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Review article

EXPLOSIVE POWER IN BASKETBALL PLAYERS

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Abstract. *Explosive power in basketball is manifested through various variants of jumps, starting acceleration, sudden changes in direction, deceleration, sudden stops and passing. The aim of this research is to identify and sum up the relevant literature published in the period from 2000 to 2019, focusing on the explosive power of basketball players, and to explain relations between training programs and explosive power development. The results confirmed that explosive power is a significant characteristic of professional basketball players and one of the most important factors for achieving top results. The results show that in spite of the inborn coefficient, the development of explosive power can be realized through planned, rational and well-organized training. A positive correlation was determined between explosive power and running at short distances, jumps and throwing, as well as between explosive power and lean body mass in basketball players of different ages. It is necessary to give greater attention to the training of explosive power, because it is an effective means that contributes to the efficiency of the basketball player.*

Key words: *Basketball, Explosive strength, Vertical Jump, Speed, Agility*

INTRODUCTION

Basketball is a high-intensity team sport with alternative phrases of high load, and success in basketball requires technical, tactical and physical preparation. In basketball, explosive power is manifested through various variants of jumps, starting acceleration, sudden changes in direction of movement, deceleration, sudden stops and passing. Knowing the explosive power of basketball players of different ages is in direct relation with the effects of training, and it also makes the choice of methods easier for the coach, along with the process of planning and programming (Aksović & Berić, 2017). In the first place, explosive power depends of the number of active motor units, genetic conditionality makes

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up about 80% and it is defined as the ability of an athlete to produce the highest possible force in the shortest possible time (Zatsiorsky & Kraemer, 2009).

Numerous examples of research of the explosive power of basketball players of different ages are found around the world (Maffiuletti et al., 2000; Santos & Janeira, 2008; Khlifa et al., 2010; Santos & Janeira, 2011, 2012; Kocić, Berić, Radovanović, & Simović, 2012; Snyder et al., 2018; Arede, Vaz, Franceschi, Gonzalo-Skok, & Leite, 2018). In sports such as basketball, explosive power is one of the most significant factors for achieving great sports results (McBride, Triplett-McBride, Davie, & Newton, 2002; Carlock et al., 2004; Latorre Román, Villar Macias, & García Pinillos, 2018; Hernández et al., 2018). The reason for that is today's basketball demands require players with highly developed motor abilities. For one half of time the player jumps about 16-17 times, and when we count it, we get 35 times during the whole match (Narazaki, Berg, Stergiou, & Chen, 2009). Köklü, Alemdaroğlu, Ünver Koçak, Erol, & Findikoğlu (2011) discovered the differences between the lower extremities of basketball players from Turkish I and II leagues and they showed huge differences in their performances which depended of their playing position on the team. The basketball players who belong to the category of younger players (10-12 years old), train to develop explosive power in different ways, through different ways of moving, through the play, and in this way the body makes itself more resistant, and explosive power is developed in short sprints. Young basketball players (13-14 years old) can be influenced the most in terms of explosive power development with minimal outside loads. In later ages (15-16 years old) the outside load possibilities increase (Pavlović, 2007). It is also familiar that growth and the maturing process among men have a positive effect on developing explosive power. Explosive power in that period is positively related with chronological age, constitution and variation in body weight (Bosco, 1994).

During the last few years, trainers have recognized the significance of explosive power such as the sprint, since in the past they were convinced that the speed of running is genetically conditioned and that it cannot be improved by training (Moreno, 1994). Today, genetics are considered as one of the factors for determining the maximal speed of the potential athlete. Zhang (2013) examined explosive power, running speed on short distances, strength resistance, and pointed out the positive effect on the explosive power of the lower extremities and endurance in general. Thus, it is necessary that this type of endurance training be specially designed for young basketball players and increase the development of explosive power which is a very important factor for reaching top sports results (Ademović, Kocić, Berić, & Daskaloski, 2015). Thus, it is routine training which should be given the certain time interval for explosive power development, especially during the preliminaries (Pauletto, 1994).

The aim of this research is to identify and sum up the relevant literature published in the period from 2000 to 2019 which focused on the explosive power of basketball players, and to explain the relations between training programs and explosive power development.

