



## Anthropometric and Motor Performance Variables are Decisive Factors for the Selection of Junior National Female Volleyball Players

by

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*This study examined whether anthropometric and fitness tests might successfully predict selection of young female volleyball players for a junior national team. Sixty four female players (age:  $14.4 \pm 0.5$  y, body height:  $1.76 \pm 0.05$  m, body mass:  $63.9 \pm 6.4$  kg) underwent a selection procedure for the junior national team. Anthropometric data and speed and power test results were obtained and players were graded for their performance in a volleyball tournament. Selected players differed from the non-qualified in body height (3.4%;  $p = 0.001$ ), standing reach height (2.6%;  $p = 0.001$ ), the sum of skinfolds (15.4%;  $p = 0.035$ ), body mass index (BMI; 7.1%;  $p = 0.005$ ) and spike jump and reach (SJR) (2.5%;  $p = 0.001$ ). Selected players were classified in the  $99.2 \pm 1.6$  percentile in body height and in the  $51.4 \pm 20.6$  percentile in the BMI, which were significantly different from those of the non-qualified players ( $95.4 \pm 7.0$  and  $66.7 \pm 18.6$ ,  $p = 0.02$  and  $p = 0.004$ , respectively). Stepwise discriminant analysis yielded a discriminant function ( $p < 0.001$ ,  $\eta^2 = 0.78$ ) that was highly loaded by height, SJR and the BMI ( $r = 0.79$ ,  $r = 0.74$  and  $r = -0.53$ , respectively). Cross validation results showed that selection was correctly predicted in 15 out of the 20 selected players (predictive accuracy: 75.0%) and in 35 out of the 44 non-qualified players (predictive accuracy: 79.5%). In conclusion, body height, the BMI and SJR height successfully discriminated between selected and non-qualified elite young female junior national team volleyball players. The equal vertical jump, sprint and agility of selected and non-qualified players, highlight the importance of body height and the BMI for selection of elite junior female volleyball players.*

**Key words:** physical fitness, anthropometrics, discriminant analysis, vertical jump.

### Introduction

Volleyball is a team sport involving short explosive activity bursts, such as serves, receptions, passes, spikes, short sprints, jumps and high speed movements with change of direction (Hank et al., 2015; Lidor and Ziv, 2010a; Valladares et al., 2016; Vlantes and Readdy, 2017). Successful volleyball players are tall and lean, and are characterized by a high level of jumping ability, as well as technical and tactical skills (Gabbett et al., 2007; Malousaris et al., 2008; Rikberg and Raudsepp, 2011; Sheppard et al., 2009). Previous research has shown that anthropometric and physical variables are able to

discriminate players as starters vs. non-starters or selected vs. non-qualified (Gabbett et al., 2007; Milic et al., 2017; Smith et al., 1992). For example Lidor and Ziv (2010b), in a review of literature, concluded that anthropometric data were correlated with volleyball skills' proficiency and game performance, especially in female players. Furthermore, Gabbett and Georgiev (2007) highlighted the importance of anthropometric characteristics in junior volleyball players, by showing that as the playing level increased, junior volleyball players were taller and leaner. In contrast, Smith et al. (1992) found that volleyball

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players of a national team did not differ in anthropometric characteristics compared with a university team, but were significantly faster and had greater vertical jump performance, as well as superior strength and aerobic fitness. Based on these results, it seems that volleyball performance is multidimensional (Rikberg and Raudsepp, 2011) and successful players are leaner and taller with greater motor abilities compared with lower level players (Milic et al., 2017).

Volleyball training at a young age does not appear to affect the pattern of growth and maturation (Baxter-Jones and Maffulli, 2002; Malina et al., 2004). In female athletes, the onset of the pubertal growth spurt is around the age of 10 years and adult height is reached around the age of 14-15 (Malina et al., 2004). Pubertal growth in girls is accompanied by an increase in body fat, and this negatively influences sports performance (Lidor and Ziv, 2010b; Rogol et al., 2002). Successful female volleyball players have lower body fat, as shown by differences in adiposity between first and second division players (Malousaris et al., 2008).

