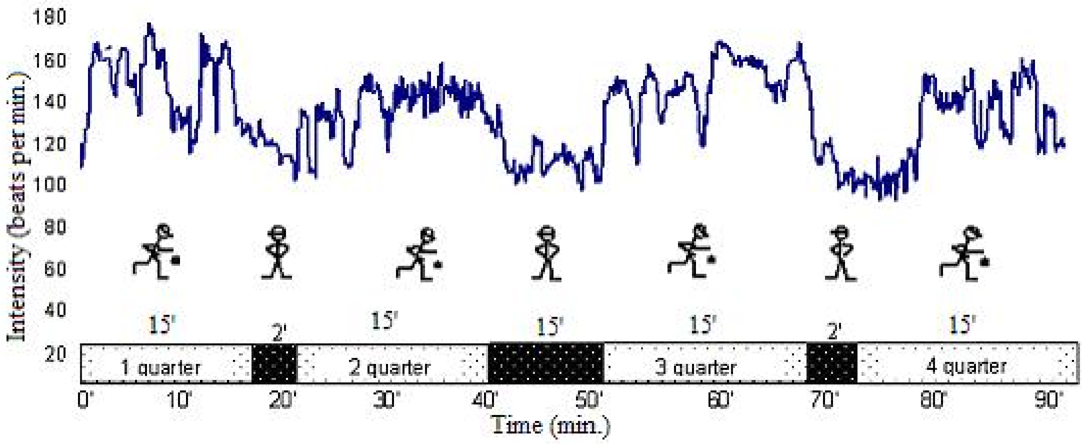


Figure 1. Variation of heart rate values during the power endurance practice sessions.

GE – General endurance (continuous exercise)
This training model is based on time motion analysis data. The drills are planned and performed continuously using situations which generally occurs during the basketball competition, i.e., athletes will never perform high-intensity drills more then 10-15 sec., run farther than 20 m. without a change of direction, perform less than 50-60 high-intensity jumps (McInnes, 1995). The main focus was on active defence during the exercises and the drills have been chosen from the most usual basketball game situation, e.g., plays 1×1; 2×2, 3×3. The training sessions consisted of 6 exercises repeated 15 times; with an approximate duration of 10 – 15 s and 15 s pauses. Each exercise lasted for approximately 10 min. for a 60 min. total time (Figure 2). The main goals of these exercises were the improvement of ball passing, dribbling and shooting. Short active pauses of 10 free-throws were done between exercises. The remaining 30 min. of the training session were accounted to tactical work (5x5 full-court game).

CG – Regular basketball training
During this training period the coaches planned the workouts with regular basketball skills, drills and game periods according to the program usually applied by the Lithuanian basketball schools. In this program, coaches are advised to plan the following typical parts of the training sessions: warming up (up to 20 min.); exercises for the improvement of individual technical actions (up to 40 min., ball dribble for 10 min., shooting for 20 min. and passing for 10 min.); tactical training (up to 30 min.).

Testing
Subjects had all the same type of training in the pre-season (during 4 weeks). Then, the training models were applied on the two experimental groups during 16 weeks in the competition period (see Table 1). The average training time intended for endurance development was similar in all groups (PE = 56.8 min GE 52.8 min and CG = 57.4 min).

Field testing was performed at the same hours in the same indoor terrain for the pretest and for the posttest. By the same order, players were tested for vertical jump, speed and anaerobic capacity in the following tests: a) *20 m speed run*, two infrared

