Profiling in Basketball

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Profiling in Basketball: Physical and Physiological Characteristics of Elite Players

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Abstract. Ostojic, S.M., S. Mazic, and N. Dikic. Profiling in basketball: Physical and physiological characteristics of elite players. *J. Strength Cond. Res. 20(4):740–744. 2006.*—The purpose of this study was to describe structural and functional characteristics of elite Serbian basketball players and to evaluate whether players in different positional roles have different physical and physiological profiles. Five men's basketball teams participated in the study and competed in the professional First National League. Physiological measurements were taken of 60 players during the final week of their preparatory training for competition. According to positional roles, players were categorized as guards ($n = 20$), forwards ($n = 20$), and centers ($n = 20$). Guards were older ($p < 0.01$) and more experienced ($p < 0.01$) as compared with both forwards and centers. Centers were taller and heavier than guards and forwards ($p < 0.01$), whereas forwards had significantly higher height and weight than guards ($p < 0.01$). Centers had more body fat ($p < 0.01$) as compared with forwards and guards. Also, centers had significantly lower estimated $\dot{V}O_2max$ values ($p < 0.01$) compared with forwards and guards. In addition, the highest heart rate frequencies during the last minute of the shuttle run test were lower in guards ($p < 0.01$) as compared with forwards and centers. Vertical jump power was significantly higher in centers ($p < 0.01$) as compared with guards. The results of the present study demonstrate that a strong relationship exists between body composition, aerobic fitness, anaerobic power, and positional roles in elite basketball.

Key Words. body composition, $\dot{V}O_2max$, muscle fiber types

Introduction

Basketball is one of the world's most popular court games, being played in almost every nation without exception. However, basketball in the United States is considered by many to be at the level that most countries strive to reach; many teams try to adopt the U.S. style of play with specific physiological requirements of the athlete and original athlete training programs. In the last 2 decades, there has been a significant accumulation of scientific data regarding basketball physiology and medicine (3, 7, 10, 19, 21, 26). Previous investigations have evaluated ideal physiological and anthropometric profiles of successful basketball players (mostly from North America), although there is a lack of descriptive data concerning characteristics of elite basketball players from Europe, particularly Serbia. Yet during the last 30 years, Serbian basketball players and coaches, along with U.S. players, have established a well-known and successful style of play. The Serbian (Yugoslav) National Team won the European Cup in 1999 and 2001 and the World Championship in 2002. The physique of the basketball players may be one of the essential factors that have contributed to the success of Serbian national basketball teams in international competition (18). Aspects such as experience, body composition, endurance, balance between anaerobic power and aerobic power, among other factors, are of primary importance in evaluating elite players (8, 20). However, it is difficult to find specific physiological and anthropometric correlates of success. The purpose of this study was to describe structural and functional characteristics of elite Serbian basketball players and to evaluate whether players in different positional roles have different physical and physiological profiles. Understanding the profile of successful players could give coaches, trainers, and exercise scientists better working knowledge of this particular group of athletes.

Methods

Experimental Approach to the Problem

Five men's basketball teams participated in the study. All of the teams in the study competed in the professional First National League, which consists of 10 basketball squads and won 5 first places in the 2002/2003 season. Eight players were members of National Olympic team and 7 players went on to play in the U.S. National Basketball Association (NBA) league in the following seasons. All of the subjects gave their informed consent and volunteered to participate in the study, which had the approval of the Academy's Ethical Advisory Commission. All participants were fully informed verbally and in writing about the nature and demands of the study, as well as the known health risks. They completed a health history questionnaire and were informed that they could withdraw from the study at any time, even after giving their written consent.

Subjects

Physiological measurements were taken of 60 players during the final week of their preparatory training for competition. According to positional roles, players were categorized as guards ($n = 20$), forwards ($n = 20$), and centers ($n = 20$). All subjects were assessed on the same day, and the tests were performed in the same order. Seven days before the experiment, all subjects consumed the same diet (55% of the calories were derived from carbohydrate, 25% from fat, and 20% from protein), and the last meal was undertaken 3 hours before the test. After that period, all subjects drank only plain water as necessary. In the 24 hours before the experiment, the subjects did not participate in any prolonged exercise.

