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Somatotype-variables related to muscle torque and power output in female volleyball players

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The purpose of this study was to investigate the relationship between somatotype, muscle torque, maximal power output and height of rise of the body mass centre measured in akimbo counter movement jump (ACMJ), counter movement jump (CMJ) and spike jump (SPJ), and power output measured in maximal cycle ergometer exercise bouts in female volleyball players. Fourteen players participated in the study. Somatotype was determined using the Heath–Carter method. Maximal muscle torque was measured under static conditions. Power output was measured in 5 maximal cycle ergometer exercise bouts, 10 s each, at increasing external loads equal to 2.5, 5.0, 7.5, 10.0 and 12.5% of body weight (BW). All jump trials (ACMJ, SPJ and CMJ) were performed on a force plate. The mean somatotype of volleyball players was: 4.9-3.5-2.5. The value of the sum of muscle torque of the left upper extremities was significantly correlated only with mesomorphic component. Mesomorphic and ectomorphic components correlated significantly with values of maximal power measured during ACMJ and CMJ. Power output measured in maximal cycle ergometer exercise bouts at increasing external loads equal to 2.5, 5.0 and 7.5% of BW was significantly correlated with endomorphy, mesomorphy and ectomorphy.

Key words: *female, volleyball players, somatotype, strength, power, jump*

1. Introduction

Motor abilities, morphological and physiological characteristics play an important role in determining a success of a sportsperson. Competitors representing the highest level in their sport disciplines show the greatest similarity in morphological traits and motor abilities, as a result of selection and adaptation to physical effort, developed in the course of specific training [1], [2]. Those traits of athletes achieving highest results in particular sport discipline, create a specific "model" – somatic and physical pattern for that discipline. Empirical and practical knowledge emerging from studies on the highest level volleyball players, such as their body composition, anthropometric dimensions and somatotype, aerobic profile, agility and speed, strength and power, allow us to determine the complex physique profile of a competitive men and female volleyball players. Kinanthropometric profile of volleyball players includes great height, muscular power, jumping ability, velocity and coordination as well as strength and elevation to block, strength and speed to spike, resistance to play the sets and great technical ability [3], [4]. These parameters are an essential part of the evaluation and selection of volleyball competitors and should be integrated and applied when planning annual training programs for volleyball players [5]. The planning of volleyball players training should not concern only the applied training loads, but it should also focus on the practitioners' physical abilities. Research of body build of the volleyball players point to anthropometric attributes required in this sport. It has been suggested that somatotyping is superior to linear anthropometric measures, for estimation of body build of athletes, as

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it combines adiposity, musculoskeletal robustness, and linearity into one rating [1]. Somatotype analysis can provide better identification of body build specification of athletes in various sports than simple anthropometric characteristics, which strongly, positively correlate with body height [6]. Somatotype analysis may be useful in terms of talent identification or development of training programs. Somatotype, as well as some other physical characteristics, differ between sports and have the smallest diversity among sportspersons practicing the same sport and employing the same techniques [1], [7], [8].

Measurements of maximal muscle torques in group muscles under static conditions [9]–[12] and power output in jumps on force plate [13]–[15] are routine methods used for determination of muscle force and power in laboratory testing.

The relationship between strength, power and sport performance of athletes has been documented by several investigators [16]–[20]. In the studies of Quarrie et al. [21] and Quarrie and Wilson [22], a relationship between anthropometric (somatotype) and strength, power measures of rugby athletes was described. Although similar investigations are needed and useful for volleyball competitors, we could not find any results of such research in the literature. There are also a number of studies either on morphological traits or tests of motor features and physiology in volleyball competitors, but there is lack of research linking these characteristics and studying correlations between them.

The aim of this study was to investigate the relationship between components of somatotype and muscle torques, maximal power and height of rise of the body mass centre measured in akimbo counter movement jump (ACMJ), counter movement jump (CMJ) and spike jump (SPJ), and power output measured in maximal cycle ergometer exercise bouts in female volleyball players.

2. Materials and methods

The study was approved by the Senate Ethics Committee of the Josef Pilsudski University of Physical Education in Warsaw. All participants were informed about the aim and course of the study, and about the possibility of immediate resignation without giving the cause. All subjects gave their written consent. Fourteen Second Division female volleyball players from the AZS AWF Warszawa (age 21.8 ± 1.6 years, body height 177.0 ± 6.0 cm, body mass 72.0 ± 7.5 kg, training experience 8.9±3.3 years) volunteered to participate.

