Anthropometry and Functional Movement Patterns in Elite Male Volleyball Players of Different Competitive Levels

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Abstract

Toselli, S and Campa, F. Anthropometry and functional movement patterns in elite male volleyball players of different competitive levels. *J Strength Cond Res* 32(9): 2601–2611, 2018—The aim of this study was to establish specific profiles for anthropometry and functional movement parameters and identify which characteristics can be modified by training to achieve a better quality of movement in elite male volleyball players competing at the Italian National League (Super Lega = 39, aged 25.6 ± 4.7 years and A2 = 30, aged 26.2 ± 5.3 years). Another aim was to value functional movement patterns in relation to morphological traits, with special focus on differences by division and playing positions. Statistical significance was set at $p \leq 0.05$. According to discriminant analysis, the differences between players of the 2 Divisions were primarily due to nonmodifiable parameters (humerus width, height, and bicrestiliac width) and modifiable parameters (contracted arm circumference and muscle area of upper arm). Our results highlighted differences according to playing positions. Middle hitters and opposites were taller, heavier and generally showed wide dimensions in contracted arm circumference, upper limb length widths, and handgrip strength than the players of the other roles. Percentage of fat mass was low in players of all roles, such as endomorph somatotype component. Ectomorphic component was maximal in middle hitters, whereas mesomorphic component was maximal in liberos. The players of the 2 Divisions did not show differences in the movement patterns, even if approximately 33% of them showed a dysfunctional movement, with a prevalence of asymmetric movements in the shoulder mobility test. Multiple regression showed that, in volleyball players, an optimal flexibility and mobility was closely related to anthropometric characters with particular emphasis on body fat.

Key Words body composition, Functional Movement Screen, somatotype

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Introduction

The achievement of success in elite sport is influenced by various aspects, reciprocally interconnected, which include physiological, psychological, and anthropometric factors (13,24).

Volleyball is a fast-paced game, characterized by intense efforts of short intensity. The aspects that mainly characterize the athletes are jumping ability, power output, and force (4). In turn, these advantages are influenced by anthropometric traits such as height, body composition, and somatotype components (7,30,31).

The anthropometric characteristics of the athletes can influence the level of performance and help to determine a suitable physique for a certain sport. The assessment of body composition (fat mass [FM] and fat-free mass [FFM]) of the athletes is one of the most valued aspects to test the physical and fitness conditions, to test the result of a training program, and to create specific profiles for a specific sport. In volleyball, numerous studies have addressed these issues (19,22–24,26), with particular regards to female athletes, whereas scientific data on male players are scarce. The excess FM seems to be counterproductive in the fast movements and jumps, reducing performance and increasing energy demands during the execution of a particular action. Conversely, lean mass is closely linked to speed, strength and power, and injury prevention (8). Also, the somatotype estimation of the athletes allows for a characterization of their body build because it combines adiposity, musculoskeletal robustness, and linearity into one rating (5). According to Giannopoulos et al. (14), approximately 24% of performance of volleyball players in attack could be predicted by the linear combination of somatotype, competition level, and playing position.

Unfortunately, athletes during training and competition are often subjected to strain that can cause injury; so, to assess the movement patterns in daily sport practice, it is important to detect eventually functional deficits. As a consequence, besides anthropometric characters, the identification of deficits in neuromuscular ability is another important

TABLE 1. Anthropometry, strength, and functional movement patterns in volleyball players.*