METHODS

The database sources and the research strategy

The electronic search of papers was done in the next databases: PubMed, ScienceDirect and Google Scholar. The researched papers were published on the SCI list in the period

between 2000 and 2019. The search was conducted by a combination of terms, which are first of all related to the area of explosive power among the players. In order to get papers related to this topic, the search was limited on certain keywords: “explosive power”, “explosive strength”, “basketball players”, “plyometric training”, “resistance training”, and “training”.

The descriptive method was used to analyze the obtained data. All the titles and abstracts were reviewed for the potential papers which could be included in the systematic review. The lists of previous and original studies were also reviewed. Relevant papers were obtained when they met the criteria for = inclusion, after a detailed search. Whereever = possible, the strategy of the search was modified and adapted to each database with the aim of increasing the sensitivity of the research.

A systematic review of the papers is shown according to methodological instruction and in accordance with the consensus of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses-PRISMA (Moher, Liberati, Tetzlaff, & Altman, 2009).

The criteria for inclusion

Type of study:

Randomized controlled and non-randomized studies were examined and included in further analysis, while uncontrolled studies were excluded. Papers that were published in English and Serbian were included in the study.

The sample of participants:

Professional basketball players, aged 13-28, without any acute or chronic diseases.

Type of intervention:

If the studies confirmed the effects of training they were included if the training program lasted four weeks or more.

The type of obtained results:

The primary result to be included in the systematic review was explosive power. The secondary results consisted of motor abilities in correlation with explosive power, the concentration of lactate, body composition, fatigue before and after training of explosive power, and VO2max in correlation with explosive power.

Criteria for exclusion

The type of study: 1) studies in which the participants suffered from some acute or chronic disease; 2) studies written in a language other than English or Serbian; 3) studies without a control group or experimental group; 4) duplicates; 5) studies involving a program with a duration of less than four weeks.

RESULTS

Initially, there was 63 prospective papers identified and six additional ones, according to their references. After deleting duplicates and after paper elimination due to their titles, the number of studies remaining was 34. These papers were examined in detail and 24 of them satisfied the given criteria to be included in the systematic review.

The total number of research participants from 24 of the papers included in the systematic review was 1186, and of this number 870 were male and 316 female. 18 studies (Maffiuletti et al., 2000; Trninić, Marković, & Heimer, 2001; Castagna et al., 2007; Santos & Janeira, 2008, 2011, 2012; Castagna, Chaouachi, Rampinini, Chamari, & Impellizzeri, 2009; Khlifa et al., 2010; Tsimahidis et al., 2010; Casartelli, Müller, & Maffiuletti, 2010; Zemková & Hamar, 2010; Shalfawi, Sabbah, Kailani, Tønnessen, & Enoksen, 2011; Stojanović, Ostojić, Calleja-González, Milosević, & Mikić, 2012; Marić, Katić, & Jeličić, 2013; te Wierike et al., 2014; Rodriguez-Rosell, Mora-Custodio, Franco-Márquez, Yáñez-García, & González-Badillo, 2016; Snyder et al., 2018; Gonzalo-Skok, Sánchez-Sabaté, Izquierdo-Lupón, & Sáez de Villarreal, 2019) included all male participans, five studies included female participans (Delextrat & Cohen, 2009; Erculj, Blas, & Bracic, 2010; Noyes, Barber-Westin, Smith, Campbell, & Garrison, 2012; Battaglia, Paoli, Bellafiore, Bianco, & Palma, 2014; Bouteraa, Negra, Shephard, & Chelly, 2018), and one of the studies included both male and female participants (Garatachea et al., 2014).

Three of the studies included not only basketball players as a sample, they also included volleyball (Battaglia et al., 2014), football players (Rodriguez-Rosell et al., 2016), and resistance-trained adult men (Snyder et al., 2018).

Twelve of the studies were aimed at determining the effects of training on the development of explosive power. The most common duration of the training program (in 5 studies) was 10 weeks (Santos & Janeira, 2008, 2011, 2012; Khlifa et al., 2010; Tsimahidis et al., 2010), and after that in three studies the program lasted for 6 weeks, (Zemková & Hamar, 2010; Noyes et al., 2012; Gonzalo-Skok et al., 2019), in two studies 8 weeks (Trninić et al., 2001; Bouteraa et al., 2018), in one study program duration four weeks (Maffiuletti et al., 2000), and one study aimed to determine the influence of three years of a sport-specific training background (SSTB) program (Battaglia et al., 2014).

Two studies aimed to determine the validity and reliability of measuring instruments for estimating explosive power (Casartelli et al., 2010; Rodriguez-Rosell et al., 2016).