The maximal muscle torques of ten muscle groups: flexors and extensors of an elbow, shoulder, hip, knee and trunk were measured under static conditions with the use of new special devices ("JBA", Zbigniew Staniak, Poland) – type LR1-P (upper extremities) and TBK2-PM (lower extremities and trunk). Technical characteristics of the measuring device are as follows:

- torque meter: strain gauge head – measuring range for 0 to 500 N·m for LR1-P and 0–2000 N·m for TBK2-PM,
- relative error in strain-gauge bridge amounts to 1.0%.

a) b)

Fig. 1. The positions of the measurement of muscle torque: (a) LR1-P, for example, the elbow joint flexion, (b) TBK2-PM, for example, the hip joint flexion

Measurements of muscle torque were performed according to the generally accepted principles [10]. During the measurement of muscle torque of elbow flexors and extensors the subject was sitting, with his arm bent at a proper angle and placed on the armrest, and with his trunk stabilized (Fig. 1). The muscle torques of shoulder flexors and extensors were measured also in a sitting position. The flexion angle was set at 70° and the extension angle at 50° during the measurement. The trunk was stabilized so that the potential presence of synergic movements could be excluded. The measurements of muscle torque taken for knee flexors and extensors were carried out on subjects in a sitting position. The hip and knee joints were bent at 90°. The subjects were stabilized at the level of anterior superior iliac spines and thighs, with the upper extremities resting on the chest. The subjects were lying face up during the measurements of hip extensors and flexors muscle torque. The subjects were stabilized at the level of anterior superior iliac spines. The hip joint angle remained at 90° during the measurement. The maximal, physiological extension of an elbow, knee and hip joints was accepted as 0°. For the shoulder joint, the positioning of the arm along the side was taken as 0°. The joint axis of rotation during the muscle torque measurements corresponded to the axis of rotation of the torque meter. The muscle torques of the right and left limbs were measured separately, always in the order flexion–extension. Each subject was told to develop a maximal power output during the measurement.

The force–velocity (F–v) and power–velocity (P–v) relationships were determined on the basis of results of exercises performed on a Monark 874 E cycloergometer (Sweden) connected to a PC, using the MCE 4.0 software package ("JBA" Zb. Staniak, Poland). After adjusting the ergometer saddle and handlebars, each subject performed the tests in a stationary position, without lifting off the saddle, with their feet strapped onto the pedals. Each player performed five 10-second maximal cycloergometer tests with increasing external loads amounting to 2.5, 5.0, 7.5, 10.0 and 12.5% of body weight (BW), respectively. There were 2-min breaks between the tests. The standard procedures of exercise performance were followed, and the subjects were verbally encouraged to achieve and maintain as quickly as possible the maximal pedaling velocity. With the use of MCE, the maximal power output at a given load (P_i; i – load value) and velocity (v_i) necessary to achieve P_i were determined [23], [24].

The power output of lower extremities and the height of rise of the body mass center during vertical jumps were measured on a force plate with a Kistler amplifier for counter-movement jumps (CMJ), akimbo counter-movement jumps (ACMJ) and spike jumps (SPJ). The amplifier was connected to a PC via an A/D converter. The MVJ v. 3.4. software package ("JBA" Zb. Staniak, Poland) was used for taking the measurements. In the physical model applied, the subject's body mass bouncing on the platform was reduced to a particle affected by the vertical components of external forces: the body's gravity force and the vertical component of ground reaction force. The maximal power and maximal height of rise of the body mass center (h) were calculated from the registered reactive force of the platform [13], [25]. Each subject performed nine vertical jumps with maximal force on the force plate: three counter-movement jumps (CMJ), three akimbo counter-movement jumps (ACMJ) and three spike jumps (SPJ). There were 5 s breaks between the CMJs and between ACMJs, and 1 min breaks between the SPJs. A jump with the highest elevation of the body's center of mass was taken for statistical analysis, for each type of jumps.

Anthropometric examinations included the following variables: body height, body mass, four skinfolds (triceps, subscapular, suprailiac, medial-calf), biceps girth (with forearm flexed at 90° and with biceps tensed), standing calf girth, bicondylar femur breadth, bicondylar humerus breadth [26], [27]. Body height was determined using a SiberHegner anthropometer (Switzerland), body mass was measured on electronic weighting machine Tanita TBF 300 (Japan), skinfolds were measured using a Harpenden skinfold caliper, girth measurements were acquired with a steel measuring tape and bicondylar diameters of femur and humerus were measured using small spreading caliper (SiberHegner, Switzerland).