	Super lega ($n = 39$)			A2 ($n = 30$)					95% CI of the difference	
	Mean	*SD*	*SEM*	Mean	SD	*SEM*	*t*	*p*	Lower	Upper
Age	25.62	4.74	0.75	26.16	5.32	0.97	−0.43	0.662	−2.95	1.89
Age at starting volleyball	11.46	4.49	0.45	11.71	4.25	0.92	−0.27	0.784	−2.09	1.58
Age at starting competition	16.25	3.29	0.36	15.57	3.29	0.71	0.98	0.33	−0.93	2.08
Anthropometric parameters										
Height (cm)	195.28	8.31	1.33	192.01	11.04	2.01	1.40	0.165	−1.38	7.91
Sitting height (cm)	58.55	4.49	0.71	56.48	4.00	0.74	1.95	0.054	−0.03	4.16
Lower limb length index	136.73	5.87	0.94	135.59	8.34	1.54	0.65	0.512	−2.30	4.57
Mass (kg)	90.50	9.08	1.45	86.43	9.52	1.73	1.80	0.075	−0.42	8.57
BMI	23.72	1.78	0.28	23.44	1.87	0.34	0.63	0.528	−0.60	1.16
Arm circumference (contracted) (cm)	32.12	2.18	0.35	31.22	2.46	0.54	1.60	0.113	−0.74	1.72
Arm circumference (relaxed) (cm)	34.56	2.11	0.33	34.47	2.91	0.45	0.79	0.428	−0.21	2.00
Calf circumference (cm)	38.70	2.62	0.42	37.61	2.36	0.43	1.76	0.082	−0.14	2.32
Thigh circumference (cm)	55.68	2.82	0.90	56.51	6.32	1.17	−0.72	0.469	−0.31	1.44
Upper limb length (cm)	86.92	4.86	0.83	83.23	6.09	1.13	2.66	0.01	0.92	6.45
Upper limb length index	44.51	1.54	0.25	43.31	1.50	0.27	3.10	0.003	0.42	1.96
Humerus width (cm)	7.71	0.46	0.07	6.96	0.44	0.08	6.62	0.543	0.51	0.96
Femur width (cm)	10.25	0.68	0.10	10.00	0.74	0.13	1.44	0.153	−0.09	0.60
Biacromial width (cm)	42.48	4.30	0.69	39.19	7.95	1.47	2.17	0.034	0.26	6.31
Bicrestiliac width (cm)	30.80	3.61	0.57	28.54	5.15	0.95	2.12	0.037	0.13	4.37
Biceps skinfold (mm)	3.62	0.96	0.18	4.03	1.34	0.24	−1.28	0.204	−1.03	0.22
Triceps skinfold (mm)	6.15	2.28	0.36	8.41	2.85	0.53	−3.62	0.001	−3.50	−1.01
Subscapular skinfold (mm)	8.71	1.70	0.27	9.62	1.93	0.36	−2.03	0.046	−1.78	−0.01
Suprailiac skinfold (mm)	9.80	3.25	0.35	13.37	4.44	0.82	−3.82	0.077	−5.43	−1.70
Supraspinal skinfold (mm)	5.80	3.25	0.52	7.98	2.82	0.52	−3.54	0.001	−3.38	−0.95
Medial Calf skinfold (mm)	6.21	1.87	0.29	6.91	2.34	0.43	−1.36	0.178	−1.71	0.32
Lateral Calf skinfold (mm)	6.87	1.81	0.34	7.75	2.88	0.53	−1.36	0.178	−2.19	0.41
Thigh skinfold (mm)	9.63	2.96	0.48	12.15	4.61	0.85	−2.72	0.008	−4.37	−0.67
Body composition parameters										
%*F*	12.22	3.11	0.49	14.71	3.50	0.64	−3.09	0.003	−4.09	−0.88
FM (kg)	11.07	3.02	0.48	12.59	3.07	0.57	−2.02	0.047	−3.00	−0.02
FFM (kg)	79.43	8.30	1.33	73.55	9.38	1.74	2.73	0.008	1.58	10.18
TUA (cm^2)	82.50	10.97	1.75	78.11	12.26	2.27	1.55	0.125	−1.25	10.04
UMA (cm^2)	73.01	11.58	1.85	65.71	13.21	2.45	2.42	0.018	1.28	13.33
UFA (cm^2)	9.48	3.19	0.51	12.40	3.82	0.70	−3.41	0.001	−4.61	−1.21
AFI (%)	11.72	4.51	0.72	16.34	5.85	1.08	−3.67	0.681	−7.12	−2.10
TCA (cm^2)	119.77	16.13	2.58	113.05	14.31	2.65	1.78	0.079	−0.80	14.26
CMA (cm^2)	108.04	15.77	2.52	100.47	14.18	2.63	2.05	0.044	0.21	15.01
CFA (cm^2)	11.69	3.49	0.56	12.58	4.24	0.78	−0.94	0.349	−2.76	0.99
CFI (cm^2)	9.86	2.98	0.55	11.22	3.72	0.77	−1.69	0.123	−2.50	1.02
Endomorphy	1.68	0.56	0.90	2.29	0.76	0.14	−3.80	0.088	−0.92	−0.28
Mesomorphy	4.28	1.27	0.20	3.59	1.25	0.23	2.22	0.029	0.07	1.30

Ectomorphy	3.29	0.99	0.15	3.29	1.19	0.22	0.01	0.988	−0.52	0.53
Strength and movement parameters										
Handgrip (right) (kg)	56.92	12.57	2.37	54.06	9.08	1.68	0.98	0.328	−2.94	8.66
Handgrip (left) (kg)	52.59	9.61	1.85	52.77	8.79	1.63	−0.99	0.941	−5.11	4.75
Deep squat	2.10	0.59	0.96	1.80	0.40	0.07	2.37	0.02	0.49	0.55
Hurdle step	2.05	0.32	0.51	2.06	0.58	0.10	−0.13	0.889	−0.23	0.20
In-line lunge	2.02	0.42	0.11	2.06	0.63	0.11	−0.31	0.751	−0.29	0.21
Shoulder mobility	2.07	0.78	0.13	1.80	1.03	0.18	1.23	0.223	−0.17	0.72
ASLR	2.46	0.78	0.12	2.66	0.54	0.10	−1.21	0.228	−0.54	0.13
TSPU	2.56	0.59	0.96	2.23	0.81	0.14	1.94	0.056	−0.00	0.67
Rotary stability	2.00	0.32	0.52	1.90	0.30	0.05	1.30	0.197	−0.05	0.25
FMS (total)	15.28	1.73	0.27	14.83	2.26	0.38	0.93	0.354	−0.17	1.67
FMS (move)	6.15	0.81	0.12	6.10	1.44	0.23	0.19	0.845	−0.24	0.74
FMS (flex)	4.58	0.75	0.18	4.50	1.22	0.23	0.31	0.752	−0.51	0.65
FMS (stab)	4.58	0.75	0.11	4.23	0.77	0.15	1.92	0.058	0.05	0.81

*CFI = calf fat index; CI = confidence interval; BMI = body mass index; %F = fat percentage; FM = fat mass; FFM = fat-free mass; TUA = total area of the upper arm; UMA = muscle area of the upper arm; UFA = fat area of the upper arm; AFI = arm fat index; TCA = total area of the calf; CMA = muscle area of the calf; CFA = fat area of the calf; ASLR = active straight leg raise; TSPU = trunk stability push-up; FMS = Functional Movement Screen.

parameter to value. At this purpose, the Functional Movement Screen (FMS) is a useful screening tool to evaluate asymmetries, dysfunctions, and compensatory movement patterns in athletes (3,10,16,17).

The FMS consists of a battery of 7 fundamental movement patterns (test) and 3 additional clearing tests, assessed by visual observation using standardized criteria (10). Using FMS, a numeric score (from 0 to 3) is obtained from the performance attributes of 7 dynamic movements: deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise (ASLR), trunk stability push-up (TSPU), and rotary stability. Research showed that the FMS is a tool that demonstrates good reliability (18,28), even if the association between the presence of dysfunctional movements (total score ≤14) and the increased exposure to the risk of injury is debatable (29).

