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# Influence of anthropometric profile on physical performance in elite female volleyballers in relation to playing position

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**Abstract**

***Introduction:*** **The anthropometric profile, specifically body composition, plays a crucial role in the physical performance of volleyballers. Since there are varying positions in volleyball, it is likely that differences exist in anthropometric and physical performance profiles among players due each role's specific physical requirements.**

***Objectives:*** **The aims of this study were to analyze the anthropometric and physical performance profiles of elite female volleyballers, to determine any differences in these features among different playing positions. A further aim was to examine any relationship between anthropometric measures and measures of performance.**

***Methods:*** **This study assessed 42 female professional volleyball players (Age: 27.2±5.4 years). Players were categorized according to playing position: middle blockers (n=12), opposite hitters (n=6), outside hitters (n=12), setters (n=8), and liberos (n=4). Anthropometric measurements assessed were: height, weight, fat mass (5 skinfolds) musculoskeletal mass (5 corrected girths). Additionally, the physical performance parameters examined were: jump tests (vertical-jump and spike-jump), speed, agility, and strength tests (crunches test and overhead medicine ball throw).**

***Results:*** **In terms of height middle blockers were the tallest (186.5±1.4 cm), while liberos were the shortest (166.7±8.1 cm). There were significant differences in body mass among positions (p<0.05) with opposite hitters the heaviest (73.6±5.5 kg), and liberos the lightest (58.2±5.7 kg). Liberos displayed significantly lower (p<0.05) chest, mid-thigh, calf and waist girths and musculoskeletal mass any other position. For skinfolds (fat mass) the significant differences were as follows: liberos < setters for abdominal, setters < middle blockers for calf and opposite hitters < setters for mid-thigh. Finally,**

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## INFLUENCIA DE LA COMPOSICIÓN CORPORAL EN EL RENDIMIENTO FÍSICO DE JUGADORAS DE VOLEIBOL EN FUNCIÓN DE SU POSICIÓN DE JUEGO

**Resumen**

***Introducción:*** **La composición corporal (CC) desempeña un papel crucial en el rendimiento físico del voleibol. Debido a la existencia de diferentes posiciones de juego, es probable que existan diferencias en los perfiles antropométricos y fisiológicos de los jugadores por las funciones específicas de cada posición.**

***Objetivos:*** **Los objetivos de este estudio fueron analizar el perfil antropométrico, la composición corporal y el rendimiento físico de jugadoras de voleibol de élite y para determinar las diferencias en estas características entre las diferentes posiciones de juego. Otro objetivo fue examinar la relación entre las medidas antropométricas y el rendimiento físico.**

***Métodos:*** **Este estudio evaluó 42 jugadoras de voleibol profesional (Edad: 27,2±5,4 años). Las jugadoras fueron clasificadas de acuerdo a su posición de juego: centrales (n=12), opuestas (n=6), receptoras (n=12), colocadoras (n=8) y líberos (n=4). Las medidas antropométricas evaluadas fueron: altura, peso, masa grasa (5 pliegues cutáneos) y masa musculo-esquelética (5 perímetros corregidos). Además, diferentes parámetros de rendimiento físico fueron examinados: test de salto (salto vertical, potencia de salto), velocidad, agilidad y fuerza (abdominales y lanzamiento de balón medicinal).**

***Resultados:*** **En cuanto a la altura, las centrales fueron las más altas (186,5±1,4 cm), mientras que las líberos las más bajas (166,7±8,1 cm). Hubo diferencias significativas en la peso entre las diferentes posiciones (p <0,05) con las opuestas como las más pesadas (73,6±5,5 kg), y líberos las que menos (58,2±5,7 kg). Las líberos mostraron (p<0,05) un perímetro corregido de pecho, muslo medio, pantorrilla y cintura, así como de masa musculo-esquelética significativamente menor que cualquier otra posición. En cuanto a los pliegues cutáneos (masa grasa) se observaron las siguientes diferencias significativas: líberos < colocadoras para el abdominal, colocadoras < centrales para la pantorrilla y las opuestas < colocadoras en el muslo medio. Finalmente, hubo correlaciones positivas significativas (p<0,05) entre las**

significant positive correlations ($p<0.05$) were found between the jump tests and the mid-thigh and calf corrected girth.

***Conclusion:*** **These findings suggest that height offers a performance advantage for middle blockers, whereas lower body mass, especially a lower fat mass, seems to be advantageous for setters and liberos. Additionally, high musculoskeletal mass together with an appropriate fat mass are advantageous for opposite and outside hitters.**

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Key words: *Body composition. Sport performance. Volleyball.*

**pruebas de salto y los perímetros corregidos de muslo medio y de pantorrilla.**

***Conclusión:*** **Estos hallazgos sugieren que la altura ofrece una ventaja de rendimiento para las centrales, mientras que una masa corporal más baja, especialmente una menor masa grasa, parece ser una ventaja para las colocadoras y líberos, mientras que una alta masa musculo-esquelética, junto a una adecuada masa grasa es una ventaja para las opuestas y receptoras.**

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Palabras clave: *Composición corporal. Voleibol. Rendimiento deportivo.*

## Abbreviations

∑5SF: Sum of 5 skinfolds (Triceps, abdominal, subscapular, mid-thigh and calf).
BC: Body composition.
BM: Body mass.
BMI: Body mass index.
FM: Fat mass.
ISAK: International Society for the Advancement of Kinanthropometry.
MM: Musculoskeletal mass.
OMBT: Overhead Medicine Ball Throw.
PSJ: Absolute mechanical power during spike-jump.
PVJ: Absolute mechanical power during vertical-jump.
SJ: Spike-jump.
VJ: Vertical-jump.

