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ANTHROPOMETRIC CHARACTERISTICS AND LOWER LIMB POWER OF PROFESSIONAL FEMALE VOLLEYBALL PLAYERS

Jadwiga PIETRASZEWSKA[1], Anna BURDUKIEWICZ[1], Aleksandra STACHOŃ[1], Justyna ANDRZEJEWSKA[1] & Bogdan PIETRASZEWSKI[2]
[1] *Department of Physical Anthropology, University School of Physical Education, Wrocław, Poland*
[2] *Department of Biomechanics, University School of Physical Education, Wrocław, Poland*

ABSTRACT

Success in performing professional sport is determined by many factors. Motor skills, psychological conditions and somatic structure are important. The aim of this research was to investigate detailed anthropometrical characteristics of highly skilled female volleyball players and their non-sporting peers. Additionally, the diversity of those features based on court position was examined. The sample consisted of first league female volleyball players (N=17), while 50 students from the University School of Physical Education served as reference group. The 35 anthropometric measurements, complemented by a biomechanical evaluation of lower limb power using the counter movement jump (CMJ), were examined. The values of height, length, width and body circumference were significantly higher for female volleyball players than those obtained from the reference group. The female volleyball players revealed a balanced mesomorphic somatotype. Stature differed and was related to court position. In comparison to the attackers and setters, the receivers, middle and libero players were characterised by better CMJ. This knowledge could enable coaches to individualise and determine suitable training methods, depending on the somatic predisposition of an athlete, which will reduce the risk of injury.

Key words: Anthropometry; Body composition; Counter movement jump; Volleyball.

INTRODUCTION

Success in performing professional sports is determined by many factors. Not only motor skills and psychological conditions are important. Knowledge of morphological body build specific to different sport disciplines facilitates a pre-selection process, and in the case of team games, can be an important factor determining a player's position on the court (Gualdi-Russo, 2001; Duncan *et al*., 2006).

Anthropometric research conducted on women participating in volleyball has been investigated frequently and is often related to different levels of women's skills (Viviani & Baldin, 1993; Bayios *et al*., 2006; Malousaris *et al*., 2008; Buśko *et al*., 2012). A few studies examine the anthropometric measurements for evaluating the specific body build of volleyball players. The majority of research confirms that volleyball pre-selection is based on previously determined, basic somatic criteria, such as body height and mass. Such morphological selection results in significantly higher body height of volleyball players in comparison to their non-practising peers and women practising other sports (Viviani & Baldin, 1993; Bayios *et al*., 2006). The results of much of the research point to a certain diversification of volleyball players' body build, which depends on the playing position on the court (Giatsis *et al*., 2011, Sattler *et al.*, 2012).

Morphological predispositions frequently determine a player's functional abilities. In the case of volleyball, strength and speed training lead to changes in muscle mass, endurance, strength, power and jumping abilities. The height of vertical jump in volleyball players is determined by a certain level of strength, which also influences their efficiency (Sheppard *et al*., 2008).

Biomechanical analyses of sportspersons are related to different parameters. Those performed on volleyball players frequently examine their jumping abilities and strength. The results of this research are frequently different, and depend on players' level of participation, position on the court, training experience and age (Smith *et al*., 1992; Newton *et al*., 1999; Newton *et al*., 2006; Marques *et al*., 2008; Buśko, 2009; Ziv & Lidor, 2010; González-Ravé *et al*., 2011; Buśko *et al.*, 2012; Sattler *et al*., 2012).

RESEARCH PROBLEM

The aim of this research was to prepare detailed characteristics of morphological body build, body proportions and body tissue composition of highly skilled female volleyball players and their non-sporting peers for comparison. The diverse features were also examined based on the court playing position of the volleyball players. The anthropometric measures were complemented by a biomechanical evaluation of lower limb power of the players to establish whether there is a relationship between jumping height and the somatic features.