In conclusion, only limited data investigating individual FMS scores were available and these data showed how these individual tests deteriorate and/or are predictive of specific injuries in volleyball. Moreover, to examine individual movements and specific deficits within sport and competition levels is needed to understand how to more effectively train and treat within different sports and competition levels (2,35). In addition, no data regarding the possible relationship between movement pattern and anthropometric characteristics are at disposal.

This study had 2 primary aims. The first aim was to provide a specific players profile on morphological features and movement patterns. The identification of physical and movement pattern profiles for volleyball players would help coaches to identify vulnerabilities of the athletes and implement specific correction and training programs to improve their performance and quality of movement. Furthermore, these data may be useful in providing information on the value of anthropometric and movement pattern data for talent selection. The second aim was to value the presence of dysfunctional, asymmetrical, and painful movement in relation to anthropometric characteristics in volleyball players playing in the highest divisions of the National Italian League.

Methods

Experimental Approach to the Problem

To date, relationships have not been verified between functional movement patterns and morphological traits; moreover, there are few references about male elite volleyball player profiles. A cross-selectional study design was used to answer these study questions. A discriminant analysis was used to show which parameters (modifiable and nonmodifiable) were predictors of the highest level of competition. A regression analysis was used to investigate which anthropometric tracts were related to better movement quality. All measures were taken during the competitive season between 2016 and 2017. Before the evaluations, a questionnaire regarding sport history was provided to each subject.

Participants were asked to answer details of their past volleyball activity (age at the start of volleyball; age at the start of competition; role in the volleyball team; hours per week of training; and competitive experience).

Subjects

The sample consisted of 69 male elite volleyball players, playing in the highest divisions (Super Lega = 39–aged 25.6 ± 4.7 years and A2 = 30–aged 26.2 ± 5.3 years mean ± *SD*) of the National Italian League. Of the 39 Super Lega players, 21 compete for male National volleyball teams of Italy ($n = 10$), France ($n = 3$), Belgium ($n = 2$), Serbia ($n = 2$), Germany ($n = 2$), Czech Republic ($n = 1$), and Slovenia ($n = 1$). Of the 30 A2 players, 2 compete for male National volleyball teams of Italy ($n = 1$) and Spain ($n = 1$). The volleyball players were in their competition training period and measurements were taken on Monday morning (9.00 AM) in the facilities of the team because the athletes had rested during the weekend. Subjects had a balanced breakfast 2 hours before the test. All research procedures were reviewed and approved by the bioethical committee board of the University of Bologna (January 3, 2017) and the study conformed to the Declaration of Helsinki for medical research involving human subjects. All subjects received a clear explanation of the study, including the risks and benefits of participation, and, if after this explanation, their decision was to not be included in the analysis, this did not adversely affect any current or future team selection. All included subjects provided written informed consent for testing and data analysis.

Procedures

Anthropometry. The anthropometric traits were mass, height, sitting height, humerus, femur, biacromial and bicristal breadths, upper limb length, upper arm (relaxed and contracted), calf, and thigh girths. All anthropometric measurements were taken according to standard methods (21,36). Height was recorded to the nearest 0.1 cm using a stadiometer and body mass was measured to the nearest 0.1 kg using a high-precision mechanical scale. Body mass index was calculated as the ratio of body weight to height squared ($kg \cdot m^{-2}$). Upper limb length (acromiale-dactylion) was measured on the subject in the erect standing position using the stadiometer and upper limb length index was calculated as the ratio of upper limb length to height. Girths were taken to the nearest 0.1 cm using a tape measure. Breadths were measured to the nearest 0.1 cm using a sliding caliper. Skinfold thicknesses at 8 sites (biceps, triceps, subscapular, supraspinal, suprailiac, lateral calf, medial calf, and thigh) were measured to the nearest 0.1 mm using a Lange skinfold caliper. Skinfold values were used in anthropometric regression equations (11) to predict the following body composition parameters: body density, fat percentage (%*F*), FM, and FFM. The total area of the calf and upper arm (TUA), the muscle area of the calf (CMA) and upper arm (UMA), the fat area of the calf and upper arm (UFA), and arm fat index (AFI) were calculated according to Frisancho (12). Somatotype components were calculated according to the Heath-Carter method (6). Left and right handgrip strengths were measured to the nearest 0.5 kg using a mechanical dynamometer (Takei K.K.5001).

Functional Movement Screen. Functional movement patterns were evaluated by a physician specifically trained using standard FMS Test Kits (Functional Movement Systems, Inc., Lynchburg, VA, USA). The 7 movements (tests) examined in FMS are: deep squat, hurdle step, in-line lunge, shoulder mobility, ASLR, TSPU, and rotary stability. The protocol for administering the FMS is fully described by Kiesel et al. (16). According to FMS criteria (10,16), the athletes were awarded a score of 0–3 for each test and 5 of the 7 tests are assigned independent scores for the left and right sides of the body. A score of 3 was indicative of completing the movement perfectly and pain-free. A score of 2 was awarded when the movement was performed pain-free but with minor compensatory patterns and is considered "satisfactory." A score of 1 indicated the movement could not be completed as instructed and a score of 0 was given when pain was reported while performing the movement. In addition to considering the total score, FMS assessment was divided into 3 parts: FMSmove (deep squat, hurdle step, and in-line lunge); FMSflex (shoulder mobility and ASLR); and FMSstab (TSPU and rotary stability) (32). The total number of points was 21, and the overall result of the FMS test was only the weak side result. Composite scores ≤14 were operationally defined as indicating dysfunctional movement and players scoring differently on left and right sides were considered asymmetrical.

Statistical Analyses

To compare the groups, we used Student's *t* test, analysis of variance (ANOVA, with Tukey's HSD post hoc test), and chi-square (χ^2) test. Discriminant function analysis was used to test whether significant differences exist in anthropometric traits, handgrip strength of both sides, and FMS characteristics between the 2 division, in terms of the predictor variables, whereas stepwise regression analysis was used

TABLE 2. Discriminant function analysis for division predictors.