All measurements were taken by the same investigator, applying standard anthropometrical methods according to the procedure of the International Biological Programme [28].

Somatotype was calculated by the Heath–Carter method [29].

All measurements were performed in the morning after preparatory period.

Relationships between the muscle torques, power output and the components of somatotype were assessed by calculating Pearson's correlation coefficients. The level of statistical significance was set at $p < 0.05$. All statistical calculations were performed using a Statistica™ program (v. 8.0, StatSoft 2007) [30].

3. Results

The mean somatotype of volleyball players was: 4.9-3.5-2.5 (values for endomorphy 4.9 ± 1.0, mesomorphy 3.5 ± 1.1 and ectomorphy 2.5 ± 1.4, respectively (Fig. 2). The somatotypes spread was very large on the somatochart. The largest diversity was recorded in the ectomorphy component (ranging from 0.5 to 5.0). The lowest ectomorphy and highest endomorphy were characteristic of liberos and setters. The highest ectomorphy and the lowest endomorphy and mesomorphy had most in common with hitters and oposites.

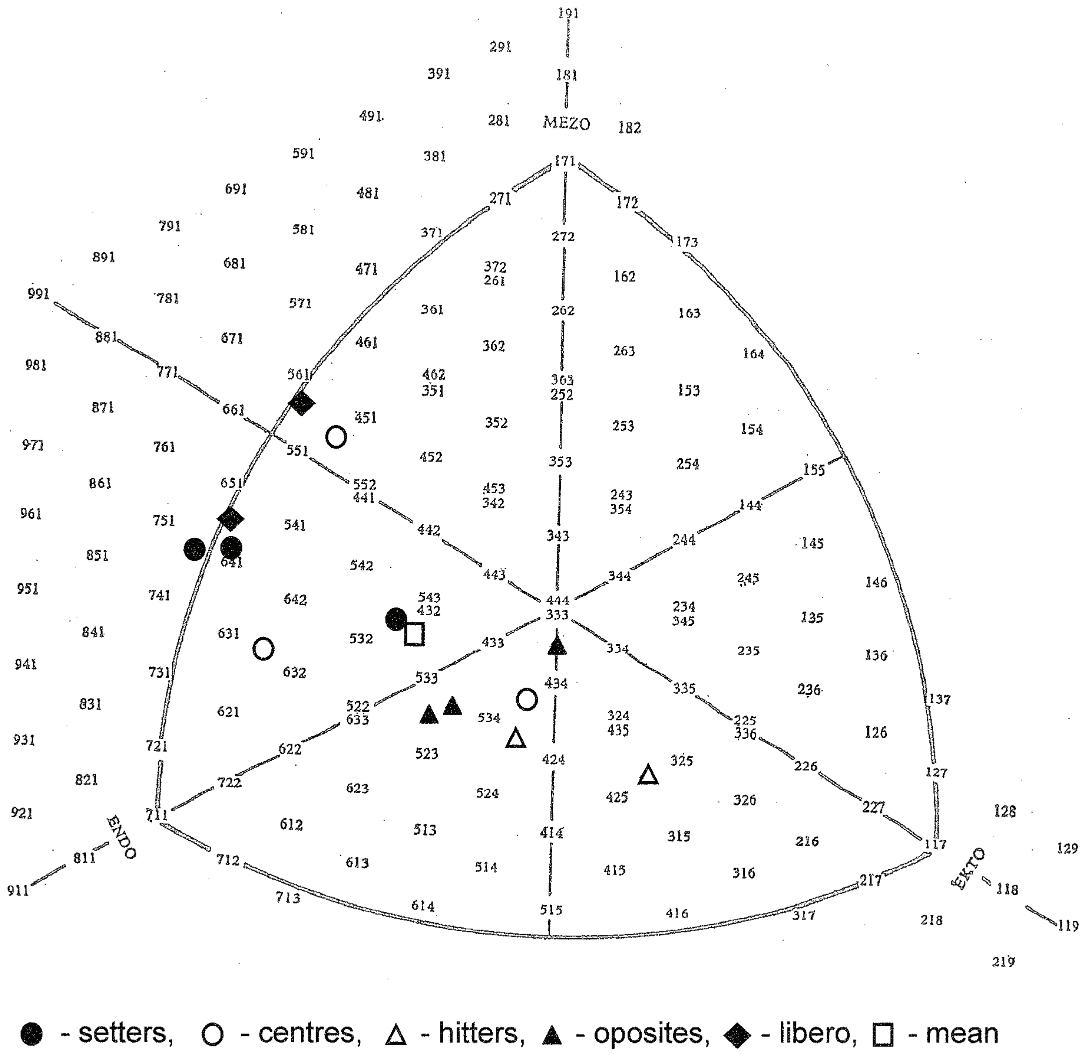

Fig. 2. Somatochart of female volleyball players (n = 14). The square denotes the mean value of somatotype