## Introduction

Volleyball is a team sport which requires intermittent bouts of high intensity exercise, followed by periods of low intensity activity (i.e. walking or standing)[1,2]. Thus, during a volleyball match, players are involved in various performance movements such as; defensive and offensive jumps, blocks, knockouts, and sprints where power, strength, agility, and speed are required[2]. As a result of these requirements optimal physical performance is necessary[3].

Moreover, research has demonstrated that body composition (BC) plays a crucial role in a volleyball athlete's performance[2] . Further, it has been postulated that excess fat mass (FM) negatively affects athletic performance and increases energy demands[4] by acting as a dead weight in activities where the body mass (BM) must be repeatedly lifted against gravity during locomotion and jumping[5]. However, increases in musculoskeletal mass (MM) are seen as a positive indicator of sports performance, by contributing to increased power production during exercise as well as greater size and strength with high dynamic and static loads[4].

A volleyball squad is comprised of 12 players and various positions. The positions are broadly defined as setters, hitters (outside and opposite), middle blockers, and liberos (players specialized in defensive skills). Each position plays a specific and different role during a volleyball match[6]. Considering the specialized and different role of each position, it is likely that differences exist and are desired in anthropometric and physiological profiles among the playing positions to optimize performance; however these anthropometric profiles are currently not well known[7]. Furthermore, determining anthropometric and physiological differences among positions is currently of great importance due to demanding competition requirements and evolving tactical play strategies, which led to even further specialization of positions[8].

Previous research has examined specificity of physiological profiles of athletes in a variety of sports[9-12]. In volleyball the majority of studies examining physiological profiles have focused on males[8, 13] or junior volleyball players[1,6,13-15]. For example, Marques et al.[13] showed differences in anthropometric and strength characteristics of elite male volleyball players according to playing position. Therefore, it is reasonable to suggest that similar differences might exist in elite female volleyball players. However, there is a paucity of research on performance characteristics of elite volleyball players[2,13]. Thus, the first aim of this study was to analyze anthropometric measures (height, weight, BC, skinfolds and girths) and physical performance (speed, agility and strength characteristics) of elite female volleyball players and to determine the differences in these characteristics according to playing position. The second aim was to examine the relationship between anthropometric measures and physical performance.

## Methods

### *Experimental Approach to the Problem*

The proposed study was designed to examine differences in anthropometric, and physical performance among playing positions of elite volleyballers. Participants were characterized by position and subjected to a battery of physical performance tests and had anthropometric measurements assessed. To undergo the testing procedures participants reported to the laboratory on only one day during the competitive season.

### *Participants*

Forty-two Spanish Super-League female volleyball players (27.2 ± 5.4 years), with more than 3 years of training experience as professional players, were evaluated for this study (Table I). Players were categorized according to playing position as follows: middle blockers (n = 12), opposite hitters (n = 6), outside hitters (n = 12), setters (n = 8), and liberos (n = 4). Prior to the study players trained a minimum of 9 sessions per week for 90 minutes per session, and competed in match play a minimum of once per week. All players represented one of two teams who are consistently ranked as 2 of the top elite female volleyball teams in Spain. Additionally, 62% of the players who participated in this study are currently or have previously represented a national team (Spain-16 players; Argentina-2 players; Brazil-6 players; and Serbia-2 players). The players participated voluntarily and gave written informed consent. The study was designed in compliance with the recommendations for clinical research of the Declaration of Helsinki of the World Medical Association (2008) and reviewed and approved by the Basque Country University ethic committee.

### *Body Composition and anthropometric measures*

Anthropometric measurements were taken following "The International Society for the Advancement of Kinanthropometry" (ISAK) protocol[16]. Additionally, all anthropometric measurements were taken by the same investigator, who was certified in anthropometric testing (ISAK level 2)[16]. Height (cm) was measured using a SECA® measuring rod, with a precision of 1