METHODOLOGY

Ethical approval

Ethical approval for the project was obtained from the Ethical Committee at the University School of Physical Education in Wrocław (Ethical clearance 23.10.12). Their ethical guidelines were honoured throughout the study. Participants provided oral informed consent prior to testing. The study conducted within the framework of scientific projects number 69/0203/S/2013 and 09/0202/S/2013.

Participants

Seventeen (n=17) First League female volleyball players. This group constituted spikers (n=3), setters (n=4), middle blockers (n=4), receivers (n=4), libero players (n=2). The reference group consisted of female students (N=50) of the University School of Physical Education who did not participate in any sports. These groups were chosen by means of simple random selection. The mean age of the players was 20.89 years and that of the reference group was 20.59 years.

Measurements

Measurements were administered according to International Standards for Anthropometric Assessment (ISAK) (Norton & Olds, 2002). They were supplemented by a few additional measurements. The following anthropometric measurements included: body stature (B-v), acromial-dactylion length (a-da3), height from the floor to the trochanterion (B-tro), tibial-lateral height (B-ti), sitting height (B-vs), arm span (da3-da3), transverse chest (thl-thl), anterior-posterior chest depth (xi-ths), bi-acromial diameter (a-a), bi-iliocristal diameter (ic-ic), bi-epicondylar humerus breadth (cl-cm), bi-epicondylar femur breadth (epl-epm), wrist breadth (spr-spu), bi-malleolare breadth (mlt-mlf), foot length (pte-ap), foot breadth (mtt-mtf), and girths and skinfolds of the trunk and limbs.

Body height, lengths and breadths were measured to the nearest 0.1cm with the use of a GPM Anthropological Instruments (SiberHegner Machinery Ltd., UK). Skinfold thickness was measured with a Tanner/Whitehouse skinfold calliper (Holtain, UK) with 0.2mm graduation. Body mass was measured with an electronic weighing scale with an accuracy of 0.1kg.

The evaluation of the body build components was based on Heath and Carter's endomporphy, mesomorphy and ectomorphy. Body tissue composition was analysed with the use of Akern BIA 101 with Bodygram software. This device determines the amount of fat (FM), lean body fat (FFM), muscle (MM) and water (TBW) in total body mass. Results showed BIA to be extremely reliable and valid techniques for estimating body composition in female athletes (Fornetti *et al*., 1999). The Counter Movement Jump (CMJ) was used to evaluate lower limb power. A *KISTLER* dynamometric plate and BioWare software was used. This measuring system enables the measurement of the vertical component of ground reaction forces and the determination of power in the take-off phase while a jump was performed. The athletes were examined in their preparatory period of training.

Statistical analysis

The results obtained were analysed with the use of basic statistical methods (Statistica 9.0). Student *t*-test was applied to determine intergroup diversity among the reference group and female volleyball players. The normalisation of the players' features was computed with reference to mean and standard deviation of the non-sporting females. Normalisation involves adjusting the values measured on different scales to a common scale. This procedure allows establishing the significance of differences between the two groups for the various variables. The evaluation of different player positions was conducted by applying the analysis of variance and the Tukey test. The somatotypes for each group are compared with SANOVA, special analysis of variance that uses the somatotype attitudinal distances within and between groups (software by Sweat Technologist©). The correlation between the height of CMJ, power and morphological features was examined using Spearman's rank correlation coefficient.

RESULTS

The values of height, length, width and body circumference were significantly higher for female volleyball players than those obtained from the reference group (Table 1).