Table 1 Systematic review of the studies dealing with the explosive power of basketball players

Ref.	Population	Sample (gender, number, groups, age, BH, BM, BE)	Measuring instruments	The aim of the research	Results
Maffiuletti et al. (2000)	Basketball players competing in division 2 of the French Basketball Federation	M: n=20, EXP: n=10, CON: n=10, Aged: 24.7±3.9 years, BH: 193.9±6.9 cm, BM: 87.8±8.9 kg, BE: 6-10 years	SJ, CMJ	To investigate the influence of a 4-week electromyostimulation training program on the strength of the knee extensors and the vertical jump performance of 10 basketball players	Isokinetic strength ↑ concentric and eccentric contraction speed. ET ↑↑ isometric strength at the two angles adjacent to the training angle, SJ ↑↑ 14% at week 4. CMJ NC

Trninić et al. (2001)	Cadet basketball players of the B.C. "Cibona"	M: n=12, Aged: 15.0-16.0 years, BE: 4-6 years	SAR, SIT, PUSH, FLEX, PULL, AG20, AN300	To determine the effects of the applied developmental training programme on some basic and specific motor-functional abilities of talented cadet basketball players during two months of the competitive season	At the multivariate level ↑↑ changes. Differences ↑↑ SAR, AG20, PUSH, SIT ↑ AN300, FLEX
Castagna et al. (2007)	Junior basketball players of the regional Italian Adriatica Junior Basket League	M: n=18, Aged: 16.8±1.2 years, BH: 181.3±5.7 cm, BM: 73±10 kg, BE: at least 5 years	Shuttle run sprints, basketball-specific repeated-sprint ability protocol consisting of ten 15-m shuttle run sprints with 30 s of passive recovery	To examine the effects of maximal aerobic power (VO2max peak) level on the ability to repeat sprints in young basketball players	Blood lactate concentrations before and after training 2.5±0.7, 13.6±3.1, and 14.2±3.5 mmol·L-1. A negative correlation between the first sprint and RSAFI. NC correlation between VO2max and RSAFI. VO2max is not a predictor of repeated-sprint ability
Santos & Janeira (2008)	Young basketball players	M: n=25, EXP: n=15, Aged: 14.7±0.5 years, BH: 175.9±9.3 cm, BM: 72.7±16.9 kg, BE: 5.6±2.6 years, CON: n=10, Aged: 14.2±0.4 years, BH: 173.2 ±7.6 cm, BM: 61.1±11.4 kg, BE: 4.03±1.2 years	SJ, CMJ, ABA, DJ, MBT, MP	To evaluate the effects of a complex training program, a combined practice of weight training and plyometrics on the explosive strength development of young basketball players	EXP ↑ SJ, CMJ, ABA, MBT. CON ↓ CMJ, ABA, MP ↑ MBT
Castagna et al. (2009)	Italian regional-level amateur basketball players	M: n=22, Senior: n=11, Aged: 24.5±3.5 years, BH: 192.2.3±8.82 cm, BM: 84.4±11.41 kg, Junior: n=11, Aged: 16.7±1.2 years, BH: 180.75±5.85 cm, BM: 69.25±5.85 kg	VO2max, fitness test (Yo-Yo) CMJ, SL	To examine the aerobic fitness and lower-limbs explosive power abilities of Italian regional-level amateur basketball players	VO2max in both groups CMJ, ABA, and MP ↑ The differences between seniors and juniors in CMJ, SL. NC between the groups on the fitness test (Yo-Yo)