**Table I**
*Body composition and anthropometric variables of the professional female volleyball players (n=42).*

| | *Middle blockers (n=12)* | *Liberos (n=4)* | *Setters (n=8)* | *Opposite hitters (n=6)* | *Outside hitters (n=12)* |
|---|---|---|---|---|---|
| **Basic variables** | | | | | |
| Age (years) | 29.4±7.4 | 32.1±7.0 | 21.4±1.2[ab] | 24.7±7.2 | 28.0±3.2 |
| Height (cm) | 186.5±1.4 | 166.7±8.1[a] | 171.2±2.9[a] | 180.7±0.6[abc] | 180.1±2.9[abc] |
| Body Mass (kg) | 71.0±5.6 | 58.2±5.7[a] | 65.0±4.5 | 73.6±5.5[b] | 71.3±5.4[b] |
| BMI (kg/m$^2$) | 20.7±1.3 | 20.9±0.8 | 22.1±0.8 | 22.8±1.6[a] | 22.0±1.0 |
| **Corrected girth** | | | | | |
| Relax arm (cm) | 22.6±1.1 | 21.7±0.7 | 22.6±0.5 | 22.8±0.6 | 23.3±1.8 |
| Chest (cm) | 82.0±1.5 | 77.5±1.9[a] | 80.3±1.5 | 83.7±3.1[b] | 82.3±3.2[b] |
| Mid-thigh (cm) | 43.8±1.3 | 41.3±2.0 | 46.0±1.7[b] | 44.8±2.5 | 45.4±2.4[b] |
| Calf (cm) | 32.0±1.8 | 28.9±0.35[a] | 33.1±0.4[b] | 32.1±0.7[b] | 33.6±0.9[ab] |
| Waist (cm) | 65.1±2.0 | 57.5±0.9[a] | 62.7±1.1[b] | 63.0±0.5[b] | 64.5±2.3[b] |
| MM Lee (kg) | 30.1±1.6 | 23.8±0.3[a] | 28.9±0.6[b] | 29.1±0.5[b] | 30.5±1.9[b] |
| **Skinfolds** | | | | | |
| Triceps (mm) | 14.6±4.7 | 13.8±1.9 | 12.3±4.3 | 14.3±2.1 | 13.0±1.3 |
| Subscapular (mm) | 11.7±4.8 | 11.4±1.2 | 13.9±5.0 | 11.8±0.3 | 9.6±1.5 |
| Abdominal (mm) | 17.5±8.8 | 10.1±1.9 | 23.7±7.8[b] | 18.1±1.5 | 14.5±5.4 |
| Mid-thigh (mm) | 20.3±4.0 | 22.3±4.5 | 16.3±3.5 | 25.2±6.5[c] | 19.6±2.7 |
| Calf (mm) | 12.4±4.8 | 10.3±2.1 | 7.7±0.8[a] | 12.6±2.3 | 11.4±0.8 |
| ∑5SF (mm) | 76.5±25.0 | 67.9±10.9 | 73.7±20.5 | 82.0±10.8 | 68.2±9.2 |

Data expressed in mean ± standard deviation.
BMI: Body mass index; MM: Musculoskeletal mass; ∑5SF: Sum of 5 skinfolds (triceps, subscapular, abdominal, mid-thigh and calf).
Significantly differences among playing positions ($p$<0.05):
a: vs. Middle Blockers.
b: vs. Liberos.
c: vs. Setters.
d: vs. Opposite Hitters.

mm and a range (130-210 cm), while BM (kg) was assessed by a SECA® model scale, with a precision of 0.1 kg and a range (2 kg - 130kg). Body mass index (BMI) was calculated using the formula BM/height$^2$ (kg/m$^2$). The sum of 5 skinfolds (∑5SF) (mm) (triceps, abdominal, subscapular, mid-thigh and calf) was calculated, using a Harpenden® skinfold caliper, with a precision of 0.2 mm. Girths (cm) (relaxed arm, chest, waist, mid-thigh and calf girth) were measured with a metallic Lufkin® measuring tape (W606PM), with a precision of 1 mm. To calculate girth in mm, the Lee[17] equation was utilized. Arm, chest, waist, mid-thigh, and calf girth were all corrected for the skinfold at the site using the following formula: [corrected girth = girth – (π x skinfold thickness at the site)]. Arm girth was corrected for triceps skinfold, chest girth corrected for subscapular skinfold, mid-thigh girth corrected for front thigh skinfold, and calf girth was corrected for medial calf skinfold. The corrected girth was calculated as it has been previously shown to be a better indicator of musculoskeletal size at each site[9].

*Physical Performance Tests*

To evaluate physical performance, a battery tests representing different aspects of volleyball physical fitness were conducted. These tests were conducted on one day in the 11th week of the season (mid-December), which was representative of their training and competition load. None of volleyball players had any previous history of injury or disease, nor was taking medications during the study. The testing session took place in an indoor sports hall with standard conditions (temperature: 21ºC and humidity: 60%). Test were performed following a 20-minute standardized warm-up consisting of 10-min. jogging, 5-min. jumping jacks, and 5min. of jumping rope, accelerations and injury prevention drills (i.e. general movements and dynamic/static stretching techniques). Players underwent the following physical performance tests.

*Jump test*

Volleyball players require high levels of lower-body muscular power to perform the spiking, blocking, and jumping tasks that are frequently executed during a match. Therefore, the vertical-jump test and the spike-jump test[6] were administered using a Yardstick vertical-jump device (Swift Performance Equipment, New South Wales, Australia) to examine lower body muscular power. In these tests the players were requested to stand with feet flat on the ground, extend their arm and hand, and mark the standing-reach height. After each jump participants were instructed to spring upward and touch the Yardstick device at the highest possible point. Jump height was calculated as the distance from the highest point reached during standing and the highest point reached during each type of jump. The jump height was measured to the nearest 1 cm, with the highest value obtained from 2 trials.

a) Vertical-jump (VJ): The jump began from a crouch position. No specific instructions were given regarding the depth or speed of the countermovement. The intra-class correlation coefficient for test-retest reliability and typical error of measurement for the VJ test were 0.96 and 2.9%, respectively.

b) Spike-jump (SJ): Players were then instructed to take a run-up or spike approach and leap as high as possible off both legs. The intra-class correlation coefficient for test-retest reliability and typical error of measurement for the SJ test was 0.99 and 2.2%, respectively.