TABLE 1. **COMPARISON (Mean±SD) BETWEEN VOLLEY BALL PLAYERS AND REFERENCE GROUP: ANTHROPOMETRICAL MEASUREMENTS**

Variables	Volleyball players	Reference group	Significance
Body mass (kg)	69.99±6.1	54.85±5.6	0.000*
B-v (cm)	178.42±6.1	164.84±5.4	0.000*
B-tro (cm)	94.64±3.4	86.74±4.3	0.000*
B-ti (cm)	48.14±2.0	43.90±2.0	0.000*
B-vs (cm)	93.98±4.0	87.64±3.1	0.000*
a-daIII (cm)	77.31±4.0	70.74±2.2	0.000*
tro-ti (cm)	46.49±1.9	42.84±3.0	0.000*
daIII-daIII (cm)	178.48±7.8	163.81±5.5	0.000*
a-a (cm)	39.10±1.6	36.08±1.3	0.000*
dl-dl (cm)	43.03±1.5	40.04±2.3	0.000*
ic-ic (cm)	29.94±1.5	26.06±1.7	0.000*
pte-ap (cm)	26.23±1.2	24.05±1.0	0.000*
mtt-mtf (cm)	9.68±0.4	8.79±0.6	0.000*
mr-mu (cm)	7.81±0.4	7.57±0.4	0.022*
cl-cm (cm)	6.34±0.3	6.02±0.3	0.000*
spr-spu (cm)	5.33±0.4	4.97±0.3	0.000*
epl-epm(cm)	9.82±0.5	8.91±0.5	0.000*
mlt-mlf (cm)	7.36±0.6	6.66±0.4	0.000*
shoulder girdle girth (cm)	107.24±3.2	98.32±4.3	0.000*
chest girth in rest (cm)	79.47±3.9	73.65±4.2	0.000*
chest girth (inspiration) (cm)	85.62±3.8	79.42±3.9	0.000*
chest girth (expiration) (cm)	76.56±3.5	70.91±4.5	0.000*
Waist girth (cm)	73.65±3.0	65.50±3.7	0.000*
arm girth relaxed (cm)	28.71±1.4	24.82±2.0	0.000*
arm girth flexed and tensed (cm)	29.98±2.5	26.43±2.0	0.000*
forearm girth (max. relaxed) (cm)	24.75±1.3	22.53±1.3	0.000*
gluteal girth (max.) (cm)	101.88±4.6	92.13±4.6	0.000*
thigh girth (cm)	59.65±2.9	52.91±3.8	0.000*
calf girth (cm)	37.13±2.0	34.30±2.3	0.000*

* Significance: $p<0.05$

Key: (B-v) body stature; (B-tro) height from the floor to the trochanterion; (B-ti) tibial-lateral height; (B-vs) sitting height; (a-da3) acromial-dactylion length; (tro-ti) length of thigh; (da3-da3) arm span; (a-a) bi-acromial breadth; (dl-dl) bi-deltoid breadth; (ic-ic) bi-iliocrista breadth, (pte-ap) foot length; (mtt-mtf) foot breadth; (mu-mr) hand breadth; (cl-cm) humerus breadth; (spr-spu) wrist breadth; (epl-epm) femur breadth; (mlt-mlf) bi-malleolare breadth.

The normalisation of the players' features with reference to the mean and standard deviation of the students are presented in Figure 1 and Figure 2.

