POSITIONAL DIFFERENCES OF PHYSICAL TRAITS AND PHYSIOLOGICAL CHARACTERISTICS IN FEMALE VOLLEYBALL PLAYERS – THE ROLE OF AGE

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Abstract:

The purpose of this study was to examine the variation in physical and physiological characteristics according to playing position in adolescent and adult female volleyball players. Adolescent (n=62, aged 15.6±1.1 years) and adult volleyball players (n=58, aged 24.9±5.3 years) were examined for anthropometric characteristics and body composition, and they performed a physical working capacity test, a 3-minute step test, the Wingate anaerobic test, sit-and-reach test, handgrip strength test, and countermovement vertical jump with arm-swing test (CMJa). Adult players were taller and had a higher percentage of fat-free mass, better performance in cardiorespiratory power, anaerobic power, handgrip muscle strength and CMJa than adolescents (Cohen's d>0.45). Positional differences in body height (centers were the tallest, whereas liberos were the shortest, p<.001) were found for both age groups. However, positional differences in body mass and fat-free mass were observed only in adolescents (centers were heavier than liberos, p<.05), whereas differences in CMJa were only in adults (hitters jumped higher than liberos, p<.05). Thus, the differences in body mass, fat-free mass and CMJa among playing positions in female volleyball were age-dependent. These findings might help coaches and trainers to develop position-specific training programs.

Key words: *positional role, exercise testing, physical fitness, anaerobic power, age groups*

Introduction

Volleyball is an intermittent high-intensity team sport that requires a combination of physical characteristics, aerobic and anaerobic power to perform a sequence of well coordinated high demanding activities (Gabbett & Georgieff, 2007). Whereas a minimal level of aerobic power is necessary to cope with the demands of training and match, anaerobic power and maximal effort during short periods of time (e.g. jumping, hitting the ball) usually determine the outcome of a game (Grgantov, Milić, & Katić, 2013). In order to meet the aforementioned demands of competition, players should be of appropriate physical and physiological characteristics, and training programs should focus on developing these characteristics.

Physical and physiological characteristics of volleyball players have been studied in a wide range of ages (Nikolaidis, Ziv, Arnon, & Lidor, 2012; Schaal, Ransdell, Simonson, & Gao, 2013), in both sexes and at various levels of competition (Gabbett & Georgieff, 2007; Malousaris, et al., 2008). It is well established that successful players should be tall with high percentage of fat-free mass and significant anaerobic power (Nikolaidis, et al., 2012; Schaal, et al., 2013). Moreover, it has been demonstrated that players of different competitive levels differ among themselves with regard to physical and physiological characteristics in adolescence (Gabbett & Georgieff, 2007) and in adulthood (Malá, Malý, Záhalka, & Bunc, 2010; Malousaris, et al., 2008).

As volleyball is a sport in which various play roles require specific tactical actions (Afonso, Mesquita, Marcelino, & Da Silva, 2010), players should possess bodily characteristics that correspond to the demands of a particular playing position. Usually, players are classified into centers, opposites, hitters, setters and liberos (Malousaris, et al., 2008; Marques, van den Tillaar, Gabbett, Reis, & Gonzalez-Badillo, 2009; Schaal, et al., 2013). Other classifications have also been used (e.g. centers, setters, and spikers; Carvajal, et al., 2012). Positional differences are related to the technical and tactical demands of each position (Carvajal, et al., 2012). For instance, centers should be the tallest due to the greater blocking demand which is placed on them compared to the other positions (Sheppard, Gabbett, & Reeberg Stanganelli, 2009), whereas hitters should jump higher than setters and defense players due to a greater emphasis on jumping actions (Schaal, et al., 2013).

Despite the differentiation of players by playing positions, only a few studies have examined positional differences in adults (Carvajal, et al., 2012; Malousaris, et al., 2008; Marques, et al., 2009; Zhang, 2010) and one in a mixed sample of adolescents and adults (Schaal, et al., 2013) with limited research on females. Since differences in game patterns exist between sexes (Costa, Afonso, Brant, & Mesquita, 2012), we considered only research on female volleyball players.

Previous research (Carvajal, et al., 2012; Malousaris, et al., 2008; Marques, et al., 2009; Zhang, 2010; Schaal, et al., 2013) has established that differences in various characteristics exist between playing positions, but it is not clear whether these differences exist equally in both adolescent and adult female players. Volleyball practiced with different age groups poses distinct constraints upon the players further complicated by diverse levels of development. These two basic features imply quite divergent tactical and technical demands, which in turn are expected to impact the physical and physiological requisites for playing in each specific age group. Understanding age-related positional differences can help coaches and fitness trainers working with adolescents to optimize the assignment of players to playing positions and to develop proper training programs.