*Absolute mechanical power*

Absolute mechanical power during vertical-jump (PVJ) and spike-jump (PSJ) was calculated in watts with the following formula[18]:

$$\text{PVJ and PSJ} = BM \bullet g \bullet (2 \bullet g \bullet h)^{1/2}$$

In which BM is in kg, “g” is the acceleration of gravity in m• s$^{-2}$, and “h” is the jumping height in meters.

*Agility*

Continuous game actions require the ability to rapidly accelerate, decelerate, and change direction.[6] The agility of players was evaluated with 9-3-6-3-9 m sprint with 180º turns test[19] (Fig. 1) using dual-beam electronic timing gates (Swift Performance Equipment, New South Wales, Australia). The timing gates were

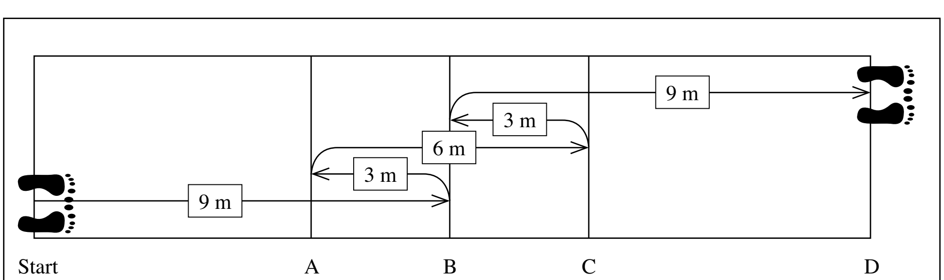


*Fig. 1.—Layout of the sprint 9-3-6-3-9 m with 180º turns.*

positioned at the starting line and at 21m, also 4 cones were placed at distances of 6m (A), 9m (B), 12m (C) and 21m (D). After the investigator gave a start signal players ran 9m from the starting line to cone B. Having touched cone B with one foot, players then made either a 180º left or right turn; however, following turns were made in the same direction. The players then ran 3m to cone A, made another 180º turn, and ran 6m forward. Then, they made another 180º turn (C) and ran another 3m forward (B), before making the final turn and running the final 9m to the finish line (D). Agility times were measured to the nearest 0.01 second, with the fastest value of 2 trials utilized for analysis.

*Speed*

The ability of a player to move quickly to achieve a position to receive a pass or to block a shot from an opponent is fundamental in volleyball[6]. Therefore, running speed of players was evaluated with a 2 x 18m sprint test (Fig. 2) using the same dual-beam electronic timing gates as in the agility test. The timing gate was positioned at the starting line and at a cone placed 18m from the start. Players were instructed to run as quickly as possible to complete the 18m-distance and then return to standing start point. Speed was measured to the nearest 0.01 second, and the fastest speed of 2 tests was used. There was a 3-minute recovery period between the 2 trials.

*Crunch test*

To evaluate abdominal muscle strength and endurance, players performed a 1-minute bent-knee sit-up test (crunch test). Participants' feet were held firmly on the floor by the investigator. Players laid flat on their back with knees flexed and feet on the floor. Participants then crossed their arms over their chest and placed their hands placed on the opposite shoulders. From this position players completed as many sit-ups as possible in 1-minute[20] .

*Overhead Medicine Ball Throw (OMBT)*

OMBT was used to evaluate upper-body muscular power[6]. While standing, players held a 3kg-medicine ball in front of the body using both hands with arms relaxed. Players were instructed to throw the ball over their head and behind them as far as possible. Thus, a backward countermovement was allowed during the action. Five trials were performed with a 1-minute rest interval between each trial. An average of the 4 best throws was used for analysis. The distance of the throw was recorded to the nearest 1cm. The ball throwing distance showed an intra-class correlation coefficient (ICC) of 0.93 and coefficient variations (CV) of 6.4%.

*Statistical analysis*

SPSS (v22.0; SPSS, Inc., Chicago, IL, USA) was used for statistical analysis. The standard statistical parameters (mean ± SD) were calculated for anthropometric data and physical performance tests. Normality was tested using a Shapiro-Wilk test (n<50). Therefore, a parametric analysis, one-way analysis of variance (ANOVA), was used to determine significant differences among positions in anthropometric and performance characteristics with a Bonferroni post hoc comparison. Bivariate correlation analysis among age, anthropometric data and physical performance tests were performed using a Pearson correlation analysis. The level of significance was set at $p<0.05$.

## Results

Tables 1 and 2 display anthropometric data and physical performance test results for each specific playing position. Significant ($p<0.05$) differences were found in all anthropometric variables and physical performance tests among all groups with the exception of the relaxed arm corrected girth, the triceps and subscapular skinfolds, (∑5SF) and the crunch test.