Delextrat & Cohen (2009)	Basketball players of the English National League Division 2	F: n=30, Aged: 25.2±3.7 years, BH: 174.5±5.4 cm, BM: 68.2±.9 kg, BE: min 2 years, Divided into 3 groups: guards (positions 1 and 2), forwards (positions 3 and 4), and centers (position 5).	30-second Wingate Anaerobic test (WAnT), isokinetic testing of the knee extensors, 2 types of jump tests, a 20-m sprint, the agility T-test, a suicide run, and a basketball chest pass	To investigate the effect of playing position on strength, power, speed, and agility on the performances of women basketball players	Guards better than centers for the relative peak and mean power during the WAnT, relative peak torque of knee extensors, SLJ, suicide run, agility T-test. Guards have better performances than forwards in the suicide run test, forwards greater peak torque of the knee extensors compared to centers
Casartelli et al. (2010)	Healthy basketball players of the regional and national Swiss basketball championships	M: n=44, Aged: 15.3±3.8 years, BH: 178±18 cm, BM: 68±18 kg	SJ, CMJ, RJs	To verify the validity and reliability of the Myotest accelerometric system (Myotest SA, Sion, Switzerland) for the assessment of vertical jump height	The Myotest-T is a valid and reliable method for the assessment of vertical jump height, and its use is legitimate for field-based evaluations, whereas the Myotest-V is neither valid nor reliable
Erčulj et al. (2010)	Young elite European basketball players	F: n=65, Aged: 14.49±0.61 years, BH: 172.6±8.0 cm, BM: 62.24±7.3 kg, BE: 5.9±1.9 years	CMJ, DJ 25cm, DJCT, sprint 20 m, sprint dribble 20 m, 6 x 5 m sprint, 6 x 5 m sprint dribble, BBT, MBT	To determine and analyze the level of certain motor abilities (acceleration and agility, the explosive strength of the arms, and take-off power) of young elite European female basketball players	The division of basketball had better results than A and B division. Differences in the tests: 6 x 5 m sprint dribble, MBT, 20 m sprint
Shalfawi et al. (2011)	Professional basketball players	M: n=33, Aged: 27.4±3.3 years, BH: 192.5±8.2 cm, BM: 89.8±.11.1 kg, BE: min 2 years	SJ, CMJ, 10 m, 20 m, 40 m sprint	To examine the relationship between vertical jump measures and sprint speed over 10, 20, and 40 m among professional basketball players	Positive correlation SJ, CMJ ↑ to running performance 10 m, 20 m, 40 m. NC correlation jumping performance peak powers and reactive strength running speed

Khlifa et al. (2010)	Tunisian First Professional Division basketball players	M: n=27, EXP1: n=9, EXP2: n=9, CON: n=9, Aged: 23.61±0.96 years, BE: 12.4±3.5 years	SJ, CMJ, 5JT	To examine the effect of a standard plyometric training protocol with (EXP1) or without added load (EXP2) in improving vertical jumping ability in male basketball players	SJ, CMJ, 5JT LPG ↑↑ PG ↑
Tsimahidis et al. (2010)	Junior basketball players	M: n=26, EXP: n=13, Aged: 18.0±1.2 years, BH: 183.0±1.3 cm, BM: 80.9±10.2 kg, BE: 5.2±2.1 years, CON: n=13, Aged: 18.0±0.7 years, BH: 186.0.2±6.1 cm, BM: 82.0±5.3 kg, BE: 6.1±1.4 years	5 sets of 8-5 (RM), SJ, DJ, CMJ, sprint 10 m, 30 m	To investigate the effect of a 10-week heavy resistance combined with a running training program on the strength, running speed (RS), and vertical jump performance of young basketball players	EXP ↑ RM, SJ, DJ, CMJ, sprint 10 m, 30 m. CON, NC. CTP is beneficial for strength, RS, and jump height. At the final measuring there were differences between groups for all the variables
Zemková & Hamar (2010)	Elite basketball players	M: n=34, EXP: n=17, CON: n=17	Agility, balance (wobble board with eyes open and eyes closed), speed of step initiation, strength differentiation accuracy, and explosive power (10-seconds maximal jumps CMJ, SJ, DJ)	To evaluate the effect of 6-week combined agility-balance training on neuromuscular performance in basketball players	Combined agility-balance training ↑ dynamic balance visual control, eyes closed conditions, run-out speed, reduced ground contact time during DJ, and improved ability to differentiate the force of muscle contraction during repeated jumps. Balance exercises ↑ neuromuscular performance CON, NC
Santos & Janeira (2011)	Young basketball players	M: n=24, EXP: n=14, Aged: 15.0±0.5 years, BH: 172.9±6.3 cm, BM: 62.6±9.9 kg, BE: 7.07±2.8 years, CON: n=10, Aged: 14.5±0.4 years, BH: 173.2±7.6 cm, BM: 61.1±11.4 kg, BE: 4.03±1.2 years	SJ, CMJ, ABA, DJ, MBT, MP	To determine the effects of (a) plyometric training on explosive strength indicators in adolescent male basketball players and (b) detraining and reduced training on previously achieved explosive strength gains	EXP ↑ SJ, CMJ, ABA, DJ, MBT, MP. Detraining and a reduced training program indistinctly contribute to maintenance of strength levels

