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Somatotype, Level of Competition, and Performance in Attack in Elite Male Volleyball

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This study investigated the relationship between somatotype, level of competition, and performance in attack in elite level male volleyball players. The objective was to test for the potential covariation of competition level (Division A1 vs. A2) and playing position (hitters vs. centers vs. opposites) considering performance in attack. Anthropometric, body composition and somatotype variables were measured according to the Heath-Carter method. The attack actions of 144 players from 48 volleyball matches were analyzed and their performance was rated using a 5-point numerical scale. Results showed that players of Division A1 were taller, heavier, more muscular, and less endomorphic compared to those of Division A2. MANOVA and follow-up discriminant function analysis revealed somatotype differences among playing positions with centers and opposites being endomorph-ectomorph and hitters being central. Centers performed constantly better than hitters and opposites regardless of the division and somatotype. Multiple linear regression analysis showed that variables defining ectomorph and endomorph players, centers, and players of Division A1 significantly determined the relative performance superiority and were able to explain the variation in performance by almost 25%. These results could be taken into account by coaches when assigning players to particular playing positions or when designing individualized position-specific training programs.

Key words: anthropometrics, division, playing position.

Introduction

Performance in team sports is traditionally linked with the physical abilities and the technical skills of the players. As early as in 1970, a seminal research on the topic supported the hypothesis that physique was selective of athletic performance (Carter, 1970). In volleyball, numerous studies have indicated that male and female players exhibit significant differences in anthropometric variables and somatotype components either between divisions or various levels of competition (Gualdi-Russo and Zaccagni, 2001; Malousaris et al., 2008) and among playing positions (Gualdi-Russo and Zaccagni, 2001;

Malousaris et al., 2008; Marques et al., 2009; Martin-Matillas et al., 2014). Gualdi-Russo and Zaccagni (2001) found higher ectomorphic traits and a tendency for greater homogeneity in the somatotype for A1 Division players; regarding playing position, they found setters to present highest mesomorphic values and centres to present highest ectomorphic values. Similar results were reported by other researchers from different countries for adult (Malousaris et al., 2008, Marques et al., 2009, Martin-Matillas et al., 2014) and junior players (Duncan et al., 2006). Recently, in a longitudinal study that compared

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anthropometric and physical characteristics of volleyball players who had participated in the World Championships and Olympic Games in the 2000-2012 period, differences were found according to the playing position and team's classification level (Palao et al., 2014). Taken together, the results of the above studies imply that the physique or anthropometric qualities of volleyball players match the actions and demands characterizing their playing position as well as competitive needs at various levels of competitions.

Apart from the player's physical abilities, volleyball is a unique game because performance depends on some discrete skills (Cox, 1974) that have a sequential pattern of actions during the game (Eom and Schultz, 1992a, 1992b; Palao et al., 2004). Blocking and attacking are undoubtedly the most important determinants of team success (Eom and Schultz, 1992a, 1992b; Palao et al., 2004) with attacking directly determining most of the points gained (Laios and Kountouris, 2005; Marcelino et al., 2008). The sequential pattern of actions in volleyball indicates that the outcome of every following skill depends much on the quality of the preceding skill and, therefore, performance also depends on the pre-attack actions (Barzouka et al., 2008; Bergeles et al., 2010). This implies that a center with the proper somatotype upon receiving a perfect set will have a high-performance outcome in a quick attack (Bergeles and Nikolaidou, 2011).

To ensure performance effectiveness in Volleyball, one needs to further examine the correlation between anthropometric qualities and efficacy in performing the basic skills of the game. A positive correlation has been found between efficacy in attack and jumping ability (Sheppard et al., 2008), especially while changing directions (Barnes et al., 2007), and between efficacy in attack, the type of a set and final scoring (Drikos and Vagenas, 2011). Furthermore, Smith and colleagues (1992) investigated physiological and performance differences between national level and university level volleyball players. Compared to the university level players, the national level players performed better in spike and block jumps as well as in the 20 m sprint test (Smith et al., 1992). So far relevant studies focused largely on the relationship between anthropometric qualities and team performance, and on the

potential impact of anthropometric qualities on the efficacy of the game's skills have been largely examined. However, there is a lack of data in the literature on the extent to which physique and particularly somatotype variation determines performance in attack. Therefore, the present study investigated the relationship between somatotype, level of competition, and performance in attack in elite male volleyball players. The secondary purpose of this study was to examine the potential covariation of the competition level (Division A1 vs. A2) and playing position regarding performance in attack. It was hypothesized that the somatotype of players of Division A1 would ensure them higher performance in attack compared to that of players of Division A2.