Vertical jump performance is a key physical fitness variable in volleyball players (Ziv and Lidor, 2010). Selected national team players have greater jump performance than lower level adult players (Fleck et al., 1985; Smith et al., 1992; Tsoukos et al., 2018; Ziv and Lidor, 2010). However, there is limited information concerning the ability of physical fitness variables, such as vertical jump height, for discriminating between the different levels of performance in younger volleyball players, and especially in females. A recent study highlighted the importance of a combined measure of the stature and vertical jump (i.e. vertical jump reach) for the selection of junior male national team players (Tsoukos et al., 2018). In contrast, a recent study comparing elite and sub-elite female players failed to identify differences in a wide range of anthropometric and physical fitness variables between these two groups, possibly due to its small sample size ( $n = 13$  elite and  $n = 8$  sub-elite players) (Pion et al., 2015). Taking into consideration the above conflicting results, the present study aimed to investigate whether a battery of anthropometric and lower body strength, speed and power tests might predict selection of young female volleyball players for the junior national team by expert

coaches. The results of the present study will provide useful data to volleyball coaches, sporting clubs and national federations regarding the importance of anthropometric and motor abilities for athletic selection.

## **Methods**

### *Participants*

Sixty four female junior volleyball players (age:  $14.4 \pm 0.5$  y, body height:  $1.76 \pm 0.05$  m, body mass:  $63.9 \pm 6.4$  kg) took part in a training camp and underwent a selection procedure by expert coaches of the junior national team. All players had a training background in volleyball of at least 3 years and had been participating in local or national junior volleyball championships for at least 2 years. They were pre-selected by regional and national coaches based on their volleyball performance. Table 1 shows their anthropometric characteristics. All athletes were free of musculoskeletal injuries for at least 1 year prior to the study and none were taking any drugs or nutritional supplements. The parents of the participants were informed in writing about the aim of the study and the possible risks involved and they signed an informed consent form. The study was approved by the local Institutional Review Board (School of Physical Education and Sports Science, National & Kapodistrian University of Athens, Greece) and all procedures were in accordance with the Code of Ethics of the World Medical Association (Helsinki declaration of 1964, as revised in 2013).

### *Measures*

#### *Assessment during competition and selection procedures*

Players took part in a 10 day training camp and underwent a selection procedure by coaches of the junior national team. Four expert volleyball national coaches graded the players on a scale from 0 to 100 on the basis of their performance in a volleyball tournament that was organized during the camp for this purpose. Each athlete played a total of 12 sets during the tournament. The best 20 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 0.976 ( $p < 0.001$ ).

#### *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). Body mass was measured to the nearest 0.1 kg by a scale (TBF-300A Body Composition Analyzer-Tanita) 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, England). The body mass index (BMI) was calculated by dividing body mass by the square of body height. Percentiles for body height and the BMI were calculated using the LMS method as previously described (Flegal and Cole, 2013).

#### *Familiarization and a standardized warm-up*

Fitness testing was performed during the first 2 days of the training camp. All athletes had been previously evaluated with these tests and had been using most of them as part of their training and testing routines 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 (Tsoukos et al., 2016). After that, participants performed a specific warm-up that included short bouts of running and jumping drills and change of direction (Saez Saez de Villarreal et al., 2007). A light meal was consumed at 13:00 and water was ingested ad libitum before and during testing.

#### *Design and Procedures*

Following the standardized warm-up, vertical jump tests (countermovement jump - CMJ, block jump and spike jump and reach) were performed. A three min rest interval separated each vertical jump test. Finally five minutes after the evaluation of jumping ability, the 10 m sprint and the 505 agility tests were performed.

#### *Vertical jump tests*

Countermovement jump and block jump performances were evaluated by an optical measurement system with a sampling frequency of 1000 Hz (Optojump next, Microgate, Italy) that measured flight time. During the CMJ, the athletes were asked to jump as high as possible with their arms akimbo, while maintaining the same body position during the take-off and landing (Tsoukos et al., 2017). Three jumps were

performed with 45 s recovery in between and the best performance was used for further analysis. The ICC for CMJ measurement was 0.967 ( $p < 0.001$ ).