Design

Subjects reported to the examination field at 10 AM after an overnight rest of 10–12 hours. Upon entering the lab-

Table 1. Characteristics of elite Serbian basketball players.*

Variable	Guards (n = 20)	Forwards (n = 20)	Centers (n = 20)	Total (n = 60)	Range
Age (y)	25.6 ± 3.2‡§	21.4 ± 2.8	23.2 ± 3.2	23.4 ± 3.5	16.8–32.4
Professional experience (y)	9.6 ± 3.2‡§	5.0 ± 2.7	7.1 ± 3.3	7.2 ± 3.6	2.1–13.8
Height (cm)	190.7 ± 6.0‡§	200.2 ± 3.4‖	207.6 ± 2.9	199.5 ± 8.2	180.3–220.5
Weight (kg)	88.6 ± 8.1‡§	95.7 ± 7.1‖	105.1 ± 11.5	96.5 ± 11.2	75.6–121.2
Body fat (%)	9.9 ± 3.1§	10.1 ± 3.2‖	14.4 ± 5.6	11.5 ± 4.6	3.1–20.4
Hemoglobin (mmol·L^{-1})	131.7 ± 10.9	132.3 ± 10.4	132.1 ± 10.7	132.0 ± 10.7	119.2–145.7
Hematocrit (%)	0.41 ± 0.03	0.41 ± 0.04	0.41 ± 0.04	0.41 ± 0.04	0.39–0.44
Forced vital capacity (L)	6.5 ± 0.8	6.6 ± 1.0	6.6 ± 0.9	6.6 ± 0.9	5.5–7.6
Forced expiratory volume in 1 s (L)	5.4 ± 1.1	5.7 ± 0.9	5.8 ± 1.1	5.6 ± 1.0	4.9–6.8
Estimated $\dot{V}O_2$max (ml·kg^{-1}·min^{-1})	52.5 ± 4.8§	50.7 ± 2.3‖	46.3 ± 4.9	49.8 ± 4.9	41.3–63.9
HRmax (b·min^{-1})	193 ± 2‡§	196 ± 5	195 ± 3	195 ± 3	186–208
Vertical jump height (cm)	59.7 ± 9.6	57.8 ± 6.5	54.6 ± 6.9	57.4 ± 7.7	31.1–89.6
Vertical jump power (W)	1,484.9 ± 200.0§	1,578.6 ± 137.5	1,683.0 ± 191.7	1,582.1 ± 193.6	1,256.1–1,889.5
Fast twitch† (%)	65.1 ± 10.2	64.7 ± 8.9	62.4 ± 9.1	64.1 ± 9.4	45.2–79.5

* Values are expressed as mean ± *SD*; HRmax = maximal heart rate obtained in the last minute of shuttle run test; $\dot{V}O_2$max = maximal oxygen uptake.
† Estimated percentage of muscle fiber types (fast twitch) of leg extensor muscles.
‡ Statistically significant at $p < 0.01$ for guards vs. forwards.
§ Statistically significant at $p < 0.01$ for guards vs. centers.
‖ Statistically significant at $p < 0.01$ for forwards vs. centers.

oratory, hemoglobin (Hb), hematocrit (Hct), and lung function were measured for normative data comparisons. Blood was drawn from a fingertip and was analyzed immediately for Hct and Hb determination by the procedures of microcentrifugation (Hawksley Ltd., Lancing, UK) and cyanometHb (Boehringer Mannheim GmbH test combination, Mannheim, Germany), respectively. Lung function expressed as forced vital capacity (FVC) and forced expiratory volume in 1 second (FEV_1) was determined using a flow screen (Jaeger, Hoechberg, Germany). Body mass was obtained to the nearest 0.1 kg using a balance beam scale (Model 3306 ABV; Avery, Ltd., Birmingham, UK), whereas height was measured using a stadiometer (Holtain Ltd., Crymych, UK) to the nearest 0.5 cm. Skinfold thicknesses at 7 sites were obtained using a Harpenden caliper (British Indicators Ltd., St. Albans, UK). The skinfold sites were triceps, subscapula, midaxillary, anterior suprailiac, chest, abdomen, and thigh. The landmarks were identified and were measured according to Wilmore and Behnke (27) with the median of 3 measurements used to represent skinfold thickness. Measurements were done by the same trained technician on all subjects. Body density and the percentage of fat were determined according to athlete-specific equation of Jackson and Pollock (12).