Significant differences ($p<0.05$) in height among every playing position were found. Middle blockers were the tallest (186.5±1.4 cm), while liberos were the shortest (166.7±8.1 cm). Further, the analysis revealed differences in body weight with opposite hitters being the heaviest (73.6±5.5 kg), whereas liberos were the lightest (58.2±5.7 kg). Regarding corrected girths and MM, the liberos showed significantly ($p<0.05$) lower chest, mid-thigh, calf and waist corrected girths and MM than the other positions. Regarding skinfolds, significant differences ($p<0.05$) only existed between set-

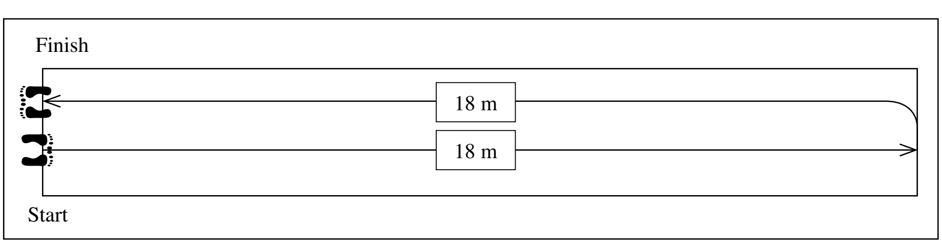


*Fig. 2.—The running speed test with a 2 x 18 m sprint.*

ters vs. liberos (abdominal), setters vs. middle blockers (calf) and opposite hitters vs. setters (mid-thigh).

Concerning the jump tests (Table II), liberos showed a significantly lower VJ (p<0.05) than the setters and opposite hitters. Additionally, liberos had significantly lower (p<0.05) PVJ and PSJ than all other positions. Furthermore, middle blockers and liberos presented lower SJ than the setters and outside hitters. Regarding the speed test, the middle blockers were significantly slower (p<0.05) than the rest of the team. The setters were the most agile compared to all other positions (p<0.05); further data showed the middle blockers to be significantly less (p<0.05) agile than liberos and outside hitters. Also, the outside hitters recorded the farthest OMBT with opposite hitters having the 2$^{nd}$ farthest OMBT.

Data showing correlations between anthropometric variables and physical performance tests can be seen in table III. Significant positive correlations (p<0.05) were found between the jump tests (VJ and SJ) and the mid-thigh and calf corrected girth. Further, both jumps (VJ and SJ), showed negative correlations with age, PVJ and PSJ. Likewise PVJ and PSJ presented significant positive correlations with height, BM, BMI and all corrected girth measurements. However, only PSJ showed a significant positive correlation with skinfold measurement, except the abdominals. Evaluation of speed did not show significant positive correlations with mid-thigh and calf corrected girth nor with the abdominal skinfold. However, the agility test showed a significant positive correlation with age, height, BM, waist corrected girth, MM and mid-thigh and calf skinfolds. The crunch test showed a significant negative correlation with subscapular and abdominal skinfolds and the $\sum$5SF. Finally, the OMBT showed a significant positive correlation with BMI, relaxed arm, mid-thigh and calf corrected girths and MM.

## Discussion

In volleyball, each playing position requires a varying skill set, which should be reflected in the player's anthropometric and performance profile. Liberos and setters were found to be the shortest players on the team, whereas the liberos were the lightest players. Further, these results are consistent with those regarding male volleyball players[13,21]. Carbajal et al.[22] also showed similar results in Cuban female volleyball players, however, a limitation of this study was that profiles of the liberos and opposite hitters were not analyzed. In addition, recent investigations with elite male volleyball players indicated a trend toward differences in height and BM among positions[13]. These differences in height and BM could be the result of different technical and tactical demands placed on players in different positions[14]. In this sense positive correlation were found between height and BM with speed (r = 0.691; r = 0.720) and agility (r = 0.670; r = 0.474), indicating that the tallest and heaviest players of the team (middle blockers and outside and opposite hitters) showed the slowest and least agile performance values. These findings are in consonance with coaches and sport researchers who believe that taller and heavier athletes, such as middle blockers, are inherently slower at performing rapid movements, which are necessary in volleyball[8].

According to the demands of elite match conditions and the physical and conditioning characteristics of elite players, volleyball coaches and sport research-

**Table II**
*Physical Performance values of the professional female volleyball players (n=42).*

| | *Blockers (n=12)* | *Liberos (n=4)* | *Setters (n=8)* | *Hitters (n=6)* | *Hitters (n=12)* |
|---|---|---|---|---|---|
| Vertical Jump (cm) | 32.0±3.0 | 28.0±3.0 | 36.0±3.0[b] | 39.0±4.0[b] | 35.0±7.0 |
| Power vertical jump (W) | 1737±126 | 1217±41[a] | 1692±131[b] | 1867±70.4[b] | 1826±140[b] |
| Spike jump (cm) | 45.0±3.0 | 46.0±2.0 | 55.0±4.0[ab] | 52.0±4.0 | 55.0±5.0[ab] |
| Power spike jump (W) | 2080±199 | 1569±34[a] | 2097±178[b] | 2155±31[b] | 2291±167[ab] |
| Speed (seg) | 7.51±0.29 | 7.24±0.06 | 7.13±0.20[a] | 7.25±0.12 | 7.37±0.26 |
| Agility (seg) | 8.86±0.11 | 8.39±0.26[a] | 7.88±0.28[ab] | 8.47±0.22[c] | 8.42±0.34[ac] |
| Crunch test (n) | 27.8±3.2 | 29.8±1.0 | 27.3±3.3 | 32.8±1.0 | 28.7±4.0 |
| Overhead Medicine Ball Throw (m) | 7.19±0.21 | 7.09±0.14 | 7.44±0.13 | 8.22±0.07[abc] | 8.79±0.29[abcd] |

Data expressed in mean ± standard deviation.
Significantly differences among playing positions ($p$<0.05):
a: vs. Middle Blockers.
b: vs. Liberos.
c: vs. Setters.
d: vs. Opposite Hitters.