Step	Entered	Wilks' Lambda	*F*	*p*
1	Humerus width	0.63	34.62	0.000
2	Height	0.44	7.21	0.010
3	Arm circumference (contracted)	0.47	11.41	0.001
4	UMA	0.42	5.27	0.026
5	Bicrestiliac width	0.45	8.56	0.005
6	Supraspinal skinfold	0.40	1.69	0.199

TABLE 3. Anthropometry, strength, and functional movement patterns in the volleyball players of different roles.*

	Setter ($n = 11$)		Middle hitters ($n = 18$)		Libero ($n = 11$)		Outside hitters ($n = 20$)		Opposites ($n = 9$)			
	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	Mean	*SD*	*F*	*p*
Age	27.1	6.80	24.83	4.22	23.81	5.4	26.30	4.90	28.9	3.32	1.31	0.297
Age at starting volleyball	8.75	1.98	13.93	2.11	11.30	4.21	10.44	3.07	12.37	3.29	5.11	0.001
Age at starting competition	15.50	1.85	16.43	3.14	15.50	3.10	15.77	2.04	16.87	2.58	0.53	0.713
Anthropometric parameters												
Height (cm)	187.41	6.45	202.30	3.31	179.29	5.68	193.81	4.42	202.77	5.63	49.34	0.000
Sitting height (cm)	55.51	3.60	60.96	3.08	52.84	3.88	57.11	3.03	60.63	3.52	13.05	0.000
Lower limb length	131.65	5.76	141.34	4.07	126.44	4.25	136.70	3.44	142.14	5.48	26.31	0.000
Weight (kg)	83.22	7.48	93.22	6.43	77.18	8.28	90.74	5.27	96.26	10.17	13.26	0.000
BMI	23.70	1.90	22.77	1.37	24.00	2.35	24.17	1.50	23.37	2.12	1.68	0.165
Arm circumference (relaxed) (cm)	31.52	2.13	32.00	2.58	30.26	2.31	31.99	2.09	32.70	1.85	1.74	0.152
Arm circumference (contracted) (cm)	33.85	2.41	35.26	2.77	32.68	2.71	35.32	1.80	36.03	1.71	3.74	0.009
Calf circumference (cm)	37.41	2.79	37.94	2.07	37.03	1.94	39.18	2.87	39.08	2.53	1.96	0.110
Thigh circumference (cm)	57.98	9.44	55.23	2.80	55.43	3.14	56.30	4.99	55.63	2.28	0.64	0.635
Upper limb length (cm)	81.21	4.66	89.14	4.20	77.91	3.86	85.46	2.99	90.53	3.50	20.15	0.000
Upper limb length index	43.37	1.49	44.04	1.98	43.65	1.33	44.04	1.31	44.78	1.88	0.98	0.421
Humerus width (cm)	7.18	0.68	7.58	0.47	6.92	0.49	7.35	0.46	7.91	0.54	5.57	0.001
Femur width (cm)	9.77	0.47	10.18	0.52	9.61	0.70	10.53	0.75	10.30	0.70	4.58	0.003
Biacromial width (cm)	39.22	4.84	41.82	5.98	38.88	6.51	41.17	6.93	43.98	6.60	1.09	0.366
Bicrestiliac width (cm)	28.28	4.04	30.71	4.72	27.90	4.42	29.83	3.67	32.22	5.17	1.71	0.157
Biceps skinfold (mm)	3.27	0.97	3.60	0.89	4.83	1.83	3.86	0.95	3.75	0.92	2.50	0.053
Triceps skinfold (mm)	7.15	2.01	6.02	2.31	8.68	3.80	7.55	2.38	6.38	3.03	1.97	0.110
Subscapular skinfold (mm)	10.05	2.15	8.22	1.88	10.22	1.95	9.12	1.47	8.38	0.92	3.46	0.013
Suprailiac skinfold (mm)	11.75	3.10	9.88	3.41	14.18	5.67	11.70	3.51	9.44	4.50	2.56	0.047
Supraspinal skinfold (mm)	7.45	2.68	6.44	2.63	8.13	3.82	6.37	2.24	5.61	1.76	1.47	0.219
Medial Calf skinfold (mm)	7.35	2.58	6.19	1.34	6.90	2.37	6.57	2.00	5.61	2.58	1.02	0.403
Lateral Calf skinfold (mm)	8.94	2.84	6.16	2.20	7.83	1.80	7.66	2.46	6.50	2.18	2.45	0.058
Thigh skinfold (mm)	11.60	3.93	9.79	2.59	12.04	4.01	11.07	4.57	9.11	4.34	1.09	0.368
Body composition parameters												
%*F*	13.78	3.45	11.85	2.80	14.97	4.32	13.82	3.25	12.29	3.51	1.84	0.131
FM (kg)	11.31	2.94	11.03	2.66	11.54	3.64	12.58	3.22	11.81	3.48	0.64	0.634
FFM (kg)	70.73	6.46	82.18	6.43	65.63	7.77	78.15	4.73	84.35	9.16	15.52	0.000
TUA (cm^2)	79.42	10.79	82.06	13.53	73.30	10.95	81.83	10.50	85.37	9.86	1.66	0.168
UMA (cm^2)	68.58	10.48	72.86	14.44	61.02	12.86	70.27	10.71	75.43	12.15	2.17	0.082
UFA (cm^2)	10.84	3.05	9.19	2.99	12.27	4.95	11.56	3.45	9.93	4.21	1.63	0.176
AFI (%)	13.73	3.75	11.63	4.90	17.34	7.88	14.29	4.54	11.97	5.89	2.17	0.077
TCA (cm^2)	111.98	17.13	114.95	12.86	109.48	11.67	122.87	17.26	122.10	15.93	2.21	0.101
CMA (cm^2)	98.70	16.75	103.50	12.14	97.08	11.24	110.33	16.35	111.57	18.01	2.34	0.064
CFA (cm^2)	13.27	4.53	11.45	2.66	12.40	4.28	12.54	3.99	10.52	4.38	0.82	0.517
CFI (cm2)	11.96	4.15	9.99	2.09	11.34	3.78	10.26	3.00	8.91	4.38	1.33	0.282
Endomorphy	2.20	0.69	1.59	0.53	2.56	0.96	1.94	0.56	1.57	0.56	4.99	0.001