When these preliminary measurements were finished, subjects completed a warm-up (15 minutes of sprints and individual exercise). Vertical jump height and percentage of muscle fiber types of leg extensor muscles were estimated using a force platform (Newtest Powertimer Testing System, Oulu, Finland). All subjects had a preparatory bounce before measurement; the computer, which was connected to the platform, calculated jump height from the time the subject was off the mat. The calculation of jump height assumed that the takeoff and landing positions of the body's center of gravity were the same. Subjects were instructed to keep the trunk as straight as possible and to try to land on the platform on the same spot and with the same body position as during takeoff (i.e., trunk and legs straight). Subjects were asked to keep hands on the hips to prevent arms from contributing to the jump. These instructions were successful in minimizing computation errors. Vertical jump height was normalized to standing height and body mass. Vertical jump power was calculated using the original formula (17). Percentage of muscle fiber types of leg extensor muscles was estimated from vertical jump height with specifically developed software according to Viitasalo and Komi (23) (correlation coefficient $r = 0.5$, $p < 0.01$).

Afterward, maximal oxygen uptake ($\dot{V}O_2$max) was indirectly obtained using a multi-stage 20-m shuttle run test (15). Heart rate (HR) was determined during the test, using short-range radio telemetry (Polar Sporttester, Polar Electro Oy, Kempele, Finland), and the highest HR during the last minute of the shuttle run test was recorded as HRmax. The athletes were familiar with these procedures as part of their regular training process.

Statistical Analyses

The data are expressed as mean ± *SD*. Statistical analysis was performed using Student's t-test with Bonferroni correction for repeated comparisons. Relationship between subjects' physique (height and weight) and body fat, estimated $\dot{V}O_2$max and vertical jump were examined using Pearson product-moment correlation coefficients. p values ≤ 0.01 were considered to be statistically significant. The data were analyzed using SPSS (version 7.5; SPSS, Inc., Chicago, IL).

Results

All results are shown in Table 1. Guards were older ($p < 0.01$) and more experienced ($p < 0.01$) than both forwards and centers were. Centers were taller and heavier than guards and forwards ($p < 0.01$), whereas forwards were taller and heavier than guards ($p < 0.01$). Centers had more body fat ($p < 0.01$) as compared with forwards and guards. Values for Hb, Hct, FVC, and FEV_1 were not significantly different among positions. Centers also had significantly lower estimated $\dot{V}O_2$max values ($p < 0.01$) compared with forwards and guards. In addition, the highest HR frequencies during the last minute of the shuttle run test were lower in guards ($p < 0.01$) than in forwards and centers. Average vertical jump height was not statistically different between different positional roles, although vertical jump power was significantly higher in centers ($p < 0.01$) than in guards. Estimated percentage of fast muscle fibers (fast twitch) was similar in all positional roles.

Positive correlation was found between weight and body fat ($r = 0.92$, $p < 0.01$) and height and body fat ($r = 0.85$, $p < 0.01$) during the study. Moreover, strong negative correlation was found between weight and vertical jump ($r = -0.99$, $p < 0.01$), weight, and estimated $\dot{V}O_2max$ ($r = -0.99$, $p < 0.01$), height and vertical jump ($r = -0.98$, $p < 0.01$), and height and estimated $\dot{V}O_2max$ ($r = -0.95$, $p < 0.01$). When we analyzed the intraclass correlation, we found no significant relationships between variables for guards ($p > 0.05$). Moreover, for centers and forwards, we found no significant relationships between most variables ($p > 0.05$) except for a significant positive correlation between weight and body fat ($r = 0.80$ for centers, $r = 0.61$ for forwards $p < 0.01$).

DISCUSSION

To our knowledge, this study has provided the most comprehensive comparison between different positional roles in top-level basketball players to date. As expected, the present study indicated that a strong relationship exists between body composition, aerobic fitness, anaerobic power, and positional roles in elite basketball.

The biographical profile of basketball players can be characterized by the heterogeneity expressed within teams, between players' competitive levels, and across nationalities (3, 10, 25). However, in modern sport, particularly basketball, professional experience and mature tactical judgment have become important factors of performance excellence (18). The average age of top Serbian players is 23.4 ± 3.5 years, which is in agreement with previous investigations (16, 19). Yet, in the present study, we found that guard players were older and had significantly higher professional experience than those in other positional roles. Today, professional players do seem prepared to stay in the game for longer than was traditional. This is probably due to fact that professional level of game-play requires competent and well-versed players and commercial attractions of maintaining players' careers as long as possible. The fact that the guards are the oldest and most experienced players may be related to the specific requirements of the position, and its unique tasks during the game (e.g., play-making, commanding, assisting) could play a role in these differences. Yet, the correlation between age and learning effects, skills, and abilities requires more investigation.