**Table III**
*Correlation between physical performance, body composition and anthropometric variables of the professional female volleyballers*

| | *Vertical Jump* | *Power Vertical Jump* | *Spike Jump* | *Power Spike Jump* | *Speed* | *Agility* | *Crunch Test* | *OMBT* |
|---|---|---|---|---|---|---|---|---|
| Age | **-0.421*** | **-0.388*** | **-0.447*** | **-0.356*** | 0.067 | **0.369*** | 0.182 | 0.144 |
| Height | -0.128 | **0.569**** | -0.282 | **0.528*** | **0.691**** | **0.670**** | -0.164 | 0.102 |
| Body mass | 0.087 | **0.746**** | 0.002 | **0.820**** | **0.720**** | **0.474*** | -0.256 | 0.288 |
| BMI | 0.610** | **0.467*** | **0.422*** | **0.644**** | 0.207 | -0.184 | -0.195 | **0.345*** |
| **Corrected girth** | | | | | | | | |
| Relax Arm | -0.251 | **0.346*** | 0.012 | **0.509*** | **0.335*** | 0.272 | -0.243 | **0.352*** |
| Chest | 0.213 | **0.733**** | 0.105 | **0.675**** | **0.438*** | 0.327 | 0.244 | 0.298 |
| Mid-thigh | **0.419*** | **0.744**** | **0.482*** | **0.743**** | 0.124 | -0.123 | -0.123 | **0.354*** |
| Calf | **0.369*** | **0.756**** | **0.527*** | **0.808**** | 0.172 | -0.087 | -0.087 | **0.530*** |
| Waist | -0.024 | **0.748**** | -0.016 | **0.775**** | **0.612**** | **0.462*** | -0.289 | 0.231 |
| MM Lee (kg) | 0.084 | **0.821**** | 0.179 | **0.879**** | **0.551**** | **0.335*** | -0.268 | **0.369*** |
| **Skinfolds** | | | | | | | | |
| Triceps | -0.136 | 0.300 | -0.070 | **0.353*** | **0.552**** | 0.243 | -0.288 | -0.197 |
| Subscapular | -0.216 | 0.164 | 0.004 | 0.291 | **0.391*** | -0.035 | **-0.514*** | **-0.369*** |
| Abdominal | -0.138 | 0.296 | 0.074 | **0.415*** | 0.322 | -0.075 | **-0.596**** | -0.222 |
| Mid-thigh | **-0.337*** | 0.072 | -0.282 | 0.139 | **0.462*** | **0.413*** | -0.136 | -0.021 |
| Calf | -0.276 | 0.274 | -0.240 | **0.339*** | **0.661**** | **0.490*** | -0.301 | -0.003 |
| ∑5SF | -0.265 | 0.286 | -0.096 | **0.402*** | **0.562**** | 0.201 | **-0.506*** | -0.215 |

$^{*}p<0.05$; $^{**}p<0.001$. OMBT: Overhead Medicine Ball Throw; BMI: Body mass index; MM Lee: Musculoskeletal mass by Lee equation; ∑5SF: Sum of 5 skinfolds (triceps, subscapular, abdominal, mid-thigh and calf).

ers should aim to select taller athletes with well-developed speed characteristics[8]. Additionally, BC is an important consideration as Fleck et al.[23] concluded that a lower FM percentage is key to the success of national level volleyball players, with skin folds being the best indicator of body FM[16]. The ∑5SF among positions showed a significant differences and positive correlations between FM, triceps and calf skinfolds and speed, similar to previous studies with elite female volleyball players[21,24,25]. Additionally, we found a significant differences and positive correlations between subscapular and mid-thigh skinfolds with speed (r = 0.391; r = 0.462 respectively), and calf and mid-thigh skinfolds with agility (r = 0.490; r = 0.413 respectively). Furthermore, a negative correlation between abdominal and subscapular skinfolds and the crunch test was present (r = -0.596; r = -0.514 respectively). These data could explain the importance of FM of implicated body zones in these sport actions, showing than a greater amount of fat in areas involved, resulting in deleterious performance effects. Thus, future researchers should analyze this possible relationship.

In contrast, to FM, increased MM is a positive indicator of sports performance, in terms of power production by providing a greater absolute size and strength for resistance with high dynamic and static loads[4]. Calculations of MM should be accomplished with different equations or with the corrected girth, due to the strength of this strategy in accurately portraying MM[9]. To our knowledge, data does not exist which compares the MM of volleyball players among different playing positions. Our results revealed that liberos had significantly lower MM ($p<0.05$) than the rest of playing positions and similar data were obtained in the corrected girth, possibly due to a lower BM of liberos. Moreover, we found a high positive correlation in MM with both power jump (PVJ: r = 0.821 and PSJ: r = 0.829) and speed (r = 0.551), and slight correlation with agility (r = 0.335) and OMBT (r=0.369). These results confirm the significant differences in physical performance tests among liberos compared to other playing positions. Interestingly, Granados et al. found that a higher fat-free mass in female handball elite players provided them with greater power and muscular potential compared with amateur players[18].