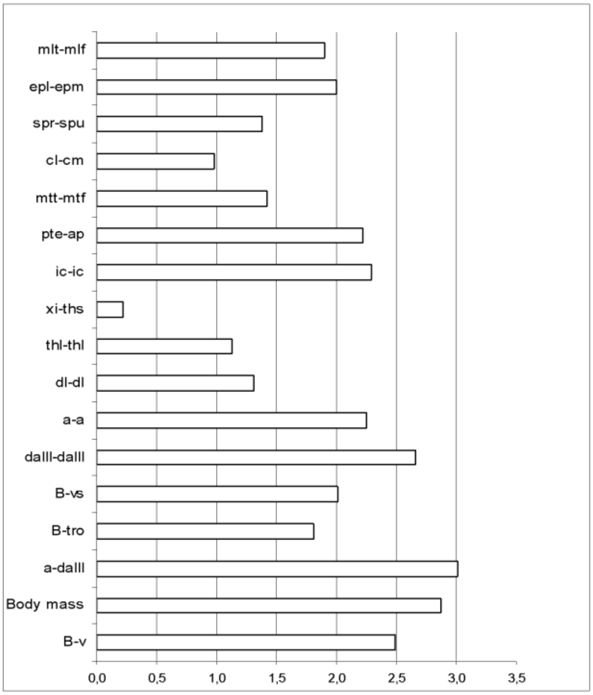

FIGURE 1. **NORMALISED VALUES OF LENGTHS, BREADTHS AND BODY MASS OF PLAYERS AND REFERENCE GROUP (MEAN±SD)**

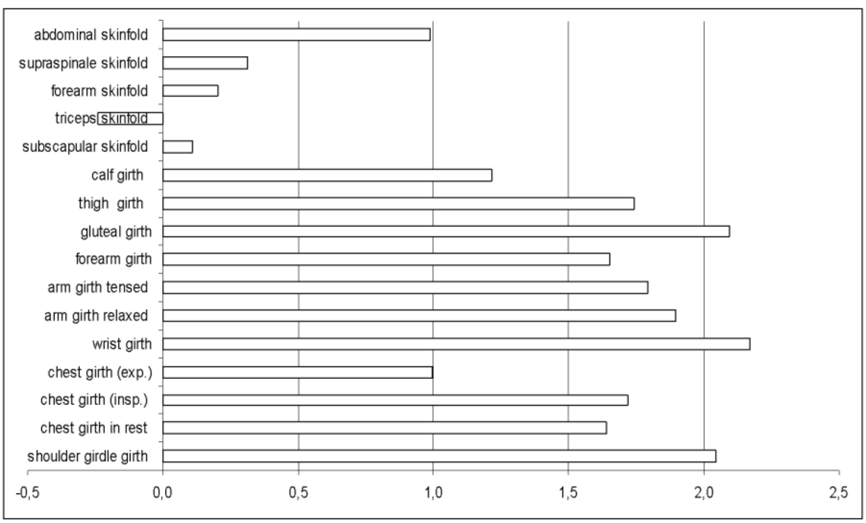

FIGURE 2. **NORMALISED VALUES OF SKINFOLDS AND CIRCUMFERENCES OF PLAYERS AND REFERENCE GROUP (MEAN±SD)**

Among the examined length and width parameters, the greatest differences were observed in body stature, acromial-dactylion length, arm span, bi-acromial and bi-iloicristal breadth, sitting height, foot length and bi-epicondylar femur breadth (Figure 1). The highest normalised positive values among those obtained for body girths were of waist, shoulder girdle, arm and thigh. There was no significant intergroup diversification with reference to skinfolds (Table 2, Figure 2).

TABLE 2. **SKINFOLD THICKNESS AND BODY COMPOSITION: COMPARISON BETWEEN PLAYERS AND REFERENCE GROUP (MEAN±SD)**

Variables	Volleyball players	Reference group	Significance
subscapular skinfold (mm)	9.69±2.4	9.42±2.5	0.698
triceps skinfold (mm)	8.60±1.5	9.29±2.8	0.339
forearm skinfold (mm)	5.04±1.3	4.29±1.1	0.025
supraspinal skinfold (mm)	12.34±2.9	11.23±5.5	0.426
abdominal skinfold (mm)	12.62±3.1	11.15±4.7	0.230
calf skinfold (mm)	9.33±1.5	6.96±2.4	0.000*
Endomorphy	3.12±0.6	3.01±0.9	0.631
Mesomorphy	3.86±0.8	3.62±0.9	0.327
Ectomorphy	2.91±1.0	3.25±0.9	0.199
FFM (kg)	50.44±3.9	40.90±3.8	0.000*
TBW (kg)	36.93±2.9	29.94±2.8	0.000*
FM (kg)	19.56±3.5	13.99±3.0	0.000*
FM (%)	27.82±3.4	25.50±3.2	0.012*
FFM (%)	72.18±3.4	74.50±3.2	0.012*
TBW (%)	52.85±2.5	54.53±2.3	0.013*

* Significance: p<0.05 Key: (FM) fat mass; (FFM) fat free mass; (TBW) total body water

