Upper and Lower Body Power Are Strong Predictors for Selection of Male Junior National Volleyball Team Players

Athanasios Tsoukos,[1] Sotirios Drikos,[1] Lee E. Brown,[2] Konstantinos Sotiropoulos,[3] Panagiotis Veligekas,[1] and Gregory C. Bogdanis[1]

[1]*School of Physical Education and Sports Science, National and Kapodistrian University of Athens, Athens, Greece;* [2]*Human Performance Laboratory, California State University, Fullerton, Fullerton, California; and* [3]*School of Physical Education and Sport Science, Democritus University of Thrace, Komotini, Greece*

Abstract

Tsoukos, A, Drikos, S, Brown, LE, Sotiropoulos, K, Veligekas, P, and Bogdanis, GC. Upper and lower body power are strong predictors for selection of male junior National volleyball team players. *J Strength Cond Res* 33(10): 2760–2767, 2019—The purpose of this study was to determine whether a battery of anthropometric and lower and upper body strength and speed and power tests predicted selection of young volleyball players for a Junior National Team by expert coaches. Fifty-two male junior volleyball players (14.8 ± 0.5 years, height: 1.84 ± 0.05 m, body mass: 72.5 ± 7.1 kg) took part in a training camp and underwent a selection procedure by expert coaches' of the junior national team. Anthropometric data and fitness tests results were obtained and players were graded on a scale from 0 to 100 on the basis of their performance in a volleyball tournament. Selected players were superior in the majority of measured variables ($p \leq 0.017$) and had higher grading scores compared with nonselected players (85.3 ± 4.1 vs. 70.5 ± 5.6, respectively, $p < 0.01$). The combination of spike jump and reach (SJR) test and 3-kg medicine ball throw (MB3) velocity explained 63.5% of the variance in expert coaches' grading ($p < 0.001$). A multivariate discriminant analysis yielded a significant discriminant function (Wilk's lambda = 0.55, $\chi^2 = 29.324$, $p < 0.001$, $\eta^2 = 0.82$). Spike jump and reach and MB3 were the only variables that contributed to the discriminant function (standardized function coefficients: SJR = 0.68, MB3 = 0.67). Cross-validation results showed that selection was correctly predicted in 14 of the 16 selected players (predictive accuracy: 87.5%) and in 32 of the 36 nonselected players (predictive accuracy: 88.9%). The SJR and MB3 fitness tests can predict a large portion of the variance of expert coaches' grading and successfully discriminate elite young male volleyball players for selection vs. nonselection for a junior national team. This result is very important as performance testing during a selection process may be reduced to only 2 measurements.

Key Words vertical jump, medicine ball throw, discriminant analysis, stepwise regression

Introduction

Volleyball is an intermittent team sport that requires high levels of technical skills as well as selected fitness and anthropometric parameters (7,15,17,23,24,26,34,36). During the game, players perform a variety of skilled actions such as serves, receptions, passes, spikes, short sprints, submaximal and maximal jumps, and high-speed movements with change of direction (9,34–36). Previous research has shown that anthropometric measurements (5), physical fitness (17,26), and specific technical parameters (7,19) can discriminate selected vs. nonselected players or starters vs. nonstarters. For example, Gabbett and Georgiev (5) showed that junior volleyball players are taller and leaner as playing level increases. Also, Smith et al. (26) found that vertical jump performance during spiking and blocking was greater in Canadian National volleyball players compared to the University Canadian Volleyball Team. In agreement with these findings, in a review concerning vertical jump in female and male volleyball players, Ziv and Lidor (36) noted that players of better-performing teams had higher vertical jump values. Taken collectively, these results highlight the importance of the combination of tall body structure and high leg power for success in volleyball. However, Milic et al. (17) noticed that the more successful female players had higher power output not only of the lower limbs but also the upper body. Moreover, there is evidence that sport-specific upper body power in volleyball, as indirectly assessed by measuring ball velocity during a spike, is higher in first-division than in second-division players (4). Considering the importance of body height and vertical jump and the potential significance of upper

Address correspondence to Dr. Athanasios Tsoukos, atsoukos@phed.uoa.gr.