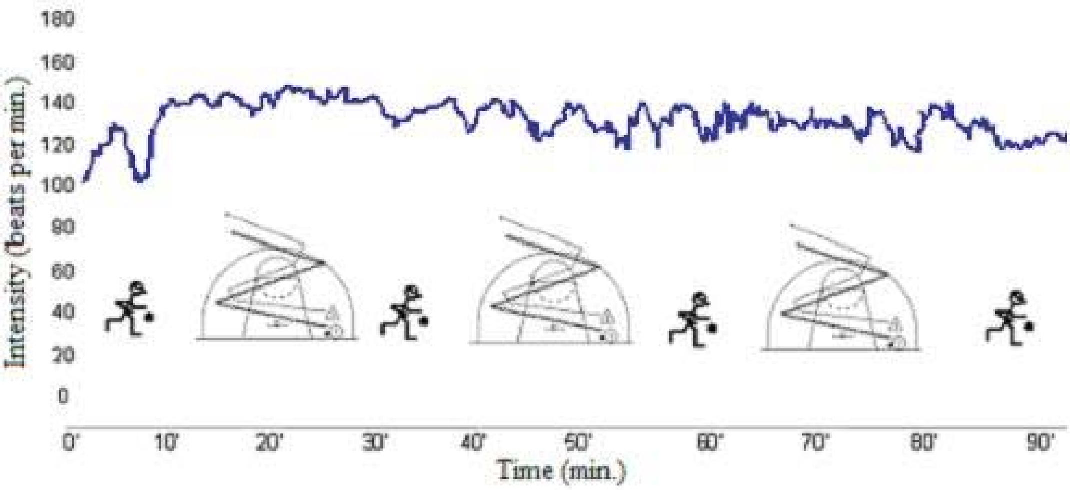


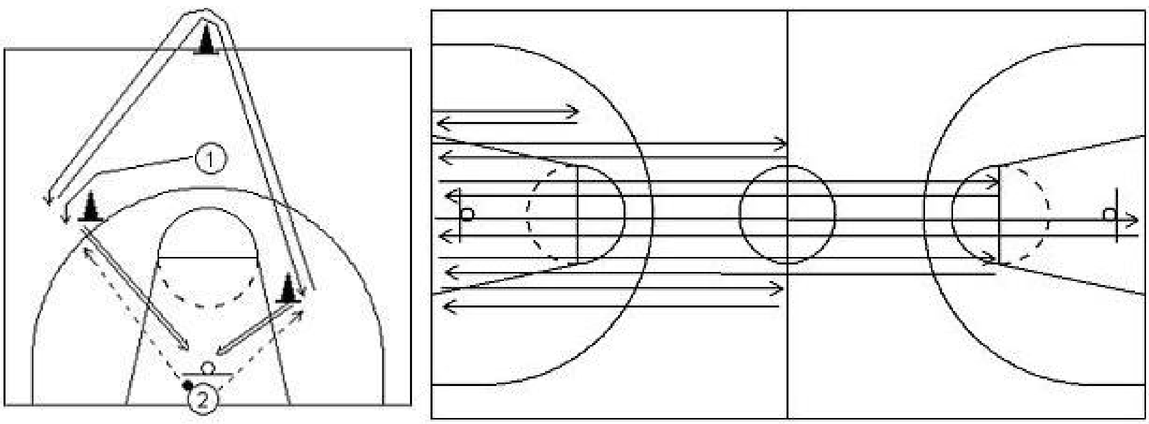
Figure 2. Variation of heart rate values during the general endurance practice sessions.

Table 1. Description of training models (PE = power endurance, GE = general endurance, CG = control group) general characteristics.

Training variables	**PE**	**GE**	**CG**
Training days	96	95	93
Resting days	22	24	24
Practices overall	68	68	64
Days of training modelling	50	47	0
Days of game overall	28	27	29
Average intensity (%HRmax)	78	54	48
General physical training (h)	24	24	21
Specific physical and technical training (h)	87	86	83
Tactical training (h)	34	33	36
Total (h)	*145*	*143*	*140*