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Mesomorphy	4.14	1.50	3.15	1.11	4.59	1.33	4.45	1.01	3.77	1.30	3.59	0.011
Ectomorphy	2.97	1.01	4.10	0.66	2.30	1.04	3.01	0.82	3.87	1.01	9.10	0.000
Strength and movement parameters												
Hand grip (right) (kg)	49.12	6.59	59.53	10.32	47.33	6.68	55.14	6.87	64.71	17.79	4.71	0.003
Handgrip (left) (kg)	47.81	7.25	56.23	7.00	46.33	6.74	52.41	9.06	59.50	11.32	3.88	0.008
Deep squat	2.00	0.63	2.05	0.53	1.81	0.40	1.95	0.60	2.00	0.50	0.33	0.852
Hurdle step	2.00	0.44	2.22	0.42	1.90	0.30	2.00	0.56	2.11	0.33	1.06	0.381
In-line Lunge	2.18	0.40	2.00	0.53	2.09	0.53	2.10	0.51	2.12	0.78	0.62	0.648
Shoulder mobility	1.45	1.00	2.22	0.80	1.81	0.98	1.90	0.96	2.33	1.01	1.68	0.165
ASLR	2.45	0.82	2.66	0.84	2.45	0.68	2.50	0.57	2.65	0.50	0.30	0.874
TSPU	2.18	0.87	2.50	0.51	2.27	0.78	2.55	0.85	2.44	0.72	0.63	0.642
Rotary stability	2.00	0.44	2.00	0.00	1.81	0.40	1.95	0.22	2.00	0.50	0.60	0.603
FMS (total)	14.27	2.41	15.55	1.24	14.18	2.48	14.90	1.68	15.62	1.93	1.58	0.198
FMS (move)	6.18	0.75	6.16	0.85	5.81	1.07	6.00	1.29	6.22	0.97	0.30	0.828
FMS (flex)	4.18	1.57	4.88	1.07	4.27	1.34	4.40	0.88	5.10	1.11	1.74	0.101
FMS (stab)	4.18	1.07	4.50	0.51	4.09	0.94	4.50	0.76	4.64	0.88	0.73	0.561

*CI = confidence interval; BMI = body mass index; %*F* = fat percentage; FM = fat mass; FFM = fat-free mass; TUA = total area of the upper arm; UMA = muscle area of the upper arm; UFA = fat area of the upper arm; AFI = arm fat index; TCA = total area of the calf; CMA = muscle area of the calf; CFA = fat area of the calf; ASLR = active straight leg raise; TSPU = trunk stability push-up; FMS = Functional Movement Screen.

for multivariable analyses using FMS score as the dependent variable and anthropometric traits, division, and role as independent variables. Probability level was set at 0.05. Statistical analyses were performed using the Package "Statistica" version 8.8 (StatSoft, Vigonza, Padova, Italy).

Results

Table 1 shows the results of sport history questionnaire and anthropometric parameters. The mean age, the age of beginning volleyball, and the age of beginning competition did not differ between the players of the 2 levels. Mean hours of training per week were 22 in Super Lega players and 16 in A2 players.

The subjects' competitive experience included Olympic Games 2016 (Super Lega = 11), World Championships 2014 (Super Lega = 12, A2 = 1), World Cup 2015 (Super Lega = 8), World Grand Champions Cup 2017 (Super Lega = 12, A2 = 1), European Championship 2017 (Super Lega = 23, A2 = 1), and World League 2017 (Super Lega = 20).

Regarding anthropometric parameters (Table 1), significant differences between Super Lega and A2 players were observed for upper limb length, upper limb length index, widths (humerus, biacromial, and bicrestiliac) because Super Lega players showed higher values. Significant lower values were detected in the same players for skinfold thicknesses (triceps, subscapular, suprailiac, supraspinal, and thigh). Body composition parameters and somatotype are reported in Table 1. Super Lega players showed significant lower values of fat parameters (FM, %*F*, UFA, and AFI) and higher for muscularity (FFM, UMA, and CMA). In the same way, endomorphy was significantly lower and mesomorphy was significantly higher in Super Lega than in A2 players. The somatotype was ectophic mesomorph in Super Lega players and mesomorphic ectomorph in A2 players.

No significant differences were observed for handgrip strength of both hands and in functional movement patterns (Table 1). The only statistical difference regarded deep squat, a test that involves multiple aspects such as mobility of different joints and control of multiple muscle groups, for which Super Lega players showed higher values. The 74.4% of Super Lega players and the 76.7% of A2 players showed asymmetries; the 10.3% of Super Lega players and the 16.7% of A2 players showed score lower than 0, whereas score ≤14 were reported in 33.3% and 33.6% of the players in Super Lega and A2, respectively. Despite the lower incidence in Super Lega players, the differences were not significant. Volleyball players showed 7% of total asymmetry in the rotary stability test, 24% in hurdle step, 22% in in-line lunge, 29% in shoulder mobility, and 14% in ASLR. In the FMS, 6 scores of 0 in the shoulder mobility test and 1 in the ASLR were assigned.