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body power for volleyball success, it was hypothesized that these parameters may predict selection of young volleyball players by high-level coaches. From a practical point of view, the results of this study will provide information to national federations, sporting clubs, practitioners, and strength and conditioning coaches, regarding the importance of certain anthropometric and physical fitness parameters to the success of junior players. Thus, the purpose of this study was to determine whether a battery of anthropometric and lower and upper body strength and speed and power tests could predict selection of young male volleyball players for the Junior National Team by expert coaches.

Methods

Experimental Approach to the Problem

All young volleyball players took part in a 10-day training camp and underwent a selection procedure by expert coaches' of the junior national team. Four expert volleyball coaches, members of the national team staff responsible for team selection, graded the players on a scale of 0 to 100 on the basis of their performance in a volleyball tournament that was organized for this purpose. During the training camp, anthropometric measurements were taken, and players also performed a series of speed and power tests for the lower and upper body. The variables examined were body height and mass, standing reach height (SRH), sum of 4 skinfolds (SF), 10-m sprint time, 505 agility test, countermovement jump (CMJ), block jump and spike jump (SJ), maximum throwing velocity of balls of different weights, and hand-grip strength.

Multiple regression and discriminant analysis were used to identify the fitness and anthropometric test parameters that predict coaches' grading of the players and discriminate between selected and nonselected players for the National male Junior Team.

Subjects

Fifty-two male junior volleyball players (age: 14.8 ± 0.5 years [mean ± *SD*: age range: 14-16 years old], height: 1.84 ± 0.05 m, body mass: 72.5 ± 7.1 kg) took part. Subjects had a training background in volleyball of at least 3 years and were participating in local or national junior volleyball championships for at least 2 years. They were preselected by regional and national coaches' based on their volleyball performance. All athletes were free of musculoskeletal injuries for at least 1 year before the study, and none were taking any drugs or nutritional supplements. The subjects and their parents were informed in writing about the aim of the study and the possible risks involved and signed an informed consent form. The study was approved by the School of P.E. and Sport Science of the National and Kapodistrian University of Athens, and all procedures were in accordance with the Code of Ethics of the World Medical Association (Helsinki declaration of 1964, as revised in 2013).

Procedures

This study took place during a selection training camp in July (off-season). After the camp, the selected players composed the national team and took part in an international tournament.

Player Assessment and Selection Procedure. All athletes took part in a volleyball tournament and played a total of 12 sets each. The expert volleyball coaches' of the national team graded the players on a scale of 0 to 100 during their participation. The best 16 players, according to the averaged expert coaches' grading, were selected for the junior national team. The inter-rater reliability (ICC) of expert coaches' grading was 0.939 ($p < 0.001$).

Physical Fitness Assessment-Anthropometric Measurements. Anthropometric measurements were taken on the second day of the camp, following a light training session on day 1. Body height was measured to the nearest 0.1 cm using a stadiometer (Charder HM-200P Portstad, Charder Electronic Co Ltd, Taichung City, Taiwan). Body mass was measured to the nearest 0.1 kg by an electronic scale (TBF-300A Body Composition Analyzer-Tanita, Tanita Corporation, Tokyo, Japan), and adiposity was assessed by the sum of 4 skinfold thicknesses (biceps, triceps, subscapular, and suprailiac) using a Harpenden skinfold caliper (British Indicators Ltd., Herts, United Kingdom).

Familiarization and Standardized Warm-Up. Fitness tests were performed on the first 2 days of the training camp. All athletes had previously been evaluated with these tests and had been using them as part of their training and testing with their local teams. All performance tests took place between 18:00 and 21:00 hours following a standardized warm-up. The warm-up consisted of 10 minutes of light jogging on the court and 10 minutes of dynamic stretching of the lower and upper body muscles (32). After that, subjects performed a specific warm-up that included brief running and jumping drills and changes of direction (20). A light meal was consumed at 13:00, and water was consumed ad libitum before and during testing. Players also replicated their dietary intake 48 hours before each measurement session and were fully hydrated.