TABLE 3. **HEIGHT, MASS AND FAT: VOLLEYBALL PLAYERS**

Positions	Height (cm)	Mass (kg)	Fat (kg)
Spikers	181.0±0.0*[a]	75.4±3.4	24.3±1.9*[c]
Setters	175.3±3.6	70.9±6.0	19.0±2.9
Middle blockers	184.6±2.7*[b]	72.8±5.1	19.4±3.6
Receivers	176.8±2.6	70.4±2.1	18.5±0.7
Libero players	167.8±4.2	61.5±3.4	15.5±2.8

* Significance: p<0.05
[a] spikers vs libero players [b] middle blockers vs receivers, setters, libero players
[c] spikers vs libero players

The comparison of the basic morphological features of the volleyball players in relation to court position suggests that the tallest players played the middle position (Table 3). Their mean body stature was 184.6±2.7cm. The next tallest players were spikers who measured 181.0±0.0cm. The next group was the receivers whose mean stature was 176.8±2.6cm. Average stature was observed in the setters (175.3± 3.6cm). The players playing the libero position were the shortest, however, they displayed greater discrepancy in values and their mean height was 167.8±4.2cm. Significant differences ($p<0.05$) regarding body stature were found between middle blockers and the receivers, setters and libero players.

The highest body mass was observed in the spikers (75.4±3.4kg). The mean weight of middle position players was 72.8 ±5.1kg, while the weight of the setters was lower and displayed a great discrepancy in values (70.9 ±6.0kg). Similar values were observed in the receivers who displayed a lower level of discrepancy (70.4±2.1kg). The lightest group of players were libero players whose mean weight was 61.5±3.4kg.

The highest values for the amount of fat were found in spikers (24.3 ±1.9kg). The setters (19.0±2.9kg), receivers (18.5±0.7kg) and middle players (19.4 ±3.6kg) had a similar fat level. Libero players displayed the least fat (15.5±2.8kg). Significant differences ($p<0.05$) were found between spikers and libero players.

TABLE 4. **BODY BUILD COMPONENTS: VOLLEYBALL PLAYERS**

Playing position	**Endomorphy**	**Mesomorphy**	**Ectomorphy**
Spikers	3.7±0.8	3.6±0.7	2.8±0.4
Setters	3.0±0.6	3.7±0.9	2.6±1.1
Middle blockers	3.0±0.5	3.8±0.3	3.5±0.9
Receivers	3.0±0.5	4.4±0.7	2.8±0.5
Libero players	3.0±0.5	3.8±0.8	2.6±1.1

The female volleyball players examined revealed balanced mesomorphic somatotypes (3.1-3.9-2.9). SANOVA analysis did not show any statistically significant differences between the groups ($F=0.45$; $p=0.228$). Nevertheless, the differences observed between the players of the examined teams might have resulted from their court position (Table 4). Spikers were characterised by endo-mesomorphic somatotype (3.7-3.6-2.8), while the middle players by meso-ectomorphic ones (3.0-3.8-3.5).

The receivers (32.2±0.36cm), middle (31.3±0.40cm) and libero players (31.0±1.14cm) performed the highest jumps, while spikers (25.4±0.19cm) and setters (26.3±047cm) obtained lower CMJ values (Table 5). On the other hand, the values of power during the take-off phase looked slightly different. In this case, the receivers obtained the highest values. The power obtained by spikers (856.3±138.1W) was over 100W smaller than the power obtained by the receivers (960.0±122.0W), while the power values obtained by the middle players (756.4±119.9W) and setters (779.5±125.3W) was approximately 100W smaller than that obtained by the strikers. The libero players (602.5±101.1W) generated much less power than the remaining players did. Significant differences ($p<0.05$) were found between receivers and libero players.