Santos & Janeira (2012)	Adolescent basketball players	M: n=25, EXP: n=15, Aged: 14.5±0.6 years, BH: 172.7±8.1 cm, BM: 61.6±8 kg, BE: 5.0±2.4 years, CON: n=10, Aged: 14.2±0.4 years, BH: 173.2±7.6 cm, BM: 61.1±11.4 kg, BE: 4.3±1.2 years	SJ, CMJ, ABA, DJ, MBT	To assess the effects of a lower- and upper-body 10-week in-season resistance training program on explosive strength development in young basketball players	EXP ↑ SJ, CMJ, ABA, DJ and MBT. CON ↓ CMJ, ABA, DJ and MBT. Groups similar on the pretest, but significant differences occurred on the posttest in all the variables
Noyes et al. (2012)	High school basketball players	F: n=57, Aged: 14.0-17.0 years, BH: 170.0±6.7 cm, BM: 60.7±10.1 kg, BMI: 20.3±3.4, BE: 5.2±2.1 years	DJ, multistage fitness test, VJ, 18 m sprint	To determine if a sports-specific training program could improve neuromuscular and performance indices in female high school basketball players	VO2max, DJ, VJ ↑↑ NC 18 m sprint
Stojanović et al. (2012)	Elite basketball players	M: n=24, Aged: 22.2±3.4 years, BH: 197.1±6.2 cm, BM: 95.7±8.8 kg, BE: 11.0±3.1 years	CMJ, and incremental pseudo-ramp test protocol with measured CMJ height and VO2max, RSA (RSAFI, RSAtot)	To examine the relationship between explosive strength and aerobic power with basketball specific repeated sprint ability in elite male basketball players	↓↓ performance for the sprint at 30 m occurred after eight sprint No significant correlation between RSA and VO2max. strong inverse correlation between CMJ height and RSA
Marić et al. (2013)	Cadet basketball players from Herzegovina members of the five first-league clubs	M: n=83, Aged: 13-15 years, BH: 174.8 cm, BM: 63.6 kg, BMI: 20.81, BE: 2-4 years	3 tests for the evaluation of explosive strength (SBJ, sprint to 20 m from a low starting point, MBT), 9 tests for evaluation: coordination, speed, flexibility, repetitive strength, static strength, precision, and five tests for evaluation of specific motor skills	To determine whether there is a correlation between motor and specific motor skills	The impact of basic motor abilities of precision and balance on specific abilities of passing and shooting precision and ball handling underlies the second linear combination. Ball handling has the largest impact on player quality in basketball cadets followed by shooting precision and passing precision

te Wierike et al. (2014)	Dutch Basketball Academy elite players	M: n=48, EXP: n=32, Aged: 16.0±1.7 years, CON: n=16, Aged: 16.1±1.8 years, BE: 6.4±2.1 years	SST for RSA, the VJ for lower body explosive strength (power), and the ISRT for interval endurance capacity, body composition was estimated (PF, LBM)	To determine whether repeated sprints affect the development of explosive strength and body composition in elite basketball players	Age, lower body, explosive strength, and interval endurance contributed to RSA. Explosive strength of the lower extremities ↑ RSA with age. NC between groups, the positive correlation LBM and explosive strength of the lower extremities
Garatachea et al. (2014)	Elite basketball players of the Spanish league	M, F: n=383, EXP: n=100 (60 male, 40 female), CON: n=283 nonathletic (216 male, 67 female), Aged: n.d., BH: n.d., BM: n.d., BMI: n.d., BE: n.d.	SJ, CMJ	To determine the association of the ACTN3 R577X polymorphism with leg-muscle explosive power in Spanish elite basketball players	NC between groups, ACTN3 R577X polymorphism. NC influenced the explosive power of the players
Battaglia et al. (2014)	Young basketball and volleyball players	F: n=31, Basketball players: n=10, Aged: 15.60±1.34 years, BMI: 22.67±3.13, Volleyball players: n=10, Aged: 14.50±0.97 years, BMI: 22.17±1.87, CON: n=11, Aged: 15.00±0.52 years, BMI: 21.10±2.09	SJ, CMJ, CMJ-AS, SCPT, SBOMBT	To evaluate the influence of 3 years of sport-specific training background (SSTB) on the vertical jump and throwing performance in young female basketball and volleyball players	SJ, CMJ, CMJ-AS, Volleyballers group showed a higher vertical jump performance than basketballers and CON. Voleyballers ↑ flight time and jump height SJ, CMJ, CMJ-AS. Basketballers and volleyballers better results in the SCPT, SBOMBT compared to the CON group. The correlation between the ↑↑ CMJ-AS, SBOMBT in the 3 groups