Testing Procedure. Following the standardized warm-up, handgrip strength (HG) of the dominant arm was measured followed by 3 minutes then the vertical jump tests (CMJ, block jump, and spike jump and reach [SJR]) were performed. A 3-minute rest also separated each vertical jump test. Five minutes after the evaluation of jumping ability, the 10-m sprint and the 505 agility tests were performed. Finally, after 5 minutes of rest, the ball-throwing test was performed using 3 balls of different weights.

Vertical Jump Tests. Countermovement jump and block jump performance were evaluated by an optical measurement system with a sampling frequency of 1,000 Hz (Optojump Next; Microgate, Bolzano, Italy) that measured flight time.

During the CMJ, athletes were asked to jump as high as possible with their arms akimbo, while maintaining the same body position during take-off and landing (33). Three jumps were performed with 45-second recovery in between, and the best performance was recorded. The ICC for CMJ measurement was 0.975 ($p < 0.001$).

Block jumps were performed in a defensive volleyball position as previously described (15,22,24). The athletes were instructed to position their hands in front of their chest. From that position, they flexed their knees to a self-selected squat and jumped as high as possible. The movement of the arms was the same that they used during a block during a game. Players tried to reach as high as possible with full arm extension (22). Three jumps were performed with 45-second recovery in between, and the best performance was recorded (ICC: 0.977, $p < 0.001$).

Spike jump and reach (offensive or attack jump; SJR) was evaluated using a Vertec device (Sports Imports, Hilliard, OH, USA). The athletes jumped vertically as high as possible, using a 3- to 4-step approach (15,21,24). Spike jump (SJ) height was calculated by subtracting the reach height when standing with the dominant arm extended from the jump height achieved (3,24). Three jumps were performed with 60-second recovery in between and the best performance was recorded. The ICC for SJR and SJ height assessment was 0.959 and 0.942, respectively ($p < 0.001$).

Hand-Grip Strength. The hand-grip strength test was measured with a hand-grip dynamometer (Takei Kiki Kogyo, Tokyo, Japan). The athletes were seated upright on a chair with their elbow flexed at 90° (8). They supported the weight of the dynamometer by positioning their arm on a table in a neutral position. They were instructed to hold the handle of the dynamometer with their dominant hand and squeeze as hard as possible for 5 seconds with 1-minute rest between each effort (8). Three trials were performed, and the best performance was recorded. The ICC for HG measurement was 0.98 ($p < 0.001$).

10-m Sprint Test. A telemetric timing system (Witty, Microgate) was used to measure the 10-m sprint time on the court. Cone markers were placed at the start and 5 m after the end line. Athletes stood 30 cm behind the first set of photocells with a staggered stance (11). The height of the photocells was 60 cm from the floor (11). Each athlete performed 2 sprint runs with 3 minutes of recovery, and the fastest performance was used for further analysis. The ICC for 10-m sprint measurement was 0.929 ($p < 0.001$).

505 Agility Test. Cone markers were placed at the start as well as, 10 and 15 m away from the starting line. A photogate (Witty, Microgate) was set laterally of the 10-m markers. The athletes ran as fast as possible from the starting line to the 15-m line. At the 15 m line, they changed direction (180° turn) and finished their effort at the 10-m line. The recorded time refers to the distance from the 10-m marker to the 15 m and back to the 10-m marker (a total of 10 m) (14). Each athlete performed 2 agility sprint runs with 3 minutes of recovery, and the fastest performance was used for further analysis. The ICC for 505 agility test assessment was 0.904 ($p < 0.001$).