Methods

Participants

The sample consisted of 144 male volleyball players (aged 27.5 ± 5.5 years) grouped by Division (68 from A1, and 76 from A2) and their playing position (52 centers, 62 hitters and 30 opposites). Each player's attacks were identified and analysed from a total of 4827 attack actions extracted from 48 videotaped official matches (24 from each Division). All players were informed about game videotaping as well as the testing procedures and provided their written informed consent to participate in the study according to the research policy of the National and Kapodistrian University of Athens.

Procedures

Anthropometrics and somatotype rating

Each player's body mass and body height were measured to the nearest 0.1 kg and 0.1 cm, respectively. The Carter and Heath (1990) method was used to measure all anthropometric variables. According to this method, the right side of the body was used for all anthropometric assessments. Ninety percent of the participants were right-handed, while only 10% of players were left-handed. Standard biceps, triceps, subscapular, supra iliac, and calf skinfolds were taken to the nearest 0.1 mm using a Harpenden skinfold caliper. The epicondylar breadth of the humerus and femur was measured to the nearest 0.1 mm using a bone caliper. Segmental girths were taken to the nearest mm for the mid-upper arm with muscles relaxed and muscles contracted,

and for the calf with the subject seated and the tested leg in a vertical position. Each somatometric estimate was taken twice per subject, condition, and body site/segment. If the difference between the two skinfold measurements was >10%, a third measurement was taken and the mean of the two closest values was kept for further analysis. Percent body fat (%BF) was estimated by the Siri equation (1956), using as components the body mass index (BMI) = BM/BH^2, fat mass (FM) = (BM*%BF)/100, and fat-free mass (FFM) = BM-%BF. The Carter and Heath (1990) method was used to rate the somatotype components (endomorph, mesomorph, ectomorph) of each participant. Intra-rater test-retest reliability was assessed for each anthropometric variable on six subjects and ranged from 0.998 for body height and body mass, to 0.975 for the mid-upper arm girth (muscles contracted). Carter (2002) proposed reasonable test-retest reliability values of approximately 0.98 for body height and mass, between 0.92 to 0.98 for girths and diameters, and between 0.90 to 0.98 for skinfolds.

Rating performance in attack

Performance in attack was assessed by video-analysis of forty-eight randomly chosen games. An experienced rater of volleyball games analyzed all attack actions included in the first two sets of each chosen game. Recorded data included the competition level (Division), team, game, set, player number, action, and player position in each action. Performance in attack was rated using a 5-point scale (0-4), according to Eom and Schultz (1992) where attack actions are rated as follows: 0 = error, 1 = average, 2 = good, 3 = very good, and 4 = excellent. Each player's score of performance in attack (RPA) was calculated as RPA= (S/P)*100, where S was defined as the sum of all attack ratings per player and P was defined as the perfect (maximum possible value) of all attack efforts, respectively. Intra-rater reliability in assessing attack performance was tested on 301 attack actions of two games and was found to be 0.987. The results of this reliability analysis were similar to those of previous research that had used the same rating method (Eom and Schultz, 1992a) and reporting an intra-rater reliability of 0.914 (Barzouka et al., 2006).