Measuring VJ and SJ are important since jumping is essential for performing blocking and spiking skills in a volleyball match[3]. Further, a "critical height" above the net exists for an optimal spiking and blocking, therefore, players who are able to reach this threshold have an advantage over players who fail to reach it[26]. Thus, the middle blockers, due their height, do not require as high a jump as the other playing positions with the exception of liberos (defensive specialists) who usually do not perform jumps for blocking and spiking[8]. The results obtained confirmed this theory, showing that the liberos have values significantly lower in both jumps than the other playing positions, while the middle blocker showed a jump height lower than setters and both hitters. Sattle et al.[27] reported similar results, however, Marques et al.[13] stated that opposite hitters had a lower jump than middle blockers. These results are controversial because the opposite hitters need a powerful jump for offensive actions from the defensive zone.

Additionally, setters and opposite hitters were found to have a higher running jump compared to any other position ($p<0.05$). This skill is essential to the position as data has shown setters to perform 11–21 jumps per set to pass block and assist hitters and middles hitters[8]. Due to such a great number of jumps which setters perform, it is necessary for setters to have a high running jump. Indeed, Marques et al.[13] obtained similar results related to setters jumping height in male volleyball players. Furthermore our results, shows that setters had the greatest mid-thigh corrected girth of the team, suggesting that greater MM could cause higher power production in exercises, which involve the thigh muscles. Conversely, the liberos and setters were lowest in BM, and were the most skillful, fastest, and most agile players of the team. Ultimately, it seems that an adequate BM, especially a low FM, is beneficial for volleyball performance, especially in the libero and setter roles.

Despite all players being between 19 to 35 years old, there was a negative correlation among age and power jumps (PVJ: $r = -0.388$; PSJ: $r = -0.353$), possibly due to a decrease in the efficiency of the neuromuscular system, and rate coding of type II muscle fibers[28]. Furthermore and as expected, significant positive correlations were found between MM and power jumps, which were significantly higher in hitters, compared any other positions. It is relevant that positive correlations were found between the Σ5SF, and PSJ ($r = 0.402$). This result was controversial and one possible explanation is that the players who had higher FM also had greater MM, which is the major contributing factor that causes the greatest force production in jumping and increasing power output.

The ability to generate high levels of upper-body muscular power during spiking and serving is an important attribute of volleyball players[6], especially in the positions that use these skills the most (opposite and outside hitters). Indeed, our results showed the highest upper-body muscular power to be present in opposite and outside hitters compared to other playing positions. Marques et al.[13] reported these same findings regarding upper-body muscular power in elite male volleyball players. Additionally, our findings showed a significant positive correlation between upper-body muscular power with corrected perimeter calf. We also observed a slight positive correlation between the mid-thigh and arm corrected girths. The fact that the execution of this test is also performed with the arms, providing stability to the movement, may explain the slight negative correlation of upper-body muscular power with the subscapular skinfold. Relating to abdominal muscle strength and endurance no differences ($p>0.05$) among playing positions were found. However, we observed a negative correlation between performance in the abdominal test with FM measured in the ∑5SF ($r = -0.506$), abdominal ($r = -0.596$) and subscapular ($r = -0.514$) skinfolds. These results indicate that an excess of FM in the area of action attenuates performance of the abdominal musculature.

Adequate BC and proportions constitute important prerequisites for successful participation in volleyball. The results of the present study demonstrate significant differences among elite female volleyball players among playing position in the next variables of height, BM, skinfolds, corrected girths, MM, jumps, speed, agility and upper-body muscular power. However, no differences were found among playing positions for abdominal muscle strength and endurance and the ∑5SF. Given that the volleyball competition requires handling the ball above the head, especially for spiking and blocking, height could be considered the most important physical attribute[13]. However, great jumping ability can help to counteract an individual player who may have a height disadvantage. The defensive characteristics of liberos and setters responsible for the second pass make it necessary that these players be fast and agile to get to the ball quickly, in order to achieve their primary purpose.

We found that middle blockers along with opposite and outside hitters were significantly taller and heavier than liberos and setters. On the other hand liberos and setters possessed the greatest agility compared to all other positions. Also, we have observed a slight positive correlation between the mid-thigh and calf corrected girth with both jumps and OMBT. These findings suggest that the increment in lower body MM may help female volleyball players to achieve greater jump height and reach the "critical height" above the net, thus enhancing spiking ability. In addition, a correlation among different skinfolds, MM, BM and height with agility and speed was observed. Although height is a parameter, which depends on genetics, and cannot be altered, BM and especially FM are factors, which can be controlled in order to enhance speed and agility.

## Limitations

The main limitation of our study was the small sample size, especially in liberos and opposite hitters;

these are specific positions and only a few players on each team performed these roles[22]. Future studies should analyze these parameters with a larger sample size among these positions. However, this study was the first to analyze physical parameters in professional and elite female volleyball players in regards to anthropometric assessments among the various playing positions.

## Conclusions

In conclusion, we found that anthropometric profile determines playing position in elite female volleyball players and influences physical performance. Moreover, height offers a performance advantage for middle blockers, whereas lower body mass, especially a lower fat mass, seems to be advantageous for setters and liberos. Finally, high musculoskeletal mass, along with an appropriate fat mass are advantageous for opposite and outside hitters.