Ball Throw Test. Upper body power was assessed by throwing balls of different weights: a volleyball (mass = 0.270 kg), a 1-kg medicine ball, and a 3-kg medicine ball (MB3) in randomized order. The maximum velocity of the ball was measured using a Doppler radar gun (Sports Radar 3300; Sports Electronics, Inc.). The radar gun had an accuracy of $\pm 0.028 \text{ m} \cdot \text{s}^{-1}$. The radar gun was set 1 m behind the athletes at ball height during the throw. The throws were performed in parallel with the ground, i.e., within a field of 10° from the level of the gun (31). Athletes were instructed to throw the ball as fast as possible with both arms over their head, aiming at a target on a net located 3 m away, at the same level as the ball. Athletes stood with their feet parallel to each other and did not leave the ground during the throw. No preliminary steps were allowed before the throw (30). Each player performed 3 attempts with each ball with 2-minute rest between each attempt. The order of the ball loads was randomized and balanced (29). The highest speed for each ball weight was used for further analysis (ICC: 0.934–0.973, $p < 0.001$).

The load-velocity (L-V) relationship was calculated using the peak velocity attained during throws with balls of different weights and the ball mass. V_0 and L_0 were calculated from the L-V relationship as the load and velocity y-intercepts, respectively (10). V_0 corresponds to the theoretical maximal velocity when the load is zero, whereas L_0 corresponds to the theoretical maximal load at zero velocity (10).

Statistical Analyses

Statistical analyses were carried out using SPSS (IBM SPSS Statistics Version 23). Differences between selected and nonselected players on all measurements were determined by independent *t*-tests. Relationships between variables were determined by the Pearson product-moment correlation coefficient. Test-retest reliability for all variables and inter-rater reliability were determined by the intraclass correlation coefficient (ICC) using a 2-way mixed model analysis of variance. Multiple regression analysis (stepwise method) was conducted to determine the best linear combination of anthropometric and fitness tests for predicting expert coaches' grading. A linear discriminant analysis (stepwise method) was conducted to determine which of the anthropometric and fitness tests distinguished selected from nonselected players. Proper scatter, normality, and box plots were used to check the assumptions of linearity, normality, and outliers. Box's M test was used to check the assumption of homogeneity of covariance matrices. Validation of the discriminant model was conducted using the "leave one

TABLE 1. Anthropometric and fitness variables for the whole group ($n = 52$) and the selected ($n = 16$) and nonselected ($n = 36$) junior volleyball players. Values are presented as mean ± *SD*.*