photoelectric cells (Newtest Powertimer, Finland) were positioned at exactly on and 20 m from the starting line at a height of 1 m. The subject had to start from a standing position placing his forward foot 70 cm before the first infrared photoelectric cell. The timing started as soon as the body of the player crossed the infrared beam of first photoelectric cell and ended when the player crossed the beam of the second photoelectric cell. Before testing, each subject performed a submaximal sprint to familiarize himself with the test procedure. Test reliability was high (r = 0.88). b) *Running-based Anaerobic Sprint Test* (RAST), It has been shown that this test can replace the Wingate test as an estimate of anaerobic power and capacity (Zacharogiannis et al., 2004). Each athlete was weighed prior to the test and warmed up for a period of five minutes which was followed by a three minute recovery. The test consists of six times 35m discontinuous sprints. Each sprint represents a maximal effort with 10 seconds allowed between each sprint for the turnaround. Power output and fatigue indexes were calculated by the following equations: 1) Power: weight (kg) x distance (m^2)/ time (s3); 2) Fatigue Index: (maximum power – minimum power)/ total time for 6 sprints (s). Test reliability was high (r = 0.90). c) 2 min. shooting test (see Figure 3a); In the official basketball court, the subject were shooting from the 2 points distance (middle and long distance) for 2 minutes. After each attempt they ran backwards to the mid-court and the ball was passed to the shooter by another player standing under the basket. The number of attempts and made shots were recorded. The rates of this test are informative in estimating the sensomotory capabilities of the player, the stability of shooting along with the ability to readjust to the situation in the game (given the quite intensive physical load and the manifestation of certain fatigue). Test reliability was high (r = 0.85). d) Shuttle ball-dribbling test (see Figure 3b), subjects covered an overall distance of 212.4 m. Performance time was determined with photoelectric cells as previously described and the better of two trials was registered. Test reliability was high (r = 0.91).

Power measurement was evaluated with two protocols: a) *Squat jump*; The subjects performed a maximal vertical jump with their hands on the waist, starting from an angle of 90º at the knee; b) *Countermovement jump*; Subjects performed a



a b

Figure 3. Illustration of the protocol for the (a) 2 minutes shooting test and the (b) high intensity shuttle ball-dribbling test.

Table 2. Changes in speed, skill and power for the different training modalities. Values are means (SD).

Variables	PE	GE	CG
20 m speed run (s)			
Pre-test	2.96 (.09)	3.10 (.07)	3.10 (.09)
Pos-test	3.02 (.08)	3.02 (.08)	3.06 (.08)
Squat jump (cm)			
Pre-test	43.68 (4.14)	41.65 (5.74)	40.39 (4.12)
Pos-test	44.76 (4.46)	43.34 (5.80)	40.60 (4.52)
Abalakov test (cm)			
Pre-test	50.10 (3.73)	51.18 (3.89)	50.21 (4.40)
Pos-test	54.67 (3.39)	51.14 (1.60)	49.08 (4.38)
Shuttle ball-dribbling test (s)			
Pre-test	48.7 (2.20) *	47.2 (2.55)	48.5 (3.44)
Pos-test	45.5 (2.31)	45.9 (2.44)	47.9 (3.02)
Number of attempted shoots in 2 min			
Pre-test	16.3 (1.20)	15.6 (1.44) *	14.4 (2.01)
Pos-test	16.7 (1.22)	17.4 (1.52)	15.4 (2.22)
Number of successful shoots in 2 min			
Pre-test	7.1 (.14)	6.3 (1.00)	5.6 (.55)
Pos-test	7.9 (.17)	7.5 (.82)	6.9 (1.12)

* $p \le 0.05$. PE = power endurance, GE = general endurance, CG = control group.

maximal vertical jump starting from a standing position with arm swing allowed. All jumps were performed on the Ergojump (Globus Inc., Italy) that recorded the flight time of all jumps. The flight time was used to calculate the change in the height of the body's centre of gravity (Bosco et al., 1983). Subjects performed three trials in each protocol and the best of them was used in the analysis. Test reliability was high for both tests (respectively, r = 0.97 and r = 0.95).

Data analysis

For statistical analysis, a 3 (PE, GE, CG) × 2 (pretest, postest) repeated measures ANOVA was carried out using group and trial as factors (between and within factors, respectively). A Tukey post-hoc test was used to identify differences between groups and trials. All data undergoing ANOVA were tested for assumptions of normality, homogeneity of variance and covariance matrices and sphericity. Neither assumption was violated. Statistical significance was set at 5%.

RESULTS

Results from the 20 m speed run, Squat jump and Countermovement jump did not changed significantly after the end of the training modelling period ($p > 0.05$, Table 2).

On the other hand, power endurance training (PE) significantly increased the subjects' anaerobic capacity. These differences could be observed in Figure 4a by the RAST test results. The greatest differences were noticed during the 5th and 6th runs (125 and 144 W, $p \le 0.001$). The PE had a mean (±SD) working capacity of 457 ± 53 W before the experiment and 565±48 W after the experiment. No statistically significant differences were observed in GE (Figure 4b) and CG (Figure 4c).