Unique types of body size and proportion may constitute important prerequisites for successful participation in basketball. Recent research on elite male basketball players has illustrated the development of the trend toward an increase in height and the variation in height and weight for positional play in basketball (14, 18, 26). Previous studies of physical and physiological characteristics of male basketball players are summarized in Table 2. In our study, we found that centers are significantly taller and heavier than guards and forwards are. On the one hand, because the game involves physical contact with the intention of getting the ball in a basket elevated 3.05 m above the ground level, physical attributes of centers could help them to dominate in a low-post position,

TABLE 2. Physical and physiological characteristics of male basketball players.*

Investigator	Population	N	Height (cm)	Weight (kg)	Body fat (%)	VJ (cm)	$\dot{V}O_2max$ (ml·kg^{-1}·min^{-1})
Parr et al., 1978 (19)	NBA league	34	C: 214.0 ± 5.2 F: 200.6 ± 5.0 G: 188.0 ± 10.3	C: 109.2 ± 13.8 F: 96.9 ± 7.3 G: 83.6 ± 6.3	7.1–13.5	— — —	C: 41.9 ± 4.9 F: 45.9 ± 4.3 G: 50.0 ± 5.4
Soares et al., 1986 (21)	Brazilian National	21	C: 206.6 ± 4.1 F: 196.9 ± 4.6 G: 185.4 ± 8.6	C: 102.1 ± 17.6 F: 92.0 ± 6.9 G: 79.3 ± 7.3	— — —	C: 55.9 ± 8.1 F: 66.8 ± 8.3 G: 61.6 ± 8.5	C: 59.7 ± 6.9 F: 59.9 ± 5.1 G: 74.4 ± 6.8
Hoffman et al., 1991 (9)	NCAA Division I	9	196.4 ± 11.9	89.0 ± 11.3	—	64.3 ± 7.9	—
Latin et al., 1994 (14)	NCAA Division I	437	C: 205.5 ± 6.1 F: 198.4 ± 3.8 G: 187.4 ± 5.8	101.9 ± 9.7 95.1 ± 8.3 82.9 ± 6.8	C: 11.2 ± 4.5 F: 9.7 ± 3.9 G: 8.4 ± 3.0	C: 66.8 ± 10.7 F: 71.4 ± 10.4 G: 73.4 ± 9.6	C: 55.0 F: 56.0 G: 56.0
Tavino et al., 1995 (22)	NCAA Division I	9	—	87.7 ± 6.7	9.8 ± 1.9	—	65.2 ± 6.2
Hoffman et al., 1996 (10)	NCAA Division I	29	197.9 ± 8.1	91.9 ± 10.1	—	67.3 ± 6.0	—
Caterisano et al., 1997 (4)	NCAA Division I	9	—	92.2 ± 8.2	5.9 ± 3.1	—	53.0 ± 4.7
Hoffman et al., 1999 (11)	Israeli National	20	194.2 ± 6.0	88.4 ± 8.0	12.9 ± 3.1	—	50.2 ± 3.8

* From studies by Hoffman et al. (1991) and Tavino et al. (1995), we included variables from preseason phase/group. From a study by Hoffman et al. (1996), we included variables from season 1991/1992 and from Caterisano et al. (1997), only characteristics of starters. VJ = vertical jump; $\dot{V}O_2max$ = maximal oxygen uptake; C = centers, F = forwards, G = guards; NBA = National Basketball Association; NCAA = National Collegiate Athletic Association.

which involves box-outs, picks, and rebounding. The shorter the center, the higher he has to jump in order to play successfully in this aerial zone. On the other hand, the playmakers (guards) with the lower mass, height, and body fat percentage are the most skillful players and are used to set up attacks that are sometimes completed by the taller players. Data on height, body mass, and body composition from other studies of basketball teams suggest that players vary widely in body size (7, 10). Thus, these parameters are not essential factors for success in basketball; moreover, they might determine the playing positional role. A particular body size may be an advantage in certain match play situations, but disadvantage in others.