	Groups						
	All group ($n = 52$)	Selected ($n = 16$)	Non selected ($n = 36$)				
Variables	Mean ± *SD*	Mean ± *SD*	Mean ± *SD*	Difference Between groups	CI 90%	Cohen's *d*	*p*
Coaches' grading	75.0 ± 8.6	85.3 ± 4.1†	70.5 ± 5.6	14.8	12.2 to 17.4	2.90	0.001
Age (y)	14.8 ± 0.5	14.9 ± 0.5	14.7 ± 0.6	0.2	0.09 to 0.05	0.34	0.27
Body height (m)	1.84 ± 0.05	1.86 ± 0.04‡	1.83 ± 0.04	0.03	0.01 to 0.05	0.77	0.015
Body mass (kg)	72.5 ± 7.1	73.4 ± 5.6	72.2 ± 7.7	1.2	−2.27 to 4.75	0.18	0.56
SRH (m)	2.39 ± 0.06	2.42 ± 0.06‡	2.38 ± 0.05	0.0	0.02 to 0.07	0.80	0.012
SF (mm)	34.1 ± 10.5	30.2 ± 7.8	35.8 ± 11.2	−5.6	−11.28 to 0.06	−0.50	0.08
HG (kg)	42.3 ± 4.8	44.2 ± 5.2	41.5 ± 4.5	2.7	0.42 to 5.08	0.60	0.057
10 m (s)	1.86 ± 0.09	1.81 ± 0.06†	1.89 ± 0.09	−0.08	−0.12 to −0.03	−0.96	0.001
agility (s)	2.43 ± 0.14	2.35 ± 0.12†	2.47 ± 0.13	−0.12	−0.17 to −0.05	−0.88	0.001
CMJ (cm)	36.3 ± 4.8	38.6 ± 3.9‡	35.2 ± 4.8	3.4	1.13 to 5.64	0.76	0.017
BLJ (cm)	40.2 ± 5.5	43.3 ± 4.1†	38.8 ± 5.5	4.5	2.00 to 7.07	0.90	0.001
SJ (cm)	68.6 ± 7.5	73.1 ± 7.1†	66.6 ± 6.9	6.5	2.5 to 9.5	0.87	0.001
SJR (m)	3.08 ± 0.09	3.16 ± 0.08†	3.05 ± 0.07	0.11	0.07 to 0.15	1.47	0.001
VBT ($m\cdot s^{-1}$)	15.6 ± 1.4	16.5 ± 1.4†	15.2 ± 1.1	1.3	0.76 to 1.95	1.14	0.001
MB1 ($m\cdot s^{-1}$)	12.6 ± 1.1	13.5 ± 1.1†	12.2 ± 0.9	1.3	0.82 to 1.73	1.41	0.001
MB3 ($m\cdot s^{-1}$)	8.3 ± 1.0	9.1 ± 1.0†	8.0 ± 0.7	1.1	0.75 to 1.55	1.45	0.001
V_0 throw ($m\cdot s^{-1}$)	15.8 ± 1.4	16.8 ± 1.4†	15.4 ± 1.1	1.4	0.77 to 1.95	1.15	0.001
L_0 throw (kg)	6.1 ± 0.6	6.4 ± 0.6	6.0 ± 0.6	0.4	0.04 to 0.64	0.58	0.065

*CI = confidence interval; SRH = standing reach height; SF = sum of skinfolds; HG = handgrip strength; 10 m = 10-m sprint; agility = 505 agility test; CMJ = countermovement jump; BLJ = block jump; SJ = spike jump; SJR = spike jump and reach; VBT = volleyball throw; MB1 = 1 kg medicine ball throw; MB3 = 3-kg medicine ball throw; V_0 = maximum velocity; L_0 = maximum load.
†$p < 0.01$.
‡$p < 0.05$ significant difference from nonselected players.

out" classification with each case being classified by applying the classification function on all the data except the particular case. Data are presented as means and *SD*. Statistical significance was set a priori at $p \leq 0.05$.

RESULTS

The anthropometric and fitness tests data for the whole group as well as for the selected and nonselected athletes are presented in Table 1. Selected players differed from nonselected ($p \leq 0.017$) in all measured variables, except for age ($p = 0.27$), body mass ($p = 0.56$), sum of SF ($p = 0.08$), HG ($p = 0.057$), and L_0 ($p = 0.065$).

There were strong correlations between expert coaches' grading vs. SJR ($r = 0.716$, $p < 0.001$) and MB3 (0.603, $p < 0.001$) (Table 2). Also, there were moderate correlations between expert coaches' grading and several fitness tests results (0.341–0.526; $p < 0.05$) and anthropometric measurements (e.g., body height, $r = 0.458$; $p = 0.001$; SRH, $r = 0.459$; $p = 0.001$ and SF, $r = -0.403$; $p = 0.003$) (Table 2).

Stepwise regression analysis showed that SJR was the best predictor of the model and explained 51.2% of the variance of the expert coaches' grading (Table 3). The combination of SJR and MB3 explained 63.5% of expert coaches' grading. No other variable was entered into the analysis, which indicates that the most important variables to predict expert coaches' grading of the players were SJR test and MB3. The equations that were generated by the analysis were:

(1) Expert coaches' grading score $= -134.606 + 68.083 \times (\text{SJR})$

(2) Expert coaches' grading score $= -119.402 + 53.905 \times (\text{SJR}) + 3.422 \times (\text{MB3})$.