Rodriguez-Rosell et al. (2016)	Basketball and soccer players of 3 different age categories	M: n=186, Basketball players: n=59, in 3 different age categories (>15 years, <15 years, and adults), Soccer players: n=127, in 3 different age categories (>15 years, <15 years, and adults)	20 m sprint, CMJ, ABA, 2-LEGS, 1-LEG	To analyze the reliability and validity of 2 standardized (CMJ, ABA) and 2 sport-specific (2-LEGS, 1-LEG take-off jump) vertical jump tests, and their usefulness as predictors of sprint and strength performance for soccer and basketball players in 3 different categories	CMJ, ABA high intraclass correlation coefficients and low coefficients of variation, 1-LEG lowest absolute and relative reliability. 1-LEG lowest associations with sprint and strength performance. CMJ and ABA are the most reliable tests for the estimation of explosive force in soccer and basketball players
Snyder et al. (2018)	Resistance-trained adult men and adolescent basketball players	M: n=20, Resistance-trained adult men: n=10, Aged: 22.6±1.6 years, BH: 180±10cm, BM: 85.7±8.6 kg, Adolescent basketball players: n=10, Aged: 16.5±0.7 years, BH: 178±0.7 cm, BM: 69.5±9.1 kg	CMJ, DJ	To compare different methods for assessing plyometric ability during the countermovement (CMJ) and drop jumps (DJ) in a group of adults and adolescents.	Adults jumped ↑ adolescents, CT decreased from CMJ to DJ. WNORM, PONORM durin g CMJ were less during RSI ↑ CMJ to DJ, plyometric indices decreased significantly. RSIMOD, RSI contributed significantly to the prediction of JH during CMJ and DJ. PWI was able to explain ≥68% of the variance in JH.
Bouteraa et al. (2018)	Adolescent basketball players of the regional level	F: n=26, EXP: n=16, Aged: 16.4±0.5 years, CON: n=10, Aged: 16.5±0.5 years	SJ, CMJ, DJ, 5, 10 and 20-m sprints, SBT, YBT, MICODT	To examine the effect of 8 weeks combined balance and plyometric training on the physical fitness of female adolescent basketball players	NC differences in SJ and CMJ. EXP ↑↑ DJ. NC differences SBT, YBT significant group interaction. EXP ↑ MICODT

Gonzalo-Skok et al. (2019)	Young basketball players	M: n=20, EXP1: n=10, EXP2: n=10, Aged: 13.2±0.7 years, BH: 172.9±7.9 cm, BM: 59.5±12.7 kg	LST,VJ, HJ, V-cut and 5+5 m with a 180°COD test, an ankle dorsiflexion test and dynamic balance tests	To compare the influence of a combined jumping direction and force application (horizontal-unilateral vs. vertical-bilateral) plyometric training on linear sprinting, jumping, change of direction and dynamic balance in young elite basketball players.	Within-group differences in unilateral VJ, HJ, V-cut test and posterior-lateral direction with the right leg. EXP1 ↑ LST, posterior-lateral direction with the left leg. EXP2 ↑ anterior direction with the left leg. Between group ↑ 10-m, V-cut test in EXP1 than in EXP2.