Statistics

All quantitative variables were summarized by means and standard deviations. In order to statistically examine the potential dependency of performance in attack on both somatotype and competition level (Division), the following statistical tests were conducted: a) independent t-tests for the differences in performance scores, anthropometric variables and somatotype between Divisions; b) a two-way ANOVA to test the combined effects of the Division and playing position on performance; The Scheffè post hoc test was used in case of significant F-tests, with the assumption of homogeneity of variance being tested by the Levene's test; c) a two-way MANOVA followed by a Discriminant Function Analysis (DFA) to test potential differences in the somatotype due to the playing position and Division; and d) multiple linear regression to determine the dependency of performance in attack on somatotype variation, with the three somatotype components as predictors, and the playing position and Division as covariates. Proper scatterplots, histograms, and normal probability plots were used to evaluate the assumptions of linearity, normality, and heteroscedasticity of the standardized residuals. All statistical analyses were carried out in SPSS v.23. Statistical significance in each seperate analysis was tested at the α = 0.05 probability level.

Results

The results on the differences between the two Divisions (A1 vs. A2) in performance in attack, anthropometric parameters, and somatotype are presented in Table 1. The players of Division A1 were older (p < 0.05), taller (p < 0.001), heavier (p < 0.001) and more muscular (p < 0.001) than those of Division A2. Hitters were central (2.83-2.47-2.80), while centers (3.26-2.04-3.17) and opposites (3.14-2.47-2.78) were endomorph-ectomorph. Hitters in Division A1 were endomorph-ectomorph (2.65-2.36-2.92) and in Division A2 were central (2.99-2.56-2.70). Centers were endomorph-ectomorph both in A1 (3.15-1.84-3.37) and in A2 (3.38-2.27-2.94), while opposites were endomorph-ectomorph (2.96-2.40-2.92) in Division A1 and balanced endomorph (3.26-2.52-2.69) in Division A2 (Table 1). Figure 1 depicts the relative positions of the group-averaged somatotype ratings per playing position and Division.

The descriptive statistics of performance in attack per Division and playing position are shown in Table 2. The two-way ANOVA showed no significant interaction between playing position and Division ($p > 0.05$), no significant main effect for Division ($p > 0.05$), but a highly significant main effect for playing position ($p < 0.001$). The Scheffé post-hoc test showed that centers outperformed hitters ($p < 0.001$) by 8.67 points and opposites ($p < 0.01$) by 9.07 points. The Levene test confirmed equality in the error variances among the six subgroups of this ANOVA (F [5, 138] = 2.209, $p = 0.057$).

The two-way MANOVA on performance in attack showed no interaction between the playing position and Division (Wilks' Lambda = 0.989, F [6, 272] = 0.245, $p = 0.961$), no difference between Divisions (Hotelling's Trace = 0.040, F [3, 136] = 1.815, $p = 0.147$), but a highly significant difference among the three playing positions (Wilks' Lada = 0.793, F [6, 272] = 5.589, $p < 0.001$) was found. A follow-up DFA for the playing position showed that this difference was primarily due to endomorphy (0.542), and secondarily to mesomorphy (-0.357) and ectomorphy (0.326).

To clarify the potential combined effects of the somatotype, Division, and playing position on performance in attack we fitted to the data (n = 144) a more comprehensive statistical model comprising the three somatotype components, the binary of division and two binary vectors reflecting playing positions (hitters vs. centers and opposites; centers vs. hitters and opposites). Statistical diagnostics revealed two outliers (z-values > 3) in the dependent variable (performance in attack) and one multivariate outlier in the independent variables (Mahalanobis distance > critical chi-square value of 16.26, df = 3, $p < .001$). We deleted these three outliers and then re-fitted the same model the reduced data (n = 141), and this resulted in an improved model both in statistical significance ($p < 0.001$) and in the variance extracted (24.1%). This revised model showed that performance in attack could be predicted by ectomorphy ($\beta = 0.381$), playing position 2 (centers vs. others, $\beta = 0.362$), endomorphy ($\beta = 0.267$) and less by Division ($\beta = 0.170$).

Table 1

Performance in attack, anthropometric characteristics and somatotype values (mean ± SD) within Division (A1 vs A2) and for the total sample.