There were no missing values, extreme scores, or outliers in the data set (univariate and multivariate), and the basic statistical assumptions were tested and met. To ensure robustness and avoid multicollinearity, 5 of the 17 variables evaluated were entered in the discriminant analysis, as previously suggested (28). Each one of these 5 variables was chosen as the most representative of 1 of the 5 following different dimensions/abilities: anthropometrics (SRH), strength (HG), speed and agility (10-m sprint), upper body power (MB3), and lower body power (SJR). The variance-covariance matrices across

Table 2. Correlation matrix of anthropometric and fitness variables of young volleyball players.*

Variables	Coaches' grading	Age	Height	Mass	SRH	SF	HG	10 m	Agility	CMJ	BLJ	SJR	SJ	VBT	MB1	MB3
Age	0.179	1														
Height	0.458†	0.115	1													
Mass	0.034	0.241	0.371†	1												
SRH	0.459†	0.035	0.883†	0.408†	1											
SF	−0.403†	0.217	−0.126	0.649†	−0.165	1										
HG	0.259	0.123	0.237	0.389†	0.276‡	0.084	1									
10 m	−0.451†	−0.008	0.101	0.250	0.053	0.535†	−0.187	1								
agility	−0.420†	−0.110	−0.011	−0.065	−0.098	0.256	−0.277‡	0.411†	1							
CMJ	0.414†	0.051	−0.029	−0.278‡	−0.020	−0.478†	0.166	−0.526†	−0.412†	1						
BLJ	0.526†	0.067	0.065	−0.293‡	0.032	−0.521†	0.176	−0.516†	−0.410†	0.864†	1					
SJR	0.716†	0.152	0.584†	−0.004	0.567†	−0.535†	0.322‡	−0.499†	−0.394†	0.607†	0.634†	1				
SJ	0.499†	0.156	0.004	−0.329‡	−0.109	−0.515†	0.169	−0.644†	−0.398†	0.748†	0.739†	0.757†	1			
VBT	0.432†	0.019	0.022	0.163	0.087	−0.107	0.220	−0.369†	−0.017	0.073	0.033	0.161	0.125	1		
MB1	0.527†	0.024	0.170	0.230	0.248	−0.090	0.257	−0.359†	−0.066	0.129	0.130	0.308	0.174	0.915†	1	
MB3	0.603†	0.173	0.263	0.368†	0.335‡	−0.004	0.269	−0.282‡	−0.243	0.174	0.213	0.391†	0.206	0.677†	0.814†	1
V_0	0.432†	−0.004	0.039	0.154	0.107	−0.112	0.224	−0.371†	0.001	0.075	0.042	0.176	0.127	0.992†	0.941†	0.660†
L_0	0.341‡	0.173	0.331‡	0.329‡	0.363†	0.141	0.099	0.048	−0.291‡	0.136	0.223	0.336‡	0.118	−0.150	0.161	0.613†

*SRH = standing reach height; SF = sum of skinfolds; HG = handgrip strength; 10 m = 10-m sprint; agility = 505 agility test; CMJ = countermovement jump; BLJ = block jump; SJR = spike jump and reach; SJ = spike jump; VBT = volleyball throw; MB1 = 1 kg medicine ball throw; MB3 = 3-kg medicine ball throw; V_0 = maximal velocity; L_0 = maximal load.
†$p < 0.01$.
‡$p < 0.05$.

Table 3. Stepwise linear regression model summary for coaches' grading.*

Model summary					
Model	R	R^2	Adj.R^2	SEE	Sig.
1	0.716[a]	0.512	0.503	6.091	$p < 0.001$
2	0.797[b]	0.635	0.621	5.32	$p < 0.001$

*SEE: standard error of estimate.
[a]Predictors: (constant), spike jump reach.
[b]Predictors: (constant), spike jump reach, throw 3-kg medicine ball.

groups were homogeneous (Box's M = 7.411, $p = 0.072$). The discriminant analysis yielded a discriminant function (Wilk's lambda = 0.55, $\chi^2 = 29.324$, $p < 0.001$, $\eta^2 = 0.82$), which was able to discriminate the 2 groups (selected and nonselected). Spike jump and reach and MB3 were the only variables that contributed to the discriminant function, as shown by the standardized function coefficients (Table 4). Discriminant analysis produced 2 equations to predict selected and nonselected players for the junior National team:

(1) Selected players: Discriminant score = −887.051 + 537.995 × (SJR) + 8.268 × (MB3)
(2) Nonselected players: Discriminant score = −820.500 + 520.899 × (SJR) + 6.681 × (MB3).