Legend: M-Males; F-Females; EXP-Experimental group; CON-Control group; BH-Body height; BM-Body mass; BE-Basketball experience; VJ-Vertical jump; HJ-Horizontal Jump; SJ-Squat jump; ET-Electromyostimulation training; CMJ-Counter movement jump; CMJ-AS-Counter movement jump with arm swing; DJ-Depth jump; DJ25CM-Drop jump 25 cm; DJCT-Drop jump contact time; SSTB-Sport-specific training background; SL-Stiff-leg jumps; SLJ-Single-leg jump; WAnT-Wingate anaerobic test; ABA-Abalakov test; SBJ-Standing broad jump; 5JT-5 jump test; SAR-Standing vertical jump with arms swing; MP-Mechanical power; PF-Percent fat; LBM-Lean body mass; BBT-Seated basketball ball throw; MBT-Seated medicine ball throw; SST-Shuttle sprint test; ISRT-Interval shuttle run test; SCPT-Seated chest pass throw; SBOMBT-Seated backward overhead ball throw; RSA-Repeated sprint ability; RSA_{tot}-Repeated sprint ability-summation of 10 sprint times; RM-Repetition maximum; RSA_{FI}-Repeated Sprint Ability-fatigue index; RJs-Repeated jumps; SIT-Sit-ups in 60 seconds; PUSH-Push-ups; FLEX-Sit-and-reach; PULL-Overgrip pull-ups; AG20-20-yard drill; AN300-300 yard shuttle run; VO2max-Maximal oxygen uptake; W_{NORM}-Normalized work; PO_{NORM}-Power output; PWI-Propulsion work; CT-Contact time; SBT-Stork Balance Test; YBT-Y-Balance Test; MICODT-Modified Illinois Change of Direction Test; COD-Change of direction; LST- Linear sprinting test; NC-No statistically significant changes $p>0.05$; ↑-Statistically significant increase $p<0.05$; ↑↑-Statistically significant increase $p<0.01$; ↓-Statistically significant decrease $p<0.05$; ↓↓-Statistically significant decrease $p<0.01$.

DISCUSSION

This research was aimed at analyzing and processing the explosive power of basketball players of different ages. It encompassed studies on the effects of programs of explosive power performed through jumps, throws and sprints, that lasted for about four weeks and more (Maffiuletti et al., 2000; Trninić et al., 2001; Santos & Janeira, 2008, Khlifa et al., 2010; Tsimahidis et al., 2010; Zemková & Hamar, 2010; Santos & Janeira, 2011, 2012; Noyes et al., 2012; Battaglia et al., 2014; Bouteraa et al., 2018; Gonzalo-Skok et al., 2019) and showed that despite the high coefficient, which is congenital, explosive power can be developed through good organized training which should be conducted methodically, rationally and in a well-organized manner.

Among the basketball players plyometric training alone and in combination with other methods is recommended as a primary means in the training process (Aksović, Berić, Kocić, Jakovljević, & Milanović, 2019) with the goal to develop explosive power (Santos & Janeira, 2011; Snyder et al., 2018; Gonzalo-Skok et al., 2019). Gonzalo-Skok et al. (2019) showed that 6-weeks of combined jumping and force oriented plyometric training leads to statistically significant improvement in explosive power, linear sprinting, change of direction speed and dynamic balance among young basketball players. Similar results

were obtained among female basketball players. Bouteraa et al. (2018) show that the addition of the 8-weeks of balance and plyometric training to regular in-season basketball training is a safe and feasible intervention that enhances the vertical jump height, balance, and agility in female adolescent basketball players. Also, the effect of complex and resistance training was confirmed in the study of Santos & Janeira (2008, 2012).

The results of this study stress that explosive power is the most significant characteristic of professional basketball players, and the most important factor in achieving top sports results. One basketball match consists of 46±12 jumps per one player (Mclennes, Carlson, & McKenna, 1995) which indicates the significance of explosive power. Explosive power in basketball is manifested through different jumps, start acceleration and the change of direction, deceleration, and passing of the ball. It is why it represents a very attractive field for research (Castagna et al., 2009; Casartelli et al., 2010; Battaglia et al., 2014). Several studies show the significant differences in jumps height between the basketball players of different levels of competition (Hoare, 2000; Delextrat & Cohen, 2009). They show that the best players on the team have a tendency to jump more than others. The research shows that if the player plays the whole match he runs over about 6000-7000 m, and makes 40 different jumps, 280 changes in direction, 120 ball catches, and 80 ball passes. For this reason Stojanović et al. (2012) point out that coaches should spend more time on explosive power development in elite basketball players, since it has a huge influence on their competitive success.

The research points to a positive correlation of jumps and throws (the three most commons ways of giving a ball to others are from the chests, above head and baseball transferring) among basketball players of different ages (Santos & Janeira, 2011; Battaglia et al., 2014). By using a medicine ball, the development of explosive strength of the upper extremities could be increased (Gambetta, 1986). The positive correlation is determined between the explosive power and running on short distances (Stojanović et al., 2012; te Wierike et al., 2014). However, Shalfawi et al. (2011) concluded that there is no relation between vertical jump height and short sprint time that are considered the most important predictors for success in basketball. Zemková & Hamar (2010) indicate that a combined 6-week training has a positive effect on agility, balance, running speed, and muscle strength increase during the execution of vertical jumps.