	Division		Total (N = 144)
	A1 ($N_1 = 68$)	A2 ($N_2 = 76$)	
Performance	67.95 ± 9.45	64.50 ± 11.63	66.13 ± 10.76
Age (years)	28.57 ± 4.87	26.55 ± 5.88*	27.50 ± 5.50
Playing Experience (years)	14.75 ±5.65	13.11 ± 6.04	13.88 ± 5.86
Body Height (cm)	196.89 ± 5.30	190.56 ± 5.98***	193.55 ± 6.48
Body Mass (kg)	94.6 ± 9.06	88.73 ± 9.86***	91.50 ± 9.91
BMI (kg/m²)	24.39 ± 1.90	24.44 ± 2.45	24.41 ± 2.20
Body Fat (%)	14.98 ±2.86	15.61 ± 3.40	15.32 ± 3.16
Fat Mass (kg)	14.34 ± 3.81	14.03 ± 4.14	14.18 ± 9.91
Fat Free Mass (kg)	80.26 ± 6.26	74.70 ± 7.07***	77.33 ± 7.23
Endomorphy	2.90 ± 0.60	3.18 ± 0.83*	3.05 ± 0.74
Mesomorphy	2.16 ± 0.98	2.45 ± 1.17	2.32 ± 1.09
Ectomorphy	3.10 ± 0.85	2.78 ± 1.12	2.93 ± 1.01

*Significant difference between Divisions: *p < 0.05; **p < 0.01; ***p < 0.001.*

Table 2

Performance in attack (mean ± SD) per playing position between sports levels (Division) for the total sample (N = 144).

Position	A1	N	A2	N	Total	N	p^*
Hitters	65.04 ± 7.31	29	61.36 ± 10.66	33	63.08 ± 9.36	62	0.123
Centers	73.37 ± 10.45	27	70.00 ± 13.04	25	71.75 ± 11.77	52	0.307
Opposites	62.78 ± 5.16	12	62.62 ± 8.67	18	62.69 ± 7.36	30	0.956
Total	67.95 ± 9.45	68	64.50 ± 11.63	76	66.13 ± 10.76	144	0.055

* Differences between Divisions per playing positions
Interaction (Division x position): F [2] = 0.337, p = 0.715; Division: F [1] = 1.874, p = 0.173 (partial η^2 = 0.153);
Position: F [2] = 12.51, p < 0.001.

Table 3

Statistics of the linear regression analysis of performance in attack considering the three components of the somatotype, Division, and player position (N = 141)

Predictors	b	Std. Error	B	t	p	95% CI for b	
(Constant)	33.785	10.713		3.154	0.002	12.596	54.974
Division	3.414	1.558	0.170	2.191	0.030	0.333	6.495
Hitters	1.268	2.043	0.063	0.621	0.536	-2.773	5.310
Centers	7.628	2.149	0.362	3.549	0.001	3.377	11.879
Endomorphy	3.805	1.464	0.267	2.600	0.010	0.911	6.700
Mesomorphy	2.071	1.393	0.226	1.487	0.139	-0.683	4.826
Ectomorphy	3.766	1.708	0.381	2.204	0.029	041.387	7.145

R^2 = 0.241, Adj R^2 = 0.207, SE = 8.979, F = 7.077, p < 0.001.
Tolerance (VIF): Division = 0.94 (1.1); Position 1 = 0.56 (1.8); Position 2 = 0.65 (1.8); Endo = 0.54 (1.9), Meso = 0.25 (4.1), Ecto = 0.19 (5.3).
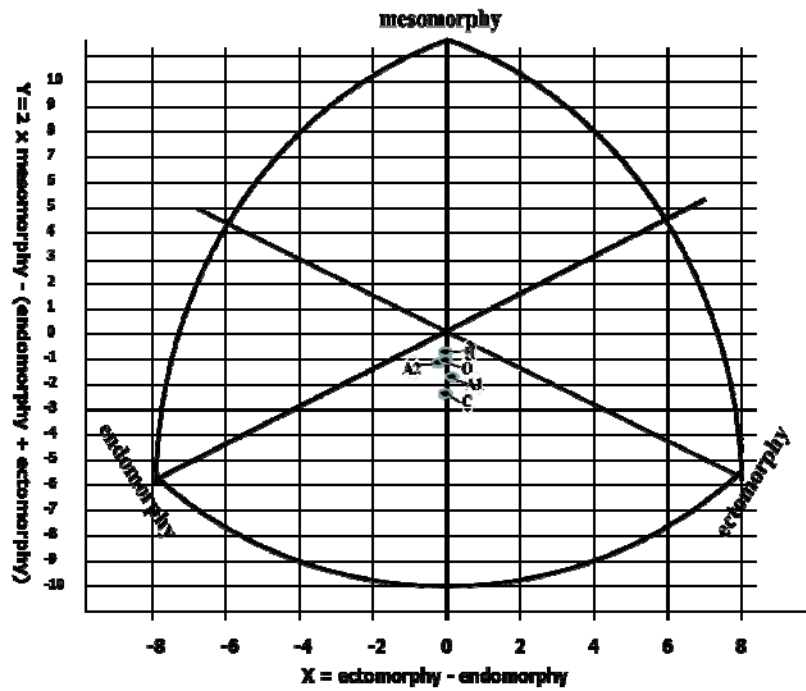
Figure 1