Discriminant function analysis was used to individuate predictor variables for differentiating the 2 different divisions. Stepwise discriminant function analysis identified 5 predictor variables (Table 2). Wilks' lambda denotes how useful a given

Table 4. Predictors of FMS: results of multivariate regression analysis.*

	FMS (tot)					FMS (flex)				
				95% CI of difference					95% CI of difference	
Predictor variable	β	*t*	*p*	Lower	Upper	β	*t*	*p*	Lower	Upper
Height (cm)	9.07	1.48	0.152	−3.59	21.73	12.1	1.88	0.073	−1.21	25.40
Sitting height (cm)	−0.76	−2.94	0.007	−1.28	−0.22	−0.35	−1.3	0.207	−0.90	0.20
Weight (kg)	−6.58	−1.52	0.142	−15.54	2.38	−10.58	−2.32	0.029	−20.00	−1.15
BMI	−1.8	−0.98	0.336	−5.59	1.99	−1.88	−0.98	0.339	−5.87	2.10
ACC (cm)	−1.91	−0.37	0.717	−0.69	1.05	0.11	0.02	0.984	−0.95	0.88
ARC (cm)	0.18	0.43	0.674	−12.66	8.85	−0.03	−0.08	0.939	−11.20	11.42
CC (cm)	2.07	0.38	0.705	−9.12	13.27	1.74	0.31	0.763	−10.03	13.51
TG (cm)	0.02	−0.01	0.994	−0.40	0.40	0.01	0.01	0.992	−0.42	0.42
ULL (cm)	−0.39	−1.19	0.245	−1.07	0.28	0.05	0.13	0.894	−0.66	0.50
Humerus width (cm)	−0.45	−1.36	0.187	−1.13	0.23	−0.74	−2.14	0.043	−1.45	−0.02
Femur width (cm)	0.09	0.43	0.669	−0.35	0.54	0.51	2.26	0.034	0.04	0.98
BAW (cm)	−0.09	−0.31	0.761	−0.69	0.51	−0.47	−1.54	0.136	−1.10	0.16
BCW (cm)	0.19	0.71	0.488	−0.36	0.74	−0.08	−0.29	0.777	−0.66	0.50
Triceps skinfold (mm)	3.64	0.29	0.777	−22.66	29.95	15.86	1.19	0.248	−11.80	43.51
SB skinfold (mm)	−0.37	−0.23	0.821	−3.71	2.97	−2.67	−1.57	0.13	−6.18	0.84
SI skinfold (mm)	−1.62	−3.45	0.002	−2.58	−0.64	−1.77	−3.6	0.002	−2.79	−0.75
SS skinfold (mm)	−0.18	−0.08	0.94	−5.01	4.65	−3.38	−1.38	0.182	−8.46	1.70
MC skinfold (mm)	−11.1	−0.97	0.342	−34.74	12.54	4.63	0.39	0.703	−20.22	29.49
Thigh skinfold (mm)	−0.04	−0.14	0.89	−0.60	0.52	0.54	1.87	0.074	−0.05	1.13
%*F*	−1.88	−0.64	0.531	−7.98	4.23	−7.09	−2.28	0.032	−13.51	−0.67
TUA	−9.89	−0.59	0.563	−44.71	24.93	−40.09	−2.27	0.033	−76.70	−3.47
UMA	13.49	0.69	0.498	−27.05	54.03	45.52	2.21	0.037	2.89	88.14
AFI	0.57	0.07	0.948	−17.26	18.39	−6.63	−0.73	0.472	−25.38	12.11
TCA	31.95	1.56	0.133	−10.50	74.40	−1.24	−0.06	0.955	−45.87	43.40
CMA	−34.76	−1.5	0.148	−82.81	13.29	−1.83	−0.07	0.941	−52.34	48.69
CFI	2.34	0.36	0.72	−11.00	15.69	−5.73	−0.84	0.407	−19.76	8.31
Division (Super Lega)	0.17	0.77	0.451	−0.28	0.62	0.49	2.12	0.045	0.01	0.97
Roles										
Setter	0.11	0.36	0.724	−0.47	0.66	−0.38	−1.31	0.204	−0.97	0.22
Middle Hitters	0.12	0.35	0.727	−0.58	0.82	0.39	1.09	0.287	−0.35	1.13
Libero	−0.41	−1.2	0.244	−1.11	0.29	−0.75	−2.09	0.047	−1.48	−0.00
Outside Hitters	−0.29	−1.51	0.145	−0.68	0.10	−0.16	−0.79	0.437	−0.57	0.25
R^2	0.80					0.78				
Adjusted R^2	0.48					0.43				
p value	0.011					0.024				

*FMS = Functional Movement Screen; CI = confidence interval; BMI = body mass index; ACC = arm contract circumference; ARC = arm relaxed circumference; CC = calf circumference; TG = thigh circumference; ULL = upper limb length; BAW = biacromial width; BCW = bicrestiliac width; SB = subscapular; SI = suprailiac; SS = supraspinal; MC = medial calf; %F = fat percentage; TUA = total area of the upper arm; UMA =muscle area of the upper arm; TCA = total area of the calf; CMA = muscle area of the calf.

Table 5. Anthropometric characteristics of male elite volleyball players according to competition level with comparison with previous studies (mean ± *SD*).*