TABLE 5. **MEAN±SD FOR CMJ AND POWER OF FEMALE VOLLEYBALL PLAYERS**

Players & positions	CMJ (cm)	Power (W)
Whole group	29.2±0.51	797.3±149.6
Spikers	25.4±0.19	856.3±138.1
Setters	26.3±0.47	779.5±125.3
Middle blockers	31.3±0.40	756.4±119.9
Receivers	32.2±0.36	960.0±122.0
Libero players	31.0±1.14	602.5±101.1*

* Significance: p<0.05 for difference between the scores of libero players vs receivers

TABLE 6. **RANK CORRELATION BETWEEN CMJ AND POWER FOR ALL EXAMINED FEATURES**

Variable	CMJ	Power	Variable	CMJ	Power
Body mass (kg)	-0.108	0.404	shoulder girdle girth (cm)	0.083	0.497*
B-v (cm)	0.271	0.133	chest girth in rest (cm)	0.006	0.208
B-tro (cm)	0.015	0.074	chest girth (inspiration) (cm)	0.137	0.245
B-ti (cm)	0.246	-0.022	chest girth (expiration) (cm)	-0.105	0.245
B-vs (cm)	0.305	0.193	waist girth (cm)	0.014	0.051
daIII-daIII (cm)	0.301	0.226	arm girth relaxed (cm)	0.219	-0.084
a-a (cm)	0.044	0.277	arm girth tensed (cm)	0.064	-0.071
dl-dl (cm)	0.069	0.399	forearm girth (cm)	0.317	0.363
ic-ic (cm)	0.211	0.426	gluteal girth (cm)	0.118	0.302
mr-mu (cm)	0.289	0.094	thigh girth (cm)	-0.075	0.106
cl-cm (cm)	0.499*	0.074	calf girth (cm)	0.239	0.378
spr-spu (cm)	0.361	0.113	subscapular skinfold (mm)	-0.007	-0.375
epl-epm(cm)	0.122	0.137	triceps skinfold (mm)	-0.116	-0.042
mlt-mlf (cm)	-0.059	-0.025	forearm skinfold (mm)	-0.205	0.248
Endomorphy	-0.085	-0.275	supraspinal skinfold (mm)	0.052	-0.139
Mesomorphy	-0.233	0.164	abdominal skinfold (mm)	-0.046	-0.172
Ectomorphy	0.516*	-0.263	calf skinfold (mm)	-0.059	0.112
FFM	0.440	0.151	FM	-0.272	0.418

* Significance: p<0.05

Key: (B-v) body stature; (B-tro) height from the floor to the trochanterion; (B-ti) tibial-lateral height; (B-vs) sitting height; (a-da3) acromial-dactylion length; (tro-ti) length of thigh; (da3-da3) arm span; (a-a) bi-acromial breadth; (dl-dl) bi-deltoid breadth; (ic-ic) bi-iliocrista breadth, (pte-ap) foot length; (mtt-mtf) foot breadth; (mu-mr) hand breadth; (cl-cm) humerus breadth; (spr-spu) wrist breadth; (epl-epm) femur breadth; (mlt-mlf) bi-malleolare breadth.

The analysis of correlation coefficients between the power and the examined anthropometric features mostly did not reveal any significant correlations (Table 6). The only significant interrelationship was observed between power and shoulder girdle. The height of CMJ jumps indicated a significant positive correlation with ectomorphy (r=0.516) and elbow breadth (r=0.499).

DISCUSSION

This research has confirmed that the volleyball players were taller than their non-practising peers which is typical for the sport discipline. Many researchers have confirmed that female volleyball players are the tallest sportswomen, regardless of their age (Viviani & Baldin, 1993; Bayios *et al.*, 2006; Lidor & Ziv, 2010). However, the literature describes differences observed in the body stature in different teams. The height of top Polish female volleyball players examined by Buśko *et al.* (2012) was 184.8cm, while those from the Academic Sports Association (ASA) measured 177.9cm (Buśko & Lipińska, 2012). Bozo and Lleshi (2012) have also observed differences in height in Albanian female volleyball players. They stated that it depends on the level of their sport skills. These researchers have also observed that the height of players depends on court position. The tallest players took the middle and spiker positions, while those shorter, took the position of a setters and receivers. The results obtained (Viviani & Baldin, 1993; Giatsis *et al.,* 2011) was confirmed by the current research.