The block jump was performed in a defensive volleyball position as previously described (Martinez, 2017; Sattler et al., 2012; Sheppard et al., 2009). The athletes were instructed to position their hands in front of their chest. From that position, they flexed their knees to a self-selected depth and jumped as high as possible. The movement of the arms was the same as they used during a block during a game. Players tried to reach as high as possible with full arm extension (Sattler et al., 2012). Three jumps were performed with 45 s recovery in between jumps and their best performance was used for further analysis (ICC: 0.961,  $p < 0.001$ ).

Spike jump reach (offensive or attack jump, SJR) was evaluated using a Vertec device (Sports Imports, Hilliard, OH, USA). Athletes jumped vertically as high as possible, using a 3 to 4 step approach (Martinez, 2017; Sattler et al., 2015; Sheppard et al., 2009). Spike jump height (SJ) was calculated by subtracting the height when standing with the dominant arm extended from the height achieved when jumping (Borràs et al., 2011; Sheppard et al., 2009). Three jumps were performed with 60 s recovery in between and their best performance was registered for further analysis. The ICC for SJR and SJ assessments was 0.943 and 0.945, respectively ( $p < 0.001$ ).

#### *10 m sprint test*

A telemetric timing system (Witty, Microgate, Italy) 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 (Johnson et al., 2010). The height of the photocells was 60 cm from the floor (Johnson et al., 2010). Each athlete performed 2 sprints with 3 minute recovery between them and the fastest performance was used for further analysis. The ICC for 10 m sprint measurement was 0.942 ( $p < 0.001$ ).

#### *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, Italy) was set laterally of the 10 m markers. The athletes ran as fast as possible from the starting line to the 15-

meter line. At the 15 meter line they changed direction (180° turn) and ran as fast as possible to the 10 m line. The recorded time was the distance from the 10 m marker to the 15 m and back to the 10 m marker (a total of 10 m) (Maio Alves et al., 2010). Two trials were performed with a 5 min rest interval in between, and the best result was kept for further analysis. The ICC for 505 agility test assessment was 0.89 ( $p < 0.001$ ).

### Statistical Analysis

Statistical analyses were executed with SPSS (IBM SPSS Statistics Version 23). Differences between selected and non-qualified players on all measurements were determined by independent t-tests. Relationships between variables were calculated by Pearson product-moment correlation coefficients. Test-retest reliability for all variables and inter-rater reliability was estimated by calculating the intraclass correlation coefficient (ICC) using a two-way mixed model ANOVA. A linear discriminant analysis (stepwise method) was conducted to determine which of the anthropometric and fitness tests distinguished between the selected and non-qualified athletes. Proper scatter, normality and box plots were used to check the assumptions of linearity, normality and outliers. The Box's M test was used to check the assumption of homogeneity of covariance matrices. Validation of the discriminant model was conducted using "leave one out" classification with each case classified by applying the classification function on all the data except the particular case. Data are presented as means and standard deviations (SD). Statistical significance was set at  $p < 0.05$ .

## Results

The anthropometric and fitness tests' data for the whole group as well as for the selected and non-qualified athletes are presented in Table 1. Selected players differed from the non-qualified in coaches' grading by 22.0% ( $p = 0.001$ ), in body height by 3.4% ( $p = 0.001$ ), in standing reach height by 2.6% ( $p = 0.001$ ), in the sum of skinfolds by 15.4% ( $p = 0.035$ ), in the BMI by -7.1% ( $p = 0.005$ ) and in the spike jump and reach (SJR) by 2.5% ( $p = 0.001$ ) (Figure 1). However, there were no other differences between the selected and non-qualified groups in speed, vertical jumping and agility measures (Table 1).

The calculations of percentiles showed that

selected players were classified in the  $99.2 \pm 1.6$  percentile in body height and in the  $51.4 \pm 20.6$  percentile in the BMI, which were significantly different from those of the non-qualified players ( $95.4 \pm 7.0$  and  $66.7 \pm 18.6$ ,  $p < 0.02$  and  $0.004$ , respectively, Table 1).

There were moderate correlations between expert coaches' grading vs. body height ( $r = 0.53$ ,  $p < 0.001$ ) and SJR ( $r = 0.502$ ,  $p < 0.001$ ) (Table 2). Also, there were small and moderate correlations between expert coaches' grading and the results of performance and anthropometric measurements, with standing height and spike jump reach exhibiting the highest correlation coefficients ( $r = 0.502$  and  $0.529$ , respectively, Table 2).