Results from RAST test fatigue index followed the same tendency (see Figure 4d). The average indexes of PE changed statistically significantly ($p \le 0.05$) from 7.0 ± 1.3 scores to 5.4 ± 0.8 scores.

In the 2 minutes shooting test the average number of attempted shots of GE improved significantly from 15.8 to 17.2. In the remaining groups, no differences were observed either for attempts or made shots.

Finally, results from PE in the shuttle ball-dribbling test improved significantly ($p \le 0.05$). No statistically significant differences were observed in GE and CG.

DISCUSSION

The main purpose of this study was to identify the effects of two basketball training models in players' power index, speed, skill and anaerobic capacity. Our results suggest that both training modalities were able to maintain initial values of speed and power, however, the anaerobic capacity and skill increased only in the players from the power endurance group.

Training loads have an important effect on an athlete's performance and can be a determinant factor in achieving success. Therefore the ultimate goal of training modelling is to optimize

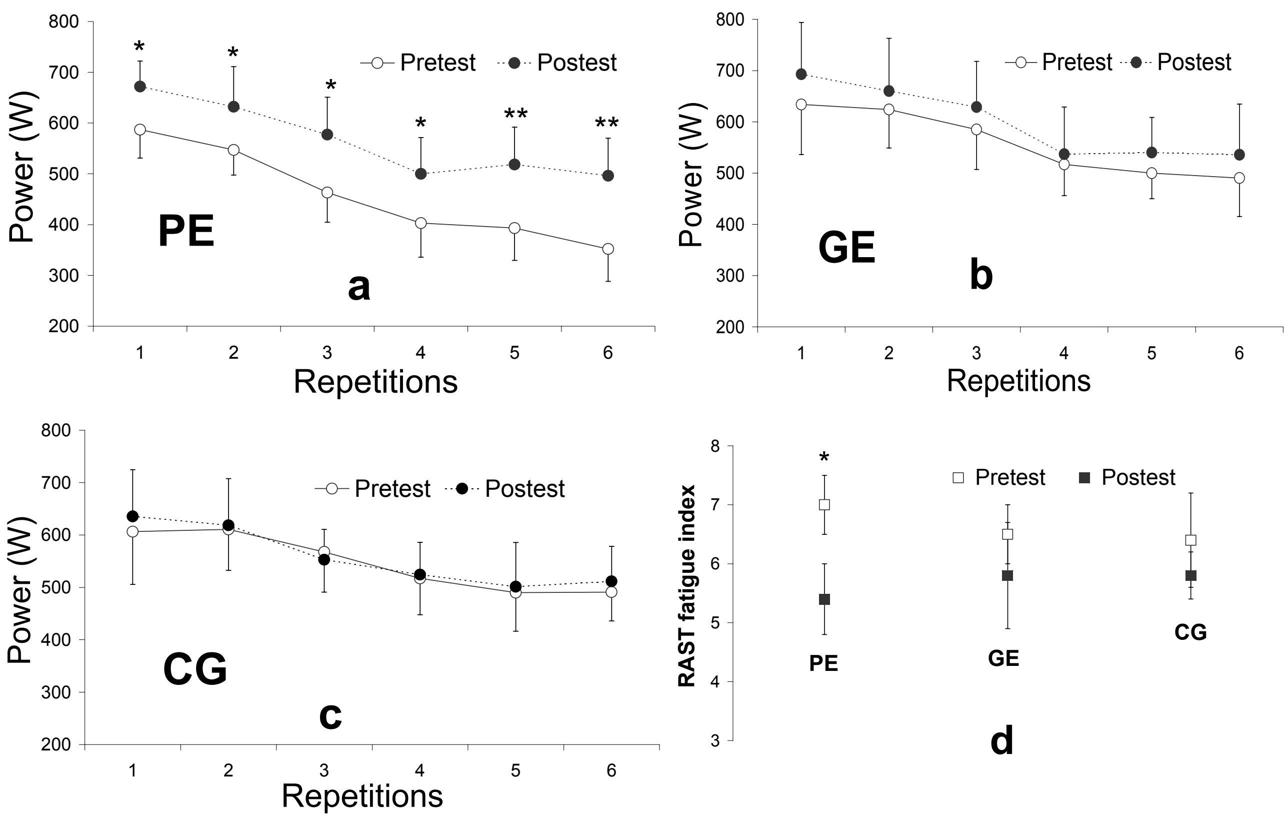


Figure 4. Changes in the RAST test for the different training modalities (a = power endurance – PE; b = general endurance – GE; c = control group – CG; d – fatigue index). *$p \leq 0.05$; ** $p \leq 0.001$.