Differentiation of the mesomorphy and endomorphy components was also very large (ranges of 2.1–5.6 and 3.5–6.5, respectively).

Table 1. Mean values (±SD) of the sums of the maximal muscle torque of the right (R) and left (L) upper extremity (SUE), lower extremity (SLE), trunk (ST) and all ten muscle groups (TOTAL), and Pearson's linear correlation coefficients between muscle torque and endomorphy (ENDO), mesomorphy (MESO) and ectomorphy (ECTO)

Variables	Muscle torque [N·m]	ENDO	MESO	ECTO
SUER	200.6±27.3	0.53	0.50	–0.47
SUEL	174.0±20.9	0.43	0.64*	–0.51
SUE	374.6±46.9	0.50	0.57*	–0.50
SLER	731.1±107.9	0.31	0.08	–0.11
SLEL	709.0±95.1	0.04	–0.18	0.11
SLE	1440.1±198.0	0.19	–0.04	–0.01
ST	552.6±74.1	0.50	–0.05	–0.18
TOTAL	2367.4±272.6	0.36	0.05	–0.14

* $p < 0.05$.

Table 2. Mean values (±SD) of power output (P) and Pearson's linear correlation coefficients between power output and endomorphy (ENDO), mesomorphy (MESO) and ectomorphy (ECTO)

Load [% BW]	P [W]	ENDO	MESO	ECTO
2.5% BW	297.8±31.8	0.67*	0.65*	–0.64*
5.0% BW	530.1±48.8	0.79*	0.65*	–0.71*
7.5% BW	650.1±57.0	0.55*	0.75*	–0.74*
10.0% BW	675.5±82.7	0.19	0.32	–0.22
12.5% BW	565.3±121.7	0.21	0.27	–0.22

* $p < 0.05$.

Results of the strength measurements of players and relationships between the muscle torques and components of somatotype are presented in Table 1. Values of the sum of the muscle torques of right and left upper extremities (SUE) and sum of the muscle torques of left upper extremities (SUEL) were significantly correlated only with mesomorphic component: r = 0.57 and r = 0.64, respectively. The correlations between endomorphy, ectomorphy and the sums of muscle torques were not significant.

Absolute power outputs recorded for an external force–velocity relationship (mean values ±SD) are presented in Table 2. Only the power output measured in maximal cycle ergometer exercise bouts at increasing external loads equal to 2.5, 5.0 and 7.5% of BW was strongly correlated with endomorphy (positively), mesomorphy (positively) and ectomorphy (negatively). No significant correlations were found between power output measured at external loads equal to 10.0 and 12.5% of BW and all the somatotype components.

Mean (±SD) values of the maximal power (P_{max}) and height of rise of the body mass center measured at ACMJ, SPJ and CMJ jumps are presented in Table 3.

Table 3. Mean values (±SD) of the height of rise of the body mass center (h), maximal power (P_{max}) during akimbo counter-movement jump (ACMJ), counter-movement jumps (CMJ) and spike jumps (SPJ) on a forceplate and Pearson's linear correlation coefficients between power output and endomorphy (ENDO), mesomorphy (MESO) and ectomorphy (ECTO)

Variables		ENDO	MESO	ECTO
$P_{maxACMJ}$ [W]	1270.1 ± 267.4	0.06	0.73*	–0.60*
$P_{maxACMJ}$/body mass [W/kg]	17.20 ± 3.91	–0.28	0.43	–0.28
h_{ACMJ} [m]	0.300 ± 0.0	–0.30	0.11	0.05
P_{maxCMJ} [W]	1701.4 ± 216.8	0.06	0.78*	–0.62*
P_{maxCMJ}/body mass [W/kg]	23.08 ± 3.29	–0.07	0.18	–0.07
h_{CMJ} [m]	0.338 ± 0.036	–0.59*	0.11	0.11
P_{maxSPJ} [W]	2427.4 ± 443.3	0.10	0.46	–0.50
P_{maxSPJ}/body mass [W/kg]	33.04 ± 7.15	–0.24	0.16	–0.16
h_{SPJ} [m]	0.432 ± 0.55	–0.49	–0.09	0.22

* $p < 0.05$.