There were no missing values, extreme scores or outliers in the data set (univariate and multivariate), and the basic statistical assumptions were met. Five out of the twelve measured variables were entered into the discriminant analysis in order to ensure robustness and avoid multicollinearity, as previously suggested (Tabachnick and Fidell, 2007). Each of the five variables was chosen as the most representative from one of the five following different dimensions or abilities: body size (body height), body composition (BMI), speed (10 m sprint), agility (505 agility) and lower body power (SJR). The variance-covariance matrices across groups were homogeneous (Box's M = 3.94,  $p = 0.719$ ). Discriminant analysis yielded a discriminant function (Wilk's lambda = 0.67,  $\chi^2 = 24.56$ ,  $p < 0.001$ ,  $\eta^2 = 0.78$ ) which indicated that the model including the five variables was able to discriminate between the two groups (selected and non-qualified). Body height, SJR and the BMI were the main tests that highly loaded the discriminant function,  $r = 0.79$ ,  $r = 0.74$  and  $r = -0.53$  respectively (Table 3). The standardized function coefficients matrix also showed that body height and SJR highly contributed to distinguishing between selected and non-qualified players (body height coefficient: 0.54, SJR coefficient: 0.47 and BMI coefficient: -0.43). Standardized function coefficients of less than 0.33 (10% of the variance) were considered negligible (Tabachnick and Fidell, 2007) and thus the contribution of the 10 m sprint and 505 agility test were poor. Discriminant analysis also produced two equations to predict selected vs.

non-qualified players for the junior national team:

- (1) Selected players: Discriminant score = -1451.205 + 637.942 x (Body height) + 561.768 x (SJR) + 8.534 x (BMI)
- (2) Non-qualified players: Discriminant score = -1393.326 + 619.360 x (Body height) + 550.362 x (SJR) + 8.871 x (BMI)

Cross validation results showed that selection was correctly predicted in 15 out of the 20 selected players (predictive accuracy: 75.0%) and in 35 out

of the 44 non-qualified players (predictive accuracy: 79.5%). In the whole group, the discriminant analysis correctly classified 50 out of the 64 players (predictive accuracy: 78.1%). Interestingly, the selected players who were not predicted by the model (n = 5) had lower body height, standing reach height ( $p = 0.001$ ) and a higher sum of skinfolds ( $p = 0.049$ ), but they did not differ in other variables (e.g. vertical jump, sprint and agility tests) from the selected players predicted from the model (n = 15).

**Table 1**

*Anthropometric and fitness variables for the whole group (N = 64) as well as the selected (n = 20) and non-qualified (n = 44) junior female volleyball players. Values are presented as mean ± SD.*

Variables	Groups			Difference Between groups	CI90% of difference	Cohen's d	p
	All (N = 64)	Selected (n = 20)	Non-qualified (n = 44)				
Coaches' grading	77.8 ± 9.9	88.8 ± 3.4*	72.8 ± 7.6	16.0	12.9 to 18.9	2.44	0.001
Age (y)	14.4 ± 0.5	14.3 ± 0.7	14.4 ± 0.5	-0.1	-0.38 to 0.10	-0.26	0.35
Body height Percentile (%)	96.6 ± 6.1	99.2 ± 1.6 §	95.4 ± 7.0	3.8	0.01 to 0.06	0.65	0.021
Body mass (kg)	63.9 ± 6.4	63.1 ± 5.1	64.2 ± 6.9	-1.1	-4.01 to 1.78	-1.18	0.52
BMI Percentile (%)	61.9 ± 20.4	51.4 ± 20.6*	66.7 ± 18.6	-15.3	-0.24 to 0.07	-0.81	0.004
Standing reach height (m)	2.28 ± 0.07	2.33 ± 0.05*	2.27 ± 0.07	0.06	0.03 to 0.09	0.99	0.001
Sum skinfolds (mm)	44.4 ± 10.9	40.2 ± 9.7 §	46.4 ± 11.0	-6.2	-10.93 to -1.39	-0.59	0.035
10 m Sprint (s)	1.99 ± 0.08	1.97 ± 0.06	2.00 ± 0.09	-0.03	-0.07 to 0.01	-0.45	0.10
505 agility test (s)	2.67 ± 0.17	2.65 ± 0.15	2.68 ± 0.18	-0.03	-0.12 to -0.04	-0.22	0.42
CMJ (cm)	29.8 ± 4.1	30.0 ± 3.4	29.7 ± 4.4	0.3	-1.58 to 2.16	0.07	0.80
Block Jump (cm)	31.0 ± 4.8	31.8 ± 4.0	30.6 ± 5.1	1.2	-0.99 to 3.34	0.25	0.37
Spike jump (cm)	49.5 ± 6.2	50.1 ± 5.9	49.2 ± 6.4	0.9	-1.93 to 3.67	0.14	0.61