Author, year (Ref)	Proficiency	Subgroups	*N*	Age (y)	Playing experience (y)	Height (cm)	%*F*	Endomorphy	Mesomorphy	Ectomorphy
Current study	Italian National League	Super Lega	39	25.6 ± 4.7	13	195.3 ± 11	12.2 ± 3.5	1.7 ± 0.8	4.3 ± 1.3	3.3 ± 1.2
		A2	30	26.2 ± 5.3	12	192 ± 8.3	14.7 ± 3.1	2.3 ± 0.6	3.6 ± 1.3	3.3 ± 1
Giannopoulos et al., 2010 (14)	Greek National League	A1	68	28.5 ± 4.8	14	196.8 ± 5.3	14.9 ± 2.8	2.9 ± 0.6	2.1 ± 0.9	3.1 ± 0.8
		A2	76	26.5 ± 5.8	13	190.5 ± 5.9	15.6 ± 3.4	3.1 ± 0.8	2.4 ± 1.1	2.7 ± 1.1
Sattler et al. (33)	Slovenian National League	1st and 2nd Division	113	23.5 ± 5.5	6	186.9 ± 7	10.7 ± 2.8	–	–	–
Borràs et al. (1)	Spanish National Team	2008 team	13	26.4 ± 3.7	–	191.9 ± 7.4	10.4 ± 2.4	–	–	–
Zary et al. (40)	Brazilian National Team	2009 team	14	28.6 ± 3.5	–	–	–	2.6 ± 0.6	4.2 ± 1.6	2.6 ± 0.8
Gualdi-Russo et al. (15)	Italian National League	Super Lega	107	24.5 ± 4.6	11	193.9 ± 6.5	–	2.1 ± 0.6	4.1 ± 0.8	3.3 ± 0.7
		A2	127	24.9 ± 4.3	11	191.1 ± 7	–	2.3 ± 0.7	4.3 ± 1	3.0 ± 0.8

*%*F* = fat percentage.

variable is in the stepwise analysis and determines the order in which the variables enter the analysis. Humerus width entered the discriminant analysis first followed by height, contracted arm circumference, UMA, and bicrestiliac width. The discriminant function was significant (Wilks' lambda = 0.39, $p < 0.001$), indicating that the selected variables differentiate well between players of the 2 divisions. By this function, the 92.3% of Super Lega players and 93.1% A2 players were correctly classified.

Regarding role differences (Table 3), the age of beginning of volleyball significantly differed only between middle hitters, on one side, and setters and outside hitters, on the other. As expected, height significantly differed between all the players, with the exception of opposites and middle hitters. Setters did not significantly differ in sitting height from liberos and outside hitters, such as to opposites from middle hitters and outside hitters, whereas the rest of the players did. Regarding body weight, setters and liberos showed significantly lower values than opposites and middle hitters, and liberos than outside hitters, too. In the same way were the differences in contracted arm circumference as regards liberos and the players of the above cited roles. Great differences were observed for upper limb length among the players of the different roles, with the exception of liberos and outside hitters and of opposites and middle hitters. Humerus width was significantly wider in opposites than in liberos and setters, such as in middle hitters in comparison with liberos, whereas femur width was significantly wider in outside hitters than in liberos and setters.

A difference in subscapular and suprailiac skinfolds was observed between middle hitters and liberos. Fat-free mass differed among roles, with the exception of middle hitters with opposites and outside hitters, and liberos with setters. Regarding somatotype components, the greatest differences were observed in endomorphy between liberos with opposites and middle hitters, in mesomorphy between middle hitters with outside hitters and liberos, and in ectomorphy between middle hitters with outside hitters, setters, and liberos. Liberos significantly differed from opposites too. Handgrip strength of both hands showed a significant difference between liberos with middle hitters and opposites; in addition, a significant difference in handgrip strength of right hand was also observed between opposites and setters. Functional movement patterns did not show differences among roles (Table 3).

The stepwise regression analysis using the FMS total score (FMSmove, FMSflex, and FMSstab) as the dependent variable and anthropometric characteristics as independent variables yielded a model with the variables reported in Table 4. Functional Movement Screen total score varied according to sitting height and suprailiac skinfold, which were thus the most informative predictors and showed a significant negative association with FMS total score. The model explained about the 50% of variance. More predictors are involved in FMS total score: weight and fat parameters (%*F*, suprailiac skinfold) showed a significant negative association with FMSflex, whereas UMA showed a positive one. In addition, being an A1 player was positively associated with FMSflex and playing the role of libero was negatively related. The total explained variance of this second model was 43%. FMSmove and FMSstab did not show significant relations with anthropometric parameters.

Discussion

Our study provided a large and updated reference anthropometric and movement pattern database of male volleyball players participating in the highest Italian divisions (Super Lega and A2). There are limited data regarding male volleyball players because most studies considered females athletes.

The data confirmed that significant and large differences exist in anthropometric characteristics between players of different competitive levels and within positional roles. Moving from A2 to Super Lega level, players showed higher values of upper limb length and of skeletal width, such as lower values of fat parameters and higher values for muscularity, in the total body and in the arm. The existence of a "physique gradient" across competitive levels is probably indicative of physique-based selection that shows distinct trends reflecting game needs, player selection, and training practices. Height of the Super Lega players of this study was comparable with that reported by Giannopoulos et al. (14), but higher than those shown in the other studies (Table 5). Players have to make fast movements to do blocking and defense. Therefore, volleyball requires agility, and this requires low body fatness. Super Lega volleyball players presented a body %*F* of 12%, significantly lower than in A2 volleyball players, even if both were within the optimal percentage suggested for male volleyball players by Wilmore and Costill (38). The %*F* of Super Lega and A2 Italian National League players was lower than that of Greek National League players of the same level (14), but higher than that of Slovenian and Brazilian players (Table 5). Somatotype of Italian Super Lega players of this study was in accordance with the ectomorphic mesomorph somatotype of the players of the National Italian League, measured in 2001 by Gualdi-Russo and Zaccagni (15). In the other sample, a balanced mesomorph somatotype (40) or high values of endomorphy (14) prevailed (Table 5). As a whole, noteworthy are the lower rating of endomorphy and the high rating of mesomorphy in the present sample.

In discriminant analysis, among the anthropometric characters, nonmodifiable measures (humerus width, height, and bicrestiliac width) and modifiable measures (contracted arm circumference and UMA) seemed to be the most valid predictor of category (Super Lega vs. A2). Although nonmodifiable variables can be considered in talent selection, modifiable variables must be trained to reach the specific player profile required in the highest divisions. Increasing arm masses can enhance the expression of strength and power and allow athletes to achieve higher performance.