performance (Kuipers, 1996; Taylor, 2003). Designing research-based basketball training protocols for young players is difficult, because there are no validated sport-specific measures to evaluate adolescent basketball-specific training. Additionally, our main concern was to identify the changes not in the preseason but in the competition period. This way coaches could also have a precise idea on how the players adapt to this training model along with the strong loads imposed by competitions.

Therefore, our results seem to place an emphasis on the importance of simulating physiological requirements, while at the same time honouring the external structure of a basketball game. From an overall analysis, it is clear that the 4 months of training modelling have produced different adaptations on players' physical fitness. Our data support the notion that the anaerobic capacity and probably game performance were most likely result of the performed training models, with PE showing significant improvements, whereas no improvements were detected in the GE and or in the CG. Also, it is probable that subjects from PE could be less fatigued throughout the competitions, and could show a better level of fitness throughout the season (Hoffman et al., 2000). Our overall results demonstrate that PE training model not only better exemplifies the external structure of basketball but also develops the aerobic and anaerobic component of the players. In fact, the metabolic requirements of the basketball game are both aerobic and anaerobic (Giliam, 1985; Stone and Steingard, 1993). Despite the role that each one of these energy systems plays is not completely understood, it is however consensual that the primary energy system used in the anaerobic metabolism (Hoffman and Maresh, 2000; Hoffman et al., 2000).

The statistically significant differences obtained in the RAST test and in the Shuttle ball-dribbling test are the main focus of our results. These tests identified differences in anaerobic capacity because training modelling in PE was based on basketball game external structure and simulation of game intensity through heart rate. The same did not happen in GE or in CG, i.e., players submitted to general endurance training and regular basketball training failed to improve results in the performed anaerobic capacity tests. In fact, evidence supports that extensive aerobic training decreases power endurance performance when interfering with gains in lean muscle mass, strength and power (Dudley and Fleck, 1987; Hickson, 1980; Taylor, 2004). From our results, the greatest differences between general endurance and power endurance training effects were noticed during the 5th and 6th runs of the RAST test.

Anaerobic performance is mainly determined by fibre type proportion and glycolytic enzyme capacity of skeletal muscle which are very influenced by genetic factors, however there is always a training potential to be considered. The anaerobic trainability increases with age (from childhood to adulthood with greater increases during puberty) and also with the increase in glycolytic enzyme activity (particularly phosphofructokinase) triggered by training (Fournier et al., 1982). Abrantes et al. (2004) compared the repeated sprint ability on six different groups of football players and verified that sub-16 young players were already able to perform very close to professional senior players, confirming the high trainability of anaerobic pathways for energy turnover at these ages.

On the other hand, it could be argued that 16 weeks of training modelling based on power endurance could have a diminished effect on power or speed performance. Our results, however did not detect any changes in these performances. Additionally, PE speed results (2.96-3.02 s, $p > 0.05$) correspond to very good results, when comparing them with results from elite basketball players' (Brittenham, 1996).

The results of this study should be viewed in the context of the analysed sample (very experienced junior basketball players). Further research on the chronic effects of power endurance training in younger players is needed. However, the implementation of a basketball specific intermittent, high-intensity exercise program (power endurance) during the competitive season appears to be beneficial to prepare junior players according to the game cardiovascular and metabolic specific determinants. In fact, this type of training seems to be better suited for basketball players because it exactly simulates the external structure of the sport and because extrinsic motivation is enhanced during PE practice.

CONCLUSIONS

Our results suggest that both training modalities were able to maintain initial values of speed and power, however, the anaerobic capacity and skill increased only in the players from the power endurance group. Therefore, the power endurance training (intermittent high intensity exercise) may be more beneficial to prepare junior players according to the game cardiovascular and metabolic specific determinants.