\*:  $p \leq 0.01$ ; §:  $p < 0.05$  significantly different from non-qualified players

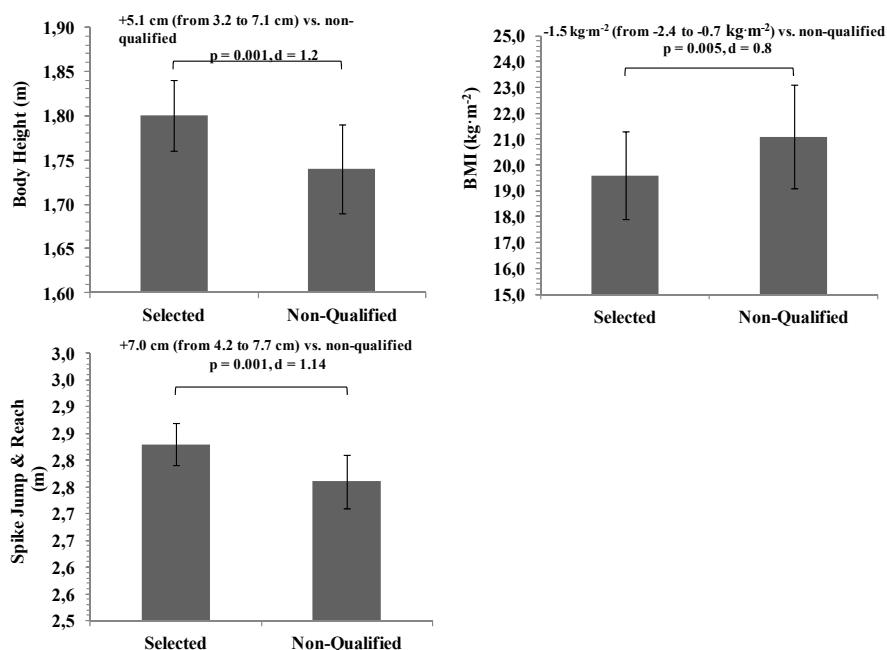
**Table 2**  
Correlation matrix of anthropometric and fitness variables of young female volleyball players.

	Coaches' grading	Age (y)	Body height (m)	Body Height Percentile (%)	Body mass (kg)	BMI (kg·m <sup>-2</sup> )	BMI Percentile (%)	Sum skinfolds (mm)	Standing reach height (m)	10 m Sprint (s)	505 agility test (s)	CMJ (cm)	Block Jump (cm)	Spike jump reach (m)
Age (y)		1												
Body height (m)	.53**	-.11	1											
Body Height Percentile (%)	.37**	-.03	.78**	1										
Body mass (kg)	-.05	.22	.31*	.28*	1									
BMI (kg·m <sup>-2</sup> )	-.35**	.28*	-.25*	-.17	.84**	1								
BMI Percentile (%)	-.33**	.13	-.28*	-.16	.78**	.95**	1							
Sum skinfolds (mm)	-.29*	.39**	-.19	-.15	.65**	.77**	.69**	1						
Standing reach height (m)	.46**	-.03	.94**	.77**	.37**	-.16	-.20	-.14	1					
10 m Sprint (s)	-.27*	-.02	.03	-.10	.18	.17	.10	.34**	.07	1				
505 agility test (s)	-.26*	.03	.10	.07	.18	.14	.07	.33**	.14	.62**	1			
CMJ (cm)	.11	-.14	-.21	-.05	-.24	-.13	-.06	-.33**	-.23	-.68**	-.56**	1		
Block Jump (cm)	.11	-.10	-.24	-.12	-.28*	-.15	-.09	-.28*	-.29*	-.65**	-.45**	.87**	1	
Spike jump reach (m)	.50**	-.01	.56**	.56**	.08	-.24	-.23	-.35**	.60**	-.47**	-.25	.47**	.42**	1
Spike jump (cm)	.06	.02	-.40**	-.22	-.31*	-.09	-.04	-.25	-.43**	-.60**	-.43**	.79**	.79**	.47**