Delextrat & Cohen (2009) in their study aimed to examine the role of the team's position on strength, power, speed and agility. They determined that guards are better than centers at performing the Wingate Anaerobic test, Single-leg jump, agility T-test, and suicide run test. On the other hand, guards are better than forwards at performing the suicide run test, and forwards are better than centers in isokinetic testing of the knee extensors.

It should be announced that during the performance of the mentioned tests some injuries can occur and it is proven that the frequency of injuries depends of the player's position on the team. The most common players with injuries are shooting guards (47.8%), centers (34.7%), and point guards (17.4%). Age, height, body mass and the training time represent the risk factors for the shooting guards, while for point guards the biggest risk factor is body mass. Except this, individual characteristics and training may be related to the risk factors of the player's position 1, 2, 3, 4, 5 (guards, forwards, and centers) and the body mass is the risk factor for the players in all positions (Vanderlei et al., 2013).

The sttudy of Casartelli et al. (2010) confirmed the validity and reliability of the Myotest-T flight time, i.e., accelerometric system measuring instrument for evaluating explosive

power (Myotest SA, Sion, Switzerland). However, the hand test Myotest-V (vertical takeoff velocity) is not considered as a valid and reliable one. The counter movement jump and Abakalov test (CMJ, ABA) are reliable for evaluating the explosive power of basketball and football players (Rodriguez-Rosell et al., 2016). It should also be announced that the volleyball players obtain better results in performing vertical jumps when comparing basketball players and a control group (Battaglia et al., 2014). No significant correlation between VO_{2max} and repeated sprint ability was found, and can be explained by the lack of phosphocreatine that is fundamental in the performance maintenance in repeated 6s sprinting and $VO_{2max.}$ Additionally, a strong inverse correlation between Countermovement jump height and repeated sprint ability was found. Improvements in repeated sprint ability could be expected after prolonged explosive strength training (Stojanović et al., 2012). Wierike et al. (2014) determined a moderate but positive correlation of the repeated sprint ability and explosive strength of the lower body (r=.35), a moderate but positive correlation of explosive power with lean body mass (r=0.44), and a small but positive correlation between repeated sprint ability and lean body mass (r=0.23) in adolescent basketball players. According to them, repeated sprint ability is significantly influenced by explosive strength and age (improved between 14-17 years at the level $p \leq 0.05$ and reached a plateau at 17–19 years).

CONCLUSION

The results of this study confirmed previous findings that explosive power is a significant characteristic of basketball players and that it is one of the most important factors for achieving top sports results. In spite of the inborn coefficient, the development of explosive power can be realized through planned, rational and well-organized training. A positive correlation between explosive power and running on short distances, jumps and throwing was determined, as well as between explosive power and lean body mass in basketball players of different ages. Motor test performance depends on playing positions on the team and can lead to injuries. It is necessary to give high attention to the training of explosive power, because it is an effective means that contributes to the efficiency of the basketball player.

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EKSPLOZIVNA SNAGA KOŠARKAŠA

Eksplozivna snaga u košarci manifestuje se kroz različite varijante skokova, startnog ubrzanja, naglih promena pravca, usporavanja, naglih zastoja i dodavanja. Cilj ovog istraživanja je da se identifikuje i sumira relevantna literatura objavljena u periodu od 2000. do 2019. godine, usredsređena na eksplozivnu snagu košarkaša i da se objasni odnos između programa treninga i razvoja eksplozivne snage. Rezultati su potvrdili da je eksplozivna snaga značajna karakteristika profesionalnih košarkaša i jedan od najvažnijih faktora za postizanje vrhunskih rezultata. Rezultati pokazuju da se uprkos koeficijentu urođenosti razvoj eksplozivne snage može realizovati planiranim, racionalnim i dobro organizovanim treninzima. Utvrđena je pozitivna povezanost između eksplozivne snage i trčanja na kratke razdaljine, skokova i bacanja, kao i između eksplozivne snage i bezmasnog tkiva košarkaša različitih starosti. Potrebno je posvetiti veliku pažnju treningu eksplozivne snage, jer je to efikasno sredstvo koje doprinosi efikasnosti košarkaša.

Ključne reči*: košarka, eksplozivna snaga, vertikalni skok, brzina, agilnost*