The upper limbs were also longer in volleyball players in comparison to the limbs of reference group. This phenomenon is biomechanically justified. Long limbs are one of the most significant features of volleyball players since they play an important part during offence and defence (Papadopoulou, 2003). Owing to this feature, it is possible to obtain greater angular speed, which means that the ball may travel faster during service. What is more, long upper limbs help during hitting and their swing enables the achievement of longer upward acceleration. This produces an inertial force, which acts on the trunk and legs remaining on the surface. This pressure increases ground reaction forces and the force of a hit. Take-off and the counter jump performed by a player frequently determine the efficiency of the task (attack, block). The force in the take-off phase and the time of action of this force determines the height of the jump. Length features, in comparison to those of body breadth and circumference, are highly dependent on hereditary factors (Malina, 1970). That is why it is important to consider these when conducting pre-selection of volleyball players.

The examined female players were characterised by substantial bi-iliocristal diameter. It enables them to have greater balance during a match. Players can lower their centre of gravity due to the greater bi-iloicristal and smaller bi-acromial diameter. The examined competitors had quite a significant amount of fat in their body mass (27.8%). The amount of fat differed depending on the research. It was related to the method applied to measure its content in body mass. Research conducted by Tsunawake *et al.* (2003) who used the underwater weighing method, showed that female volleyball players had 15-19% of fat. However, much research has reported that the amount of fat can exceed 20% (Papadopoulou, 2003; Malousaris *et al.*, 2008). Similarly, Buśko and Lipińska (2012) obtained high values in research conducted on second division volleyball players from the ASA University of Physical Education in Warsaw. The differences reported by the research are the result of the different methods applied by the researchers. Some results were obtained by means of hydrostatic weighing (Tsunawake *et al.*, 2003), while others determine the amount of fat by means of skinfolds (Papadopoulou, 2003; Malousaris *et al.*, 2008). Research conducted with the use of the BIA method frequently reveals the highest percentage of body fat (Buśko & Lipińska, 2012). An analysis of existing research enables concluding that the greater amount of fat may influence the lower level of motor fitness. Papadopoulou (2003) has observed a negative relation between fat and explosive jumps in volleyball. According to him, the superfluous body weight caused by high body fat decreases jumping abilities, and therefore, height of the vertical jump of a player. Furthermore, excessive fat has a negative effect on horizontal movements, thus top athletes have less fat. Our research did not confirm these findings where the correlations between body fat and jump height were not statistically significant.

Somatotype of the examined female volleyball players was determined by the level of morphological features. It could be referred to as balanced mesomorphic somatotype (3.1-3.9-2.9). However, the observed differences depended on the player's court position. Other authors have also reported similar diversification. According to Bayios *et al.* (2006), Greek female volleyball players were represented by a balanced endomorphic somatotype (3.4-2.7-2.9). On the other hand, players examined by Viviani and Baldin (1993) had an endo-mesomorphic somatotype (4.9-3.8-2.6 and 4.7-3.9-2.3). Turkish top players were characterised by ectomorphic body build (3.4-2.1-4.5) (Ayan *et al*., 2012). Gualdi-Russo and Zaccagni (2001) described their somatotype as balanced (3.0-3.3-2.9), but they determined that the differences were based on court position. The most ectomorphic body build was observed in middle players, while the remaining competitors displayed more mesomorphic somatotypes. Dunkan *et al*. (2006) have also pointed to the somatotype differences determined by court position. Setters' body build was described as endomorphic and ectomorphic, strikers and receivers as balanced ectomorphic, while middle blockers displayed ectomorphic and mesomorphic somatotype. Carvajal *et al*. (2012) and Martín-Matillas *et al*. (2014) also described differences according to playing positions. Our research results are compatible with those published in the literature to some extent.