\*\* $p \leq 0.01$ ; \* $p < 0.05$

**Table 3**  
Standardized function coefficients and correlation coefficients between fitness tests and the discriminant function

Variables	Standardized Function Coefficients	Correlations between variables and discriminant function
Body Height	0.54	0.79
Spike jump reach (SJR)	0.47	0.74
BMI	-0.43	-0.53
10 m Sprint		-0.16
505 Agility Test		-0.06



**Figure 1**

Body height, body mass index (BMI) and Spike jump & reach performance differences between the selected ( $n = 20$ ) and non-qualified ( $n = 44$ ) junior female volleyball players. Values are presented as mean  $\pm$  SD, difference between means (with 90% confidence intervals in parentheses);  $d$ : Cohen's  $d$ .

## Discussion

The main finding of the present study was that variables related to body composition (BMI and sum of skinfolds), body size (body height and standing reach height) along with the vertical jump and reach height (SJR), significantly differed between selected and non-qualified junior female volleyball players. In addition, body height, the BMI and SJR successfully discriminated between selected and non-qualified elite young female volleyball players for a junior national team with high predictive accuracy (78.1%).

The majority of previous research in volleyball has shown that body height and body composition play a vital role in game performance (Stamm et al., 2003) with players of higher level teams exhibiting greater values (Gabbett and

Georgieff, 2007; Giannopoulos et al., 2017; Malousaris et al., 2008; Milic et al., 2017). In particular, body height is crucial since volleyball players have to overcome the net's height (2.43 m for men and 2.24 m for women) and the opponent's team block. Malousaris et al. (2008) compared morphological characteristics of competitive female volleyball players (age:  $23.8 \pm 4.7$  y) who played in A1 and A2 divisions of the Greek National League and found that A1 players were taller and leaner than their A2 counterparts. Interestingly, body height of elite adult female players in that study was equal to that of the selected junior players in the present study ( $1.80 \pm 0.06$  m vs  $1.80 \pm 0.04$  m, respectively). The importance of anthropometric measurements in volleyball performance of young female players has been highlighted by Stamm et al. (2003) who

found that body size was a significant determinant in volleyball performance elements of the game such as serves, receptions, blocks and attacks. Furthermore, Milic et al. (2017) examined differences in anthropometric and physical performance variables of young Croatian female volleyball players (aged 13 to 15) who were of similar age to the female volleyball players in the present study, and observed that body height was significantly different in setters, outside hitters and opposites of the more successful volleyball group compared with less successful junior female volleyball players. One significant finding of the present study that highlights the importance of body height for success in volleyball is that although the total group of junior players were classified above the 90th percentile for height (average:  $96.6 \pm 6.1$  percentile i.e. they were very tall), the selected players were the tallest of that group (average:  $99.2 \pm 1.6$  percentile of body height for age, Table 2).

Lean body mass is considered an important anthropometric characteristic of successful volleyball players (Gabbett and Georgieff, 2007). This implies that players with lower body fat and thus lower weight have an advantage over players of similar abilities who are heavier and have more body fat. Previous studies have reported that higher division female players have a significantly lower sum of skinfolds compared with their lower division counterparts (by 11.1%,  $p < 0.01$ ) (Malousaris et al., 2008). A similar difference for the sum of 4 skinfolds (13.4%) was found in the present study between selected vs. non-qualified junior female players ( $p = 0.035$ ). Also, the BMI has been found to be significantly lower in more successful compared with less successful female players across different volleyball positions (Milic et al., 2017). This is in agreement with the findings of the present study, showing a large difference in the BMI and especially in the percentile of the BMI according to age and gender (Table 1). Although the BMI cannot distinguish between fat and lean mass, the results of the present study suggest that a lower BMI, classified around the 50th percentile (Table 2) is an important factor for selection and success in junior female players. Thus, the selected female players in the present study were not only significantly taller, but also leaner compared with non-qualified players,

despite the fact that in that phase of pubertal growth (14 years old) body fat in girls is increased (Lidor and Ziv, 2010b; Rogol et al., 2002).