*Somato-chart of Greek top-level male volleyball players by the competiton level
(Division A1 and A2) and positional role (O = opposites, H = hitters, C =
centrals).*

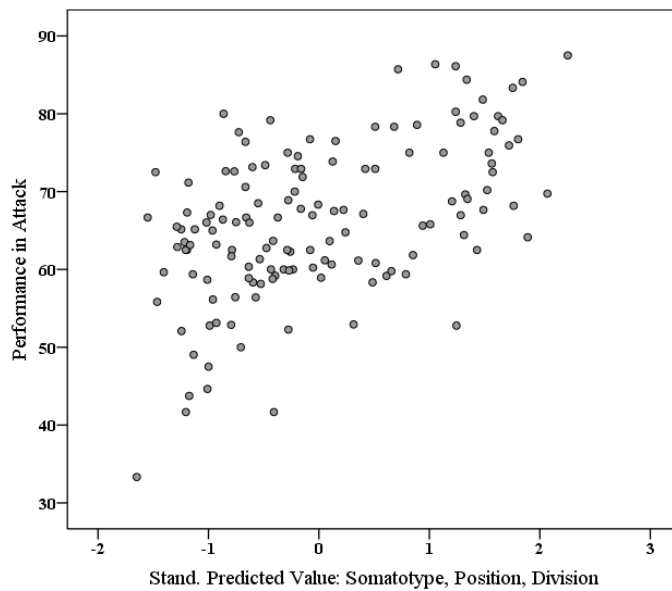

Figure 2

*Scatterplot of performance against the best linear combination of the somatotype,
position, and Division (according to the analysis shown in Table 3).*

Discussion

This study explored the relationship between the somatotype and performance in attack in elite level male volleyball having considered the effect of the competition level and playing position. Our results showed that Greek elite male volleyball players possessed an ectomorph-endomorph somatotype, hitters possess a central somatotype, whereas centers and opposites are endomorph-ectomorph. About 24% of performance in attack could be predicted by the linear combination of somatotype, competition level and playing position.

The presented results relating to anthropometric characteristics of volleyball players can be added to the pertinent literature. Division A1 has an apparent advantage over division A2 in body height and lean body mass, both of which contribute to the acquisition of active height, strength, and speed (Rodriguez et al., 2009). Players of Division A1 are less endomorph and older, with age adding some extra expertise towards achieving a higher level of performance as found in an earlier study (Palao et al.,2014).

Despite the anthropometric superiority of players in Division A1 as compared to A2, our results did not reveal a significant difference in performance in attack between the two Divisions. We hypothesized that this similarity in performance reflected a qualitative balance between attack and defense within each Division. This result appears to imply that players in Division A1 compete against opponents of a similar, high competitive level and thus, efficacy in attack is counterbalanced by similar efficacy in defense from the opposing team. Compared to Division A1, the competitive level of teams in Division A2 is lower, this resulting in players of a lower competitive level attacking against opponents of the similar competitive level in defense. Previous studies that have found significant anthropometric differences in favor of teams classified higher in the team performance ranking compared to those ranked lower (Martin-Matillas et al., 2014; Palao et al., 2014). However, these studies assessed performance according to a global criterion, that of team classification in competitions.