Cross-validation results showed that selection was correctly predicted in 14 of the 16 selected players (predictive accuracy: 87.5%) and in 32 of the 36 nonselected players (predictive accuracy: 88.9%). In the whole group, the discriminant analysis correctly classified 46 of 52 players (predictive accuracy: 88.5%).

Table 4. Standardized function coefficients and correlation coefficients between fitness tests and the discriminant function.*

Variables	Standardized function coefficients	Correlations between variables and discriminant function
SJR	0.68	0.75
MB3	0.67	0.74
SRH	–	0.45
10 m	–	−0.29
HG	–	0.25

*SJR = spike jump and reach; MB3 = 3-kg medicine ball throw; SRH = standing reach height; 10 m = 10-m sprint; HG = handgrip strength.

Discussion

The main findings of this study were that vertical jump, reach height, and upper body power, as indicated by release velocity of a MB3, predicted expert coaches' player grading and successfully discriminated elite young male volleyball players as selected vs. nonselected for a junior national team.

The majority of previous research in volleyball has shown that vertical jump test results are indicative of the performance level of an athlete (5,12,18,26,36). Vertical jumping ability is a key element for success in the sport of volleyball as the game requires up to 250 jumps (for attacking and blocking) in a match of 5 sets (15,35). The players who were selected in this study showed higher vertical jump values than did players of the same age (6,7) and similar values compared with older high-level athletes (24,27). For example, in a study by Sheppard et al. (24), the developmental national team (age: 20.9 ± 2.6 years) had SJs of 69.1 ± 5.1 cm for setters, 72.4 ± 7.5 cm for middle blockers, and 76.4 ± 8.6 cm for outside hitters, which is similar to the results of selected players in this study (73.1 ± 7.1 cm). Furthermore, results from 11 athletes from the Brazilian national team, which was a World Champion team (age: 18.0 ± 0.5 years) showed a jump average of 70.7 ± 5.5 cm in the SJ after 1 week of training during a preparatory period to participate in the world championships (27). However, vertical jump height must be combined with body height, because volleyball players have to overcome the net's height (which is at 2.43 m for men) and the opponent's team block. Selected players in this study had significantly greater body height by 1.8% ($p = 0.015$) and SJR by 3.6% ($p = 0.001$) compared with nonselected, and this is in agreement with previous studies (5,24,27). Because SJR represents the combination of body height and jumping ability, it may be the most sport-specific fitness test variable in volleyball player selection and success (2,25). This may be one reason for the explanation of the high predictive ability of SJR for coaches' grading and its ability to discriminate between selected and nonselected elite players. Our results are in accordance with the findings of Smith et al. (26) who found that volleyball players of the National team of Canada had significant greater SJR (3.43 ± 0.06 m) values compared with University volleyball players (3.39 ± 0.06 m). Also, Palao et al. (18), who analyzed a sample of 1,440 male and 1,459 female volleyball players participating in Olympic games and world championships from 2000 to 2012, observed that SJR height differentiated first teams from last teams at this level of competition in female volleyball players. In addition, male athletes who competed in the position of "setter's opposite," which is the most requested attacker in volleyball (1), had higher SJR values on the first teams than in the last teams (18).