The most popular tests applied to evaluate power and force parameters are jumping trials. An evaluation of lower limb explosive power is best performed with the use of a dynamometric plate, which enables researchers to conduct the measurement of height of a CMJ and power (Young *et al*., 2011). The results of such examinations may be useful for coaches who need to evaluate a player's skill level. Such measurements are significant in sport disciplines, which require sudden acceleration, turns and jumps, such as soccer, basketball and volleyball. Somatic body build constitutes a key to performance. The height of a vertical jump is the most significant factor in the efficiency of volleyball performance. Thus, it is important to find methods, which could improve the performance of players. The results obtained by Marques *et al.* (2008) indicated that elite female volleyball players could improve strength and power during a competition season by implementing a well-designed training programme, which includes plyometric exercises.

Both the force obtained in the take-off phase, as well as the height of CMJ jump obtained by the examined volleyball players, were small in comparison to the values obtained by different groups of competitors. The values of CMJ jump of female beach volleyball players recorded by Riggs and Sheppard (2009) were 38.58cm (28.63-48.57cm). The mean power of those players was quite low, namely only 442.11±188.29W (264.91-1061.16). The jump values obtained by Polish elite cadets (junior and senior female volleyball players) recorded by Buśko *et al.* (2012) varied from 38.8 to 40.7cm. Darlymple *et al.* (2010), in research conducted on female collegiate National Collegiate Athletic Association (NCAA) Division II volleyball players, have reported similar CMJ values to those obtained in this research. Jumps performed by players after stretching were within the range of 28-31cm. Results of research describing analysed biomechanical parameters with reference to player position are not always consistent. Marques *et al.* (2009) applied the CMJ to examine the correlation between a playing position and jumping skills. He did not observe any significant relationship between these two parameters. Duncan *et al.* (2006) examined elite junior players and found no correlation between vertical jumping ability and court position. Sattler *et al.* (2012) conducted research based on different heights of CMJs with reference to court position. According Sattler *et al*. (2012), libero players and receivers obtained the best results. Our research has not revealed any significant differences in the CMJ of the examined subjects with reference to their position. However, the receivers, middle and libero players jumped higher than the attackers and setters.

The results of this research have not revealed significant correlations between body build, CMJ height and force. Riggs and Sheppard (2009) also did not find any correlations between body mass, jump height and power, nevertheless, they observed a significant relationship between the height of a jump and mean power. Sheppard *et al.* (2008) have reported a significant correlation between the height of a CMJ and body height (r=0.77), on the other hand, they did not observe any relationship between jumping skills evaluated by the use of CMJs and the sum of skinfolds (r=0.15). In the examined players, no significant correlations between CJM, body fat and thick skinfolds were observed. However, they observed a stronger correlation between CMJ jump and the amount of lean body (r=0.44). The increased fat free mass of players may increase the strength of serve. This strength results from giving the ball suitable momentum. The momentum is influenced by many factors, such as the mass of the hitting part, which can be increased by engaging the whole body to swing and hit. The higher the fat-free mass of a player, the stronger the hit. This can be explained by the greater body mass of female volleyball players.

CONCLUSIONS AND PRACTICAL APPLICATION

The study conducted enabled the researchers to draw conclusions about the anthropometric and power characteristics of the participating group of highly skilled female volleyball players. Body height observed in the examined players differed and was related to their court position. Such dependency is typical for volleyball players. The tallest players took middle position, followed by strikers, receivers and setters. The shortest were libero players. In comparison to the attackers and setters, the receivers, middle and libero players were characterised by better jumping skills. The height of CMJ attained by the examined players indicated a significant correlation only with the ectomorphy component. The power of the lower limbs was related significantly to the shoulder girdle girth and features describing bone mass. These findings could enable coaches to individualise and determine suitable training methods, depending on the somatic predisposition of an athlete.

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Prof Jadwiga PIETRASZEWSKA: Department of Physical Anthropology, University School of Physical Education, Wrocław, Poland. Al. I.J. Paderewskiego 35, 51-612 Wrocław, POLAND. Tel.: +48 71 347 3344, E-mail: jadwiga.pietraszewska@awf.wroc.pl

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