## References


1. Gabbett T, Georgieff B. Physiological and anthropometric characteristics of australian junior national, state, and novice volleyball players. *J Strength Cond Res* 2007; 21: 902-8.
2. Gonzalez-Rave JM, Arija A, Clemente-Suarez V. Seasonal changes in jump performance and body composition in women volleyball players. *J Strength Cond Res* 2011; 25: 1492-501.
3. Lidor R, Ziv G. Physical and physiological attributes of female volleyball players--a review. *J Strength Cond Res* 2010; 24: 1963-73.
4. Malá L., Malý T., Záhalka F. et al. The profile and comparison of body composition of elite female volleyball players. *Kinesiology* 2010; 42: 90-7.
5. Reilly T. Fitness assessment. In: T. Reilly ed. Science and Soccer. London: E & FN Spon: 2006; 25-50.
6. Gabbett T, Georgieff B, Anderson S et al. Changes in skill and physical fitness following training in talent-identified volleyball players. *J Strength Cond Res* 2006; 20: 29-35.
7. Sheppard JM, Chapman DW, Gough C et al. Twelve-month training-induced changes in elite international volleyball players. *J Strength Cond Res* 2009; 23: 2096-101.
8. Sheppard JM, Gabbett TJ, Stanganelli LC. An analysis of playing positions in elite men's volleyball: Considerations for competition demands and physiologic characteristics. *J Strength Cond Res* 2009; 23: 1858-66.
9. Kerr DA, Ross WD, Norton K et al. Olympic lightweight and open-class rowers possess distinctive physical and proportionality characteristics. *J Sports Sci* 2007; 25: 43-53.
10. Geithner CA, Lee AM, Bracko MR. Physical and performance differences among forwards, defensemen, and goalies in elite women's ice hockey. *J Strength Cond Res* 2006; 20: 500-5.
11. Ostojic SM, Mazic S, Dikic N. Profiling in basketball: Physical and physiological characteristics of elite players. *J Strength Cond Res* 2006; 20: 740-4.
12. Bracko MR, George JD. Prediction of ice skating performance with off-ice testing in women's ice hockey players. *J Strength Cond Res* 2001; 15: 116-22.
13. Marques MC, van den Tillaar R, Gabbett TJ et al. Physical fitness qualities of professional volleyball players: Determination of positional differences. *J Strength Cond Res* 2009; 23: 1106-11.
14. Duncan MJ, Woodfield L, al-Nakeeb Y. Anthropometric and physiological characteristics of junior elite volleyball players. *Br J Sports Med* 2006; 40: 649,51; discussion 651.
15. Sheppard JM, Cronin JB, Gabbett TJ et al. Relative importance of strength, power, and anthropometric measures to jump performance of elite volleyball players. *J Strength Cond Res* 2008; 22: 758-65.
16. Stewart A, Marfell-Jones M, Olds T *et al*. *International Standards for Anthropometric Assessment* Lower Hutt, New Zealand: ISAK, 2011.
17. Lee RC, Wang Z, Heo M et al. Total-body skeletal muscle mass: Development and cross-validation of anthropometric prediction models. *Am J Clin Nutr* 2000; 72: 796-803.
18. Granados C, Izquierdo M, Ibanez J et al. Differences in physical fitness and throwing velocity among elite and amateur female handball players. *Int J Sports Med* 2007; 28: 860-7.
19. Sporis G, Jukic I, Milanovic L et al. Reliability and factorial validity of agility tests for soccer players. *J Strength Cond Res* 2010; 24: 679-86.
20. Toskovic NN, Blessing D, Williford HN. Physiologic profile of recreational male and female novice and experienced tae kwon do practitioners. *J Sports Med Phys Fitness* 2004; 44: 164-72.
21. Trajković N, Milanović Z, Sporiš G et al. Positional differences in body composition and jumping performance among youth elite volleyball players. *Acta Kinesiologica* 2011; 5: 62-6.
22. Carvajal W, Betancourt H, León S et al. Kinanthropometric profile of cuban women olympic volleyball champions. *MEDICC Review* 2012; 14: 16-22.
23. Fleck SJ, Case S, Puhl J et al. Physical and physiological characteristics of elite women volleyball players. *Can J Appl Sport Sci* 1985; 10: 122-6.
24. Gualdi-Russo E, Zaccagni L. Somatotype, role and performance in elite volleyball players. *J Sports Med Phys Fitness* 2001; 41: 256-62.
25. Malousaris GG, Bergeles NK, Barzouka KG et al. Somatotype, size and body composition of competitive female volleyball players. *J Sci Med Sport* 2008; 11: 337-44.
26. Gladden LB, Colacino D. Characteristics of volleyball players and success in a national tournament. *J Sports Med Phys Fitness* 1978; 18: 57-64.
27. Sattler T, Sekulic D, Hadzic V et al. Vertical jumping tests in volleyball: Reliability, validity, and playing-position specifics. *J Strength Cond Res* 2012; 26: 1532-8.
28. Guyton AC, Hall JE. *Textbook of Medical Physiology.* Philadelphia: Elsevier Saunders, 2011.