Mesomorphic and ectomorphic components were found to correlate significantly with values of maximal power measured during ACMJ (r = 0.73 and r = –0.60, respectively) and CMJ jumps (r = 0.78 and r = –0.62, respectively). Endomorphic component was found to correlate significantly with values of the height of rise of the body mass center measured during CMJ (r = –0.59). No significant correlation was found between maximal power, height of rise of the body mass center measured during SPJ jump and the somatotype components.

4. Discussion

Many studies have reported that the somatotype of volleyball players alter in relation to different level of performance (e.g., state, national, or international). It is believed that volleyball players of the highest level of performance are characterized by the ideal body build for this sport. The study on somatotype of 163 female volleyball players of the Greek National League revealed the mean somatotype of these players at 3.4-2.7-2.9 level [6]. Similar results were reported in the work of Gualdi-Russo and Zaccagni [4], who investigated the physique of 244 Italian elite female volleyball players and estimated the mean somatotype 3.0-3.3-2.9. The somatotypes of female volleyball players (in the above two studies) were significantly different in players at different level of performance (A1 vs. A2 leagues). The Greek and Italian female volleyball players from the A1 league were characterized by higher ectomorphy and lower endomorphy and mesomorphy in relation to their counterparts from A2 leaque [4], [6]. Together with the decreasing sport level of female volleyball teams, an increase in endomorphic and mesomorphic components and a decrease in ectomorphic component were observed. The highest values of endomorphic and mesomorphic components together with the lowest value of ectomorphic component were observed in somatotype of female volleyball teams that play at amateur level. Female volleyball players in our study had similar mean somatotype profile (4.9-3.5-2.5) to the somatotype of Italian amateur volleyball players (4.7-3.9-2.3) studied by Viviani and Baldin [30]. Female athletes examined by us had too high values of endomorphy and mesomorphy as well as too low values of ectomorphy when compared to the highest level (A1 leaque) female volleyball players from Greece [6] and from Italy [4], who had somatotypes 3.2-2.4-3.2 and 2.9-3.1-3.0, respectively. This lack of homogeneity of body build among the elite volleyball players, and occurrence of significant differences among athletes of different playing positions is interpreted as the result of varying physical requirements for different roles during a volleyball game [4]–[6]. For example, centers require endurance to oppose the attack, while setters need more speed and agility to organize the attack [5]. It is necessary to take the body type of volleyball player into consideration when designing individualized, position specific training programs. In our study, we have also found large diversity of players' somatotype associated with different playing positions in the game. Somatotypes of volleyball players on somatochart seemed to divide players in relation to function in the game. The most divergent groups were libero and hitters. These latter showed a considerable similarity of body build, while the centers proved to be the most diverse group. Somatotypes of centers were located between liberos and setters on somatochart. Those three were forming one group, and hitters and opposites created the other one. Liberos and setters had the lowest ectomorphy and the highest endomorphy, while the hitters and opposites had the highest ectomorphy and the lowest endomorphy and mesomorphy.

There is not much research regarding a physique suitable for a certain playing position in female volleyball. The studies on somatotype of elite female volleyball athletes playing on different positions [4], [6] can provide the pattern of body build in relation to different demands of the various game roles. In elite Greek female volleyball players, somatotypes of hitters and setters were characterized as balanced endomorphs (3.5-3.0-2.7 and 3.6-2.5-3.0, respectively), centres and opposites were characterized as endomorph-ectomorphs (3.4-2.4-3.1 and 3.4-2.4-3.5, respectively) and liberos as mesomorph-endomorphs (3.1-3.3-2.6) [6]. The somatotype characteristics of female volleyball players playing on different positions differ very clearly in our study, as compared with counterparts' model somatotypes of elite volleyball players from the study cited above. The body build of female volleyball players participating in this study was not suitable for a desired pattern in relation to certain position in the game, probably because of their low sport level, lack of proper selection process and adequate training methods.