A question concerning whether to characterize basketball as an aerobic or anaerobic sport has been a subject of debate. Most investigators classify basketball as a sport relying on the adenosine triphosphate-phosphocreatine system and on the lactic acid system (1, 9). The aerobic system is one of the secondary sources of energy provision during basketball match play and the average values of $\dot{V}O_2max$ for elite basketball players tend to be relatively low as compared with endurance athletes, supporting the above statement (4, 16). However, although $\dot{V}O_2max$ values may be influenced by differences in standards of play, training regimes, and the phase of the season, a team with superior aerobic fitness would have the advantage, being able to play the game at a faster pace. A higher level of endurance capacity (higher $\dot{V}O_2max$, lower HRmax) will give guard players a better base for on-field performance regarding intensity and demands of basketball match play. This is probably a consequence of the style of play undertaken by guard players who had the highest work rate. The estimated maximal oxygen uptake of the Serbian players was about 50 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$, which is in general agreement with previous data from other elite basketball players. It appears that Serbian players generally fall toward the center of the continuum of maximal oxygen consumption of elite basketball players from different countries.

It has been suggested by a number of investigators that success in basketball appears to be more dependent upon the athlete's anaerobic power, rather than on aerobic power and capacity (11, 19). The vertical jump height itself is a good measure of specific muscular performance (anaerobic power). For vertical jump heights, we found similar results between different positional roles, whereas vertical jump power was significantly higher in centers than in guard players. We also found strong negative correlation between subjects' physique and vertical jump. Latin et al. (14) proposed that a higher level of anaerobic and strength parameters would be preferable and would reduce the risk for injuries and would allow for more powerful rebounds, shooting, and shuffling, among other factors. It would be reasonable to expect the elite basketball player to have values higher than 60 cm, according to the recent findings (24). However, several authors have reported that the mean vertical jump in male basketball players was more than 70 cm and vertical jump power was more than 1,700 W (11, 16). Moreover, significant differences were seen between positions with significantly higher jumps from guards and forwards than from centers. The problem with making comparisons of vertical jump data from various literature sources may be related to the methods of testing employed, different testing protocols, and the phase of the season. Moreover, performance of basketball players in the vertical jump test tends to highlight influences of training stage and the specific plyometric training program employed, which requires more investigation.

In many respects, muscle performance characteristics of basketball players are determined by their distribution of different fiber types: fast twitch and slow twitch. A basketball player demands an ability to sustain physical effort, mostly discontinuous, over 40 minutes, some of which is at high intensity. Because the activity profile is compatible with both slow and fast twitch muscle fiber characteristics, a combination of muscle fiber types (with predominance of fast twitch) would be expected in elite players (1, 6). In the present study, we found a significantly higher percentage of estimated fast twitch muscle fibers in elite players, which is in accordance with previous investigations (3, 13). However, estimated percentage of fast muscle fibers was similar in all positional roles. However, any conclusions about fitness level, muscle fiber type, and elite basketball play may be incomplete. Method of assessment, as well as the nature and intensity of training, are among the factors that can influence measurement of fiber type distribution and amount.

Values for Hb, Hct, FVC, and FEV_1 in the present study were within the normal range of the male population and the between-position values were not significantly different from results reported in other studies of basketball players (2, 5).

The dominance of the Serbian basketball teams in international competitions is probably not due to players' superior physical and physiological parameters, because measured parameters were in general agreement with previous data from elite basketball players from other countries. Because basketball comprises a variety of individual and collective skills that are executed in the context of competitive match play, ideal physique and physiology is not sufficient for excellence in basketball (14). It is highly possible that other components of basketball (e.g., technique, tactics, strategy of the coach) play a key role in the final sport result, which requires further investigation. The success of the basketball team depends on how different individuals blend to become an effective playing unit. The coach could decide to alter the team's style of play according to the physical condition of the players, opponent, or the circumstances of a game. These strategic differences in playing style could have a large impact on the physiological requirements of the basketball player and an athlete's training regime (8).

More research must be done before definitive inference can be made; however, the results of the present study demonstrated the relationship between aerobic and anaerobic power and positional roles in basketball. Certain qualities are prerequisite and an advantage for playing basketball on the elite level, according to positional role. Profiling may be useful in player selection and development of sport-specific training programs, because some variables cannot be affected by conditioning (e.g., body size and proportion) and others are quite trainable (e.g., endurance capacity, anaerobic power). Being a top-level basketball player is a complex function of genetics endowment, training, and health status (e.g., injury, diet, drugs), as well as psychological, sociological, and other capabilities.

PRACTICAL APPLICATIONS

The results of this study show there are differences in physical and physiological characteristics in different positional roles of elite basketball players. Consequently, the athletes in various positional roles are inherently different, train differently, or both. The demands of the different positional roles appear to be unique, and thus training, as well as recruiting, should reflect the differences. Coaches can use this information to determine what type of profile is needed for specific positions and to design training programs to maximize fitness development in their athletes and to achieve success in basketball.

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