Another finding of the present study was that SJR was significantly greater in the selected compared with non-qualified players and successfully discriminated between selected vs. non-qualified athletes. SJR has been shown to differentiate between elite and non-elite players (Smith et al., 1992) and is considered a key variable for success in top-level volleyball (Ciccarone et al., 2008; Sheppard et al., 2008; Smith et al., 1992; Stanganelli et al., 2008). The results of the present study are in accordance with the findings of Smith et al. (1992) who found that volleyball players of the national team of Canada had significantly higher SJR values compared with university volleyball players ( $3.43 \pm 0.06$  m vs.  $3.39 \pm 0.06$  m, respectively). Similarly, Palao et al. (2014), who analyzed a sample of 2,899 volleyball players (male and female) participating in the Olympic games and world championships from 2000 to 2012, reported that SJR height differentiated the first from the last female volleyball teams at this level of competition. The main reason for these observations is that SJR represents the combination of vertical jump ability and body height and as mentioned above it makes it easier for the player to overcome the net's height and the opponent's team block. However, an interesting finding of the present study was that the CMJ, block jump and spike jump height values were similar in selected and non-qualified players (Table 1). This implies that differences in SJR between groups were not due to jumping ability of the players, but mainly due to standing reach height (Table 1). This has been previously reported in players of different levels (Gabbett and Georgieff, 2007; Palao et al., 2014) and may suggest that all players had equal relative leg muscle power, but the selected players were taller and leaner. It should also be noted that there was a weak, but significant inverse relationship ( $r = -0.40$ ,  $p < 0.01$ ; Table 2) between body height and spike jump performance, indicating that taller players tended to have a lower spike jump. This observation may have practical implications for the strength & conditioning process after the selection procedure, where the main aim of physical training for taller players should be the improvement of jumping ability.



A previous study examining discrimination between selected and non-qualified young players in volleyball (Gabbett et al., 2007) reported that technical skills (pass and serve) were the most important variables discriminating between selected and non-qualified players in a talent identification volleyball program. However, in that study, players had limited volleyball experience and they 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, players in the present study had a training background in volleyball of at least 3 years and had been participating in local or national junior volleyball championships for at least 2 years. It is important to mention that players in the present study were pre-selected by regional and national coaches, based on their volleyball performance during a national talent identification program.

A limitation of the present study was that upper body strength and power as well as technical and cognitive characteristics were not evaluated. In a recent study (Tsoukos et al., 2018) it was found that upper body power, expressed by throwing velocity of a 3-kg medicine ball, in combination with SJR, successfully discriminated between selected and non-qualified male volleyball players for a junior national team. In addition, Rikberg and Raudsepp (2011) showed that selected 16-17 year old elite Estonian volleyball players had greater passing and spiking

technique as well as cognitive characteristics than non-qualified players. Therefore, it may be suggested that the remaining unexplained 21.9% of the predictive accuracy of the discriminant function in the present study, may be attributed to some combination of upper body power, technical and cognitive variables.

In conclusion, body height, the BMI and SJR height successfully discriminated between selected and non-qualified elite young female junior national team volleyball players. According to the literature and to the findings of the present study, the vertical jump, reach height and body height are associated with key elements of volleyball performance such as serving, blocking and attacking. The equal vertical jump, sprint and agility of selected and non-qualified players, highlight the importance of body height and the BMI for selection of elite junior female volleyball players. The results of the present study provide useful data which may help national federations, volleyball clubs, practitioners and volleyball coaches, regarding the importance of anthropometric and motor abilities for athletic selection. Furthermore, this study provides normative data for junior female volleyball players in terms of requisite anthropometric and fitness levels to advance to the elite level of performance. Future research should focus on the importance of upper body strength and power abilities, reaction time, as well as technical and tactical skills of female players during talent identification in volleyball.

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