REFERENCES

Abrantes, C., Maçãs, V. and Sampaio, J. (2004) Variation in football players' sprint test performance across different ages and levels of competition. *Journal of Sports Science and Medicine* **3** (YISI 1), 44-49.

Apostolidis, N., Nassis, G., Bolatoglou, T. and Geladas, N. (2003) Physiological and technical characteristics of elite young basketball players. *Journal of Sports Medicine & Physical Fitness* **43,** 157-163.

Bosco, C., Luhtanen, P. and Komi. P. (1983) A simple method for measurement of mechanical power in jumping. *European Journal Applied Physiology Occupational Physiology* **50,** 273-82.

Brittenham, G. (1996) *Complete Conditioning for Basketball*. Human Kinetics, Champaign.

Dudley, G. and Fleck, S. (1987) Strength and endurance training: are they mutually exclusive? *Sports Medicine* **4**, 79-85.

Fournier, M., Ricci, J., Taylor, A., Ferguson, R., Monpetit, R. and Chaitman, B. (1982) Skeletal muscle adaptation in adolescent boys: sprint and endurance training and detraining. *Medicine and Science for Sports and Exercise* **14**, 453-456.

Gillam, G (1985) Physiological basis of basketball bioenergetics. *NSCA Journal* **6**, 44-71.

Hickson, R. (1980) Interference of strength development by simultaneously training for strength and endurance. *European Journal Applied Physiology* **56***,* 255-263.

Hoffman, J. and Maresh, C. (2000) Physiology of basketball. In: *Exercise and Sport Science.* Ed: Garrett, W. and Kirkendall, D. Philadelphia, Lippincott, Williams and Wilkins. 733-744.

Hoffman, J., Epstein, S., Einbinder, M. and Weinstein, Y. (2000) A Comparison between the Wingate anaerobic power test to both vertical jump and line drill tests in basketball players. *Journal of Strength and Conditioning Research* **3**, 261-264.

Janeira, M. and Maia, J. (1998) Game intensity in basketball. An interactionist view linking time-motion analysis, lactate concentration and heart rate. *Coaching & Sport Science* **2**, 26-30.

Kuipers, H. (1996) How much is too much? Performance aspects of overtraining. *Research Quarterly for Exercise and Sport* **67**, 65-69.

McInnes, S., Carlson, J., Jones, C. and McKenna, M. (1995) The physiological loads imposed on basketball players during competition. *Journal of Sports Sciences* **5**, 387-397.

Sampaio, J., Ibáñez, S. and Feu, S. (2004) Discriminative power of basketball game-related statistics by level of competition and sex. *Perceptual and Motor Skills* **99**, 1231-1238.

Siegler, J., Gaskill, S. and Ruby, B. (2003) Changes evaluated in soccer-specific power endurance either with or without a 10-week, in-season, intermittent, high-intensity training protocol. *Journal of Strength and Conditioning Research* **2**, 379-387.

Stone, W. and Steingard, P. (1993) Year- round conditioning for basketball. *Clinics in Sport Medicine* **2**, 173-191.
Taylor, J. (2003) Basketball: applying time motion data to conditioning. *Strength and Conditioning Journal* **2**, 57-64.
Taylor, J. (2004) A tactical metabolic training model for collegiate basketball. *Strength and Conditioning Journal* **5**, 22-29.
Thomas, R. (2000) A conditioning program to increase vertical jump. *Strength and Conditioning Journal* **2**, 7-11.
Trinic, S., Markovic, G. and Heimer, S. (2001) Effects of developmental training of basketball cadets realised in the competitive period. *Collegium Antropologicum* **2**, 591-604.
Zacharogiannis, E., Paradisis, G. and Tziortzis, S. (2004) An evaluation of tests of anaerobic power and capacity. *Medicine & Science in Sports & Exercise* **36** (suppl. 5)**,** S116.

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KEY POINTS

- Power endurance training produced significant increases in anaerobic capacity during the competition period.
- Power endurance training did not have a detrimental effect on power or speed performance during the competition period.
- The greatest differences between general endurance and power endurance training were noticed during the 5th and 6th runs of the RAST test.

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