Regardless of the competition level, but considering the playing position, our centers were characterized by a significantly higher performance in attack compared to hitters and opposites. These results confirm findings of a previous study on the relationship between playing position and performance in attack (Bergeles and Nikolaidou, 2011). At a high level of performance, centers are trained to perform first tempo attacks and usually face an individual or an unorganized double block. As a consequence, centers are more efficient in attacking against the offensive players of the other two positions, who attack in second or third tempo; this involves potential attacks against double or, very frequently, triple blocks, a particularly unfavorable condition.

Furthermore, we sought to clarify if the higher performance in attack of the centers could be at least partially attributed to their somatotype. Indeed, the follow-up discriminant function analysis revealed that the higher performance in attack was primarily due to endomorphy and secondarily to mesomorphy and ectomorphy. Our results showed that centers and opposites were endomorph-ectomorph and hitters were central. The somatotype variation found in the present sample of volleyball players appears not to be comparable to that reported in other national level volleyball leagues. Italian players participating in leagues of a competition level comparable to that of the present sample of players were ectomorph-mesomorph (Gualdi-Russo and Zaccagni, 2001), whereas Brazilian national team players were balanced mesomorph (Zary et al., 2010). The ectomorph-mesomorph combination appears to be effective regardless of the playing position, and this constitutes a definite superiority of internationally prominent players (Gualdi-Russo and Zaccagni, 2001). Based on the sample anthropometrics reported in the study of Gualdi-Russo and Zaccagni (2001), we estimated that our Greek volleyball players were 1.1 cm taller, 3.7 kg heavier, and 0.69 units higher in the BMI than the Italian players at the equivalent competition level. These differences mean that Italian players are more ectomorph while the trend of increased endomorphy found in the Greek players is associated with less muscle mass, thicker bodies, and, thus, more inactive mass, that potentially hinders their performance. This finding might partially explain why in 2015, the Greek National team ranked internationally 49th, whereas the

Italian ranked 4th (FIVB, 2015).

Evidently, certain somatotype traits provide players with a comparative advantage (Duncan et al., 2006; Gualdi-Russo and Zaccagni, 2001; Malousaris et al., 2008; Martin-Matillas et al., 2014). Moreover, the critical role of the body physique in volleyball has been pointed out by numerous researchers. For example, Viitasalo (1982) provided evidence of the decisive advantage of players with longer lower extremities in jumping and attacking, whereas Smith et al. (1992) demonstrated how taller players were capable of attacking with higher speeds while in maximum vertical jump heights. However, performance in attack depends not only on the physique and the somatotype of the players but also on the combined effect of the competition level and playing position. Using an inclusive statistical model, we found that a considerable percentage of efficacy in attack (24.1%) could be explained by the combined effects of the somatotype (i.e.: ectomorphy-endomorphy), playing position (i.e.: centers) and competition level (i.e.: Division A1). Figure 2 depicts the scatterplot of the overall linear dependency of performance in attack on the combined effects of those three factors. Moreover, we found that with the three factors being simultaneously tested against performance in attack (Table 3; Figure 2), and with the somatotype and playing position being constant, players of Division A1 did outperform those of Division A2 significantly (Table 3).

A limitation of the present study was that the somatotype was assessed using the right side of the body, even though a small number of players (~10% of the sample) was left-handed. Undeniably, contemporary volleyball coaches are aware of the different body physique characteristics required for each playing position, and they always attempt to assign players to playing positions according to their somatotype. Our findings may be useful to coaches and sport scientists both in selecting players based on the appropriate somatotype for each playing position and in designing playing position-specific training programs in relation to each player's somatotype.

Conclusions

Based on the results of this study it can be concluded that Greek elite male volleyball players in Division A1 possess an ectomorph-endomorph somatotype regardless of the playing position. In Division A2, hitters present a central somatotype, centers are endomorph-ectomorphs and opposites have a balanced endomorph somatotype. Independently of the competition level and responding to the more favorable conditions usually being created for attacking, centers perform better in attack than hitters and opposites. Current findings suggest that coaches and practitioners should give special training consideration to ectomorph centers since they can ensure a high level of performance in attack.

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