Regarding role specificity, unique body types and proportions constitute important prerequisites for successful participation in volleyball. The results of this study showed that significant differences exist among elite volleyball players of different playing positions in lengths (height, sitting height, and upper limb length), weight, widths (humerus and femur) and somatotype components. Our study confirmed that middle blockers and opposite hitters were significantly taller and heavier than the players from other positions. Physical characteristics of middle blockers and opposite hitters support these players to dominate close to the net, blocking the ball in a net elevated 2.43 meters above the ground level. They need to reach high and fast balls in a very short period of time to surprise the opponent's defense, and in the same time block the balls from the opponent's spike. Conversely, skillful abilities are required to the outside hitters, setters, and liberos with a lower height and body mass. The players of this study, except setters and libero showed comparable height but were lighter than the elite male volleyball athletes studied by Marques et al. (25). Middle hitters and opposites generally showed wide dimensions in contracted arm circumference, upper limb length, widths, and handgrip strength than the players of the other roles.

Because volleyball is characterized by frequent jumps and fast changes of direction, excess fat is not recommended, because it can be considered a limiting factor in reaching their maximum potential, but also represents an additional risk factor for injuries to the lower back or knee during frequent landings and sudden changes of speed and direction (27). Fat percentage was low in players of all roles, such as endomorph somatotype component. According to the study of Gualdi-Russo and Zaccagni (15), ectomorphic component was maximal in middle hitters, moreover, in our study, the mesomorphic component was maximal in liberos, a role that was not considered in their study. The differences among playing positions may provide insight into the physical qualities that are important for that position, so that appropriately structured training programs can be designed for individual positions.

The FMS has been developed to evaluate specific muscle limitations, which can suggest whether there is no proper stability and mobility in athletes (20,37). Increasingly, the FMS is being used in sports settings as a screening tool to identify the athletes whose movement characteristics may place them at risk of athletic injury. Nevertheless, the movement quality of male volleyball players measured by the FMS has not been studied. So, this study aimed to identify difference in FMS scores in male volleyball players according to divisions and roles. This information will allow strength and conditioning specialists to consider the need for corrective measures designed to improve functional movement of athletes during the season in an effort to reduce injury rates and, subsequently, improve performance. There were no differences in the FMS tests between groups (Super Lega and A2) and roles, except in deep squat test between the athletes of different divisions. The deep squat test is the most complex among the 7 proposed. This test evaluates total body mechanics and neuromuscular control. It demonstrates fully coordinated extremity, mobility, and core stability with the hips and shoulders functioning in symmetrical positions. Super Lega players got higher scores than A2 players, which may mean that major competitions require better athletic talents in players. Probably the differences found in anthropometric characteristics limit certain abilities in these athletes; however, this will be in line with their specific game requirements. Our findings indicated a high prevalence of asymmetrical movement in both groups of athletes (74.4% per Super Lega and 76.7 per A2). The presence of asymmetries in the FMS has recently been reported to contribute to a higher likelihood of athletic injury (8,17,39). In this study, most of the asymmetric movements and scores of 0 measured in the FMS were recorded in the shoulder mobility test. This may be due to the wide use of this joint during the volleyball game. Scores of 0 identify pain during the test. Coaches should develop interventions aimed at improving the quality of movement, bearing in mind that shoulder jointing is a weak point for volleyball players. Such evidence has been reported by Contemori et al. (9) that have showed proprioceptive and strength deficits of the shoulders in volleyballs players.

The results of regression analysis showed that various physical characteristics can influence the FMS. In particular, body weight, suprailiac skinfold, %*F*, and TUA are negatively correlated with the flexibility assessed with FMS, whereas UMA was positively associated. The repetitive eccentric demands of overhead striking in volleyball contributed to shoulder mobility, and the loss of that mobility has been observed in overhead athletes during the course of a competitive season on female volleyball players (34). The results of our study underline that coaches invloved in improving shoulder mobility should pay particular attention to body composition parameters of the athletes, reducing fat, and increasing arm muscularity. Division and role were also found to be discriminating factors for FMSflex; high scores in the test were correlated with high levels of play. On the contrary, the role of libero was negatively correlated with optimal flexibility assessments. Our view is that the difference in height and the low need for elastic explosive movements required in their role may have reflected in less flexibility. Marques et al. (25) presented that liberos showed a lower upper-body strength and power in comparison with players of the other roles, except setters, and this most likely reflects the limited upper-body involvement during competition. These results highlighted the need for continuous monitoring and specific corrective programming that will allow athletes to improve the quality of movement and reduce the risk of injury.

Practical Applications

This study provides an original data set of the anthropometric and movement patterns of elite male volleyball players according to division level and role. Our findings highlighted that even if players of different performance levels and roles present different anthropometric characteristics, they do not differ in movement patterns, with the exception of deep squat test between the athletes of different divisions. This study showed that the following nonmodifiable anthropometric measures should be considered in selection of players: humerus width, height, and bicrestiliac width. However, the most important modifiable anthropometric measures were related to the arm (contracted arm circumference and UMA). The training and monitoring of these parameters is of great importance because these were the discriminating variables for the elite athletes. Noteworthy is the serious deficiencies in the shoulder joints assessed by the FMS in the athletes. Regarding this, corrective exercise programs should focus on actions to improve the flexibility and mobility of shoulders in volleyball players. Moreover, athletes' mobility and flexibility were closely related to body weight, suprailiac skinfold, %*F*, and TUA, such as to high levels of play and role. This reference data can be useful to clubs and federations in identifying and assessing players for specific roles and competitive levels, helping coaches and all the staff members to plan adequate training to match the demands of the game in a specific role and category. Our results showed that, in addition to skeletal dimensions, coaches should pay attention to body composition parameters, strengthening the muscle mass of the arm, and reducing the FM to reach the player profile required in the highest volleyball divisions. Thus, the finding may be helpful for training monitoring, talent identification, and selection of players for volleyball.

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