Ideal body build of elite volleyball players for certain functions on playground corresponds to motor and physiological requirements for such position in the game. Knowledge about the relationships between characteristics of body build and strength, power and jump ability provides the basis for successful sport selection and effective, proper training program. Quarrie and Wilson [22] studied the relationships among anthropometric, strength and power measures of rugby union forwards and their individual force production in the scrum. The body mass and somatotype of the players were significantly related to the force they applied in the scrum. Heavier players, and those who were more endo-mesomorphic, were capable of producing higher individual scrummaging forces than players who were lighter or more ectomorphic. All three components of somatotype (endomorphy, mesomorphy, ectomorphy) correlated significantly with scrum force of rugby players. In the study of Lewandowska et al. [32], the values of sum of muscle torque of right and left upper extremities (SUE), sum of muscle torque of right and left lower extremities (SLE), sum of muscle torque of the trunk (ST) and TOTAL in judo athletes were significantly correlated with mesomorphic component: r = 0.68, 0.80, 0.71 and 0.78, respectively. Ectomorphic component correlated significantly with the values of SUE, SLE, ST and TOTAL: r = –0.69, –0.81, –0.71 and –0.79, respectively. The correlations between endomorphy and the sums of muscle torque were not significant. Power output measured at external loads amounting to 2.5, 5.0, 7.5, 10.0 and 12.5% BW was strongly correlated with both mesomorphy (positively) and ectomorphy (negatively) in judoists. No significant correlation between power output and endomorphy was found [32]. The maximal power and height of rise of the body mass center measured at ACMJ and CMJ jumps did not correlate with somatotype components in judo athletes (unpublished data). In our study, the statistically significant, positive correlation have been found only between values of SUE, SUEL and mesomorphic component: r = 0.57 and r = 0.64, respectively. The correlations between endomorphy, ectomorphy and the sums of muscle torques were not significant. In female volleyball players only the power output measured in maximal cycle ergometer exercise bouts at increasing external loads equal to 2.5, 5.0 and 7.5% of BW was strongly correlated with endomorphy (positively), mesomorphy (positively) and ectomorphy (negatively), too. No significant correlations were found between power output measured at external loads equal to 10.0 and 12.5% of BW and all the somatotype components. Mesomorphic and ectomorphic components correlated significantly with values of maximal power measured during ACMJ and CMJ jumps in volleyball players unlike in judo athletes. Large score of mesomorphy reflects high massiveness of the skeleton and musculature and the high level of ectomorphy shows considerable slenderness of the body. It is worth noting that the correlation between the height of the jump on the force plate (AMCJ, BMCJ and CMJ) and the score of ectomorphy and endomorphy was negative. Weak, but positive correlations were found between the scores of endomorphy and muscle torques of upper and lower extremities and trunk, and also a statistically significant, positive correlation between endomorphy and the power output measured on the cycle ergometer (at low external loads) was revealed. These results seem to agree with findings of other authors, who noticed positive correlation between body mass or/and endomorphy and sport results of athletes in disciplines demanding meso-endomorphic body build [22], [33], [34]. Janiak et al. [33] found positive correlation between muscle torques or their sum and body mass in rowers. The mass of body fat is a component of total body mass, which could explain positive correlation between endomorphy and the strength and power output. Such result was obtained in judoists [35], who were characterized by moderate level of fatness in comparison to athletes in other sports [36]. Krawczyk et al. [36] studied top class athletes representing various sports, in the context of their body components (LBM – lean body mass and fat content). They found that volleyball players belong to a group of athletes who are characterized by relatively high fatness as compared to athletes in other sport disciplines. On the other hand, investigations on elite volleyball players conducted by Gualdi-Russo and Zaccagni [4] and Malousaris at al. [6] showed that somatotypes of competitors who achieved better results (A1 vs. A2 leaques) were characterized by higher ectomorphy and lower endomorphy and mesomorphy. The contribution of mesomorphy in somatotype represents the lean body mass (LBM) level, and the endomorphy reflects body fatness. Body composition was found to play a significant role in the anaerobic power, aerobic capacity and sport results of athletes. Anaerobic power in Olympic weight lifters showed significant positive correlation with LBM and negative one with body fat [37]. In our study, mesomorphy correlated significantly with anaerobic power, too.

5. Conclusions

The results indicate that only the muscle torques of upper extremities correlate significantly with mesomorphic component. Power output developed on a cycle ergometer at increasing external loads equal to 2.5, 5.0 and 7.5% of BW correlates significantly with all the components of somatotype. Maximal power measured during ACMJ and CMJ jump correlate significantly with values of mesomorphic and ectomorphic component. It can be assumed that volleyball players' anthropometric characteristics can, in some way, influence their level of performance.

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