The results of this study are at odds with Gabbett et al. (7), who found that passing and serving discriminated between selected and nonselected players in a talent identification volleyball program. However, in that study, participants had limited volleyball experience and had participated in a wide range of sports (e.g., swimming, track and field, martial arts, mountain biking, tennis, netball, basketball, hockey, touch football, and rugby union) before being considered for selection for the talent search volleyball program. In contrast, the players in this study had a training background in volleyball of at least 3 years and were participating in local or national junior volleyball championships for at least 2 years. It is important to mention that the players in this study were preselected for the camp by regional and national coaches, based on their volleyball performance during a National talent identification program, and all players had a higher level of sport-specific fitness compared with those in the study of Gabbett et al. (7). For example, in this study, the mean value of the SJ in the selected group was 73.1 ± 7.1 cm, whereas in the study of Gabbett et al. (7), it was 50.7 ± 13.6 cm. Also, Melrose et al. (16) argued that age, experience, lean body mass, shoulder, hip, and thigh girths, strength, and balance were key physical performance characteristics of adolescent girls, whereas vertical jump performance was not considered important. The latter is in contrast with the findings of the present study, but it may be explained by the low level of the athletes who were members of a local volleyball club. Thus, it may be concluded that both fitness level and volleyball experience may modify the selection criteria for higher levels of participation. It seems that among less experienced players, the level of technical skills is decisive for selection, as shown in the study of Gabbett et al. (7), whereas at higher levels of experience, SJR and upper body power may explain a large part of the variance in coaches' grading and selection.

This study also highlights the importance of upper body power. Previous research has shown that medicine ball throw for distance discriminated youth (13–15 years) female volleyball players of different levels (17), whereas medicine ball throw performance did not differ between national, state, and novice male and female players (5) or selected vs. nonselected youth players (7). These discrepancies could be partially attributed to methodological issues. Most studies measured the distance of the medicine ball throw (5,7,17). It has been shown that the maximum distance of a projectile is dependent on release speed, height, and angle (13). Thus, the angle of throw, which depends on the technique, and the height of release, significantly influence throwing distance and may confound the evaluation of upper body power. A radar gun, as used in this study, measures the maximum velocity of release in a straight direction and may offer a more accurate evaluation of upper body power, irrespective of body dimensions and throwing technique.

A novel finding of this study is that lower and upper body power tests could predict 63.5% of the variance of the coaches' grading of the players. This result is very important for the selection of youth volleyball national teams because fitness testing may be reduced to only 2 measurements (i.e., SJR and MB3). A limitation of this study was that technical and cognitive characteristics were not evaluated. Rikberg and Raudsepp (19) found that selected 16- to 17-year-old elite Estonian volleyball players had greater passing and spiking techniques than nonselected players as well as cognitive characteristics. Therefore, the remaining 36.5% of unexplained variance in coaches' grading in this study could be attributed to technical and cognitive parameters.

In conclusion, vertical jump and reach height and release velocity of a 3-kg medicine ball can predict expert coaches' grading and successfully discriminate elite young male volleyball players as selected vs. nonselected for a junior national team. Vertical jump and reach height are associated with body height and lower body power. Use of a radar gun for the evaluation of upper body power may add to the accuracy of testing and thus be more appropriate for evaluating volleyball players, as performance is unaffected by the technique, especially in young athletes. The fact that 63.5% of the variance in coaches' grading was explained by SJR and upper body power highlights the importance of muscle power and body height for young volleyball player selection. However, a considerable portion of the remaining variance may be explained by technical, tactical, or cognitive skills that should be evaluated in future studies.

Practical Applications

The findings of this study have practical applications for national federations, sporting clubs, practitioners, and strength and conditioning coaches. The SJR and MB3 fitness tests can predict a large portion of the variance in expert coaches' grading and successfully discriminate elite young male volleyball players as selected vs. nonselected for a junior national team. This result is very important and relevant to efficiency because fitness testing during a selection process may be reduced to only 2 measurements (i.e., SJR and MB3). Strength and conditioning coaches without specialization in the sport of volleyball but with experience in fitness evaluation can use the equations presented in this study to successfully identify elite junior volleyball players.

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