Moreover, due to different maturation levels of volleyball players, it is possible that an adolescent might change positional role when entering adulthood. For instance, an early matured adolescent might be taller than her peers and might be assigned to center position, but in the meanwhile she should be prepared technically and physically for a future assignment to other position as well. Thus, knowledge about positional differences might help coaches and trainers to successfully implement future changes of positional roles. Although a main task of sport specialists working with adolescents is to prepare their athletes for a future career as adults, another training goal is successful competition performance in games and championships. Thus, being aware of age-specific volleyball demands during adolescence, including positional differentiation, might enhance players' training and selection, as well as talent identification.

To the best of our knowledge no research on positional differences in both adolescent and adult female volleyball players exists. Therefore, the aim of the present study was to examine the age effect on positional differences in female volleyball players. It is reasonable to assume that, because several studies have established differences in match demands between junior and adult players (Inkinen, Hayrinen, & Linnamo, 2013), and in physical and physiological characteristics between adolescent and adult players (Nikolaidis, 2013; Nikolaidis, et al., 2012; Schaal, et al., 2013), we might expect an age effect on positional differences, too.

Methods

Study design and participants

A non-experimental, descriptive-correlation design was used to examine the association between physical fitness and playing position in female volleyball players. Testing procedures were performed during the competitive period of seasons 2010/11 and 2011/12. The study protocol was performed in accordance with the ethical standards laid down in the Declaration of Helsinki in 1975 and approved by the local Institutional Review Board. A hundred and twenty female volleyball players were divided into two groups: adolescent (≤18 years, n=62) and adult players (>18 years, n=58), and were classified into hitters (n=22 and n=16, respectively), centers (n=16 and n=14), opposites (n=7 and n=8), setters (n=11 and n=10) and liberos (n=6 and n=10). All players were members of competitive sport clubs participating in national tournaments and volunteered for this study. Adult players competed in the best three Greek volleyball divisions. Written informed consent was received from all participants or their guardians, in the case of underage players (age≤18 years), after a verbal explanation of the study design and its potential risks. Exclusion criteria were history of any chronic medical condition and use of any medication. All participants visited our laboratory once and underwent a series of anthropometric and physiological measurements.

Equipment and protocols

Body height, body mass and skinfolds were measured, body mass index (BMI) was calculated as the quotient of body mass (kg) to body height squared (m^2), and body fat percentage (BF) was estimated from the sum of 10 skinfolds (cheek, wattle, chest I, triceps, subscapular, abdominal, chest II, suprailiac, thigh and calf; $BF=-41.32+12.59 \cdot \log_e x$, where x is the sum of 10 skinfolds) (Parizkova, 1978). An electronic weight scale (HD-351 Tanita, Illinois, USA) was used for body mass measurement (to the nearest 0.1 kg); also, a portable stadiometer (SECA, Leicester, UK) and a caliper (Harpenden, West Sussex, UK) were used for the measurement of body height (to the nearest 1 cm) and for skinfolds (to the nearest 0.5 mm), respectively. Using a two-component model of body composition, we divided the body into fat mass (FM), calculated as the product of body mass by BF, and fat-free mass (FFM), estimated as the difference between body mass and FM.

All participants performed the following physical fitness tests in the respective order:

a) Sit-and-reach test (SAR). The SAR protocol (Wells & Dillon, 1952) was employed for the assessment of low back and hamstring flexibility. An advantage of 15 cm was set at the position of just reaching the toes.
b) Physical working capacity in heart rate (HR) 170 beats·min^{-1} (PWC_{170}). PWC_{170} was performed according to Eurofit guidelines (Adam, Klissouras, Ravazzolo, Renson, & Tuxworth, 1988) on a cycle ergometer (828 Ergomedic, Monark, Sweden). Seat height was adjusted to each participant's satisfaction, and toe clips with straps were used to prevent the feet from slipping off the pedals. Participants were instructed before the tests that they should pedal with steady cadence of 60 revolutions per minute, which was displayed to participants by both visual (ergometer's screen showing pedaling cadence) and audio means (metronome set at 60 beats per minute). This test consisted of three stages, each lasting three minutes, against incremental braking force in order to elicit HR between 120 and 170 beats per minute. Based on the linear relationship between HR and power output, PWC_{170} was calculated as the power corresponding to HR 170 min^{-1} and expressed as W·kg^{-1}.
c) Step test. YMCA step test was performed on a 0.3 m height step for three minutes using a 24 ascent/min cadence (Golding, 2000). This test estimates the HR during the first minute of recovery after three minutes of stepping up and down. The lower the HR values, the higher the aerobic power. In addition to the recording of the recovery HR, the HR at the end of the 3-minute step test can also be used as an index of aerobic power.
d) Countermovement jump with arm-swing (CMJa). The participants performed two countermovement jumps (Aragon-Vargas, 2000). The height of each jump was estimated using the Opto-jump (Microgate Engineering, Bolzano, Italy); the best trial was recorded and expressed in centimeters.
e) Handgrip strength test (HGS). The participants were asked to stand with their elbow bent at approximately 90° and instructed to squeeze the handle of the handgrip dynamometer (Takei, Tokyo, Japan) as hard as possible for five seconds (Adam, et al., 1988). This test was administered twice for each hand. HGS was calculated as the best effort and was expressed in absolute (kg) and relative values (kg·kg^{-1} of body mass).
f) Wingate anaerobic test (WAnT). The WAnT (Bar-Or & Skinner, 1996) was performed on a cycle ergometer (874 Ergomedic, Monark, Sweden). Briefly, participants were asked to pedal as fast as possible for 30 seconds against a braking force that was determined by the product of body mass in kg by 0.075. Peak power (P_{peak}) and mean power (P_{mean}) were expressed in W and W·kg^{-1}.

Statistical analysis

Statistical analyses were performed using IBM SPSS v. 20.0 (SPSS, Chicago, USA). Parametric statistics were used, because the significance value of Kolmogorov-Smirnov test of normality was higher than .05 for all variables. Data were expressed as means and standard deviations of the mean (SD). One-way analysis of covariance (ANCOVA) with a subsequent Tukey's *post-hoc* test (if the differences between groups were revealed) was used to examine differences in physical and physiological characteristics among playing positions in adolescent players. In this analysis, age was used as a covariate due to the effect of growth and development on physical and physiological characteristics across adolescence. Accordingly, one-way analysis of variance (ANOVA) was used in adult players. The effect size (ES) in ANCOVA and ANOVA was assessed by eta square and interpreted as following: $.01\leq\eta^2<.06$ small, $.06\leq\eta^2<.14$ medium and $\eta^2\geq.14$ large (Cohen, 1988). Independent Student's *t*-tests examined the differences between adolescent and adult playing position groups (e.g. adolescent setters vs. adult setters). The ES for statistical differences in the *t*-test were determined using the following criteria for Cohen's d: ES≤0.2, trivial; 0.2<ES≤0.6, small; 0.6<ES≤1.2, moderate; 1.2<ES≤2.0, large; and ES>2.0, very large (Batterham & Hopkins, 2006). Statistical significance was set at α=.05 and mean difference together with 95% confidence intervals (CI) was calculated.

Results

In our first set of results (physical characteristics), the only significant differences we found were for body height, body mass and FFM, and no differences were found for age, BMI or BF (see Table 1). In adults, centers were taller than hitters (8.2 cm (2.3;14.2), mean difference (95% CI lower limits; upper limits)), setters (9.7 cm (3.0;16.4)) and liberos (13.3 cm (6.5; 20.0)); opposites were also taller than setters (8.0 cm (0.3;15.7)) and liberos (11.6 cm (3.9;19.3)); hitters jumped higher than liberos in CMJa (6.1 cm (0.4;11.9)). In adolescents, hitters (9.4 cm (2.7;16.1)), centers (13.8 cm (6.9;20.7)) and opposites (10.2 cm (1.9;18.4)) were taller than liberos, centers were also taller than setters (7.7 cm (2.0;13.3)); centers were heavier (11.7 kg (0.4;23.1)) and had higher percentage of fat-free mass than liberos (7.5 kg (0.8;14.2)). For our second set of results (physiological characteristics; see Table 2) we found very few differences, with only two of 24 comparisons being statistically significant,

Table 1. Age, anthropometry and body composition of female volleyball players according to their age and playing position

	Age group	Average	Hitters	Centers	Opposites	Setters	Liberos	Comparison
Age (yr)	Adolescents	15.6±1.1	15.5±1.2	15.7±1.1	14.8±0.8	15.9±1.1	16.0±0.5	$F_{4,57}$=1.51, p=.212
	Adults	24.9±5.3‡	25.7±5.5‡	25.1±4.7‡	22.0±4.3†	25.9±5.2‡	24.4±7.0	$F_{4,53}$=0.78, p=.546
Body mass (kg)	Adolescents	63.0±8.5	61.2±6.7	68.1±10.6^{L}	62.5±4.0	62.8±9.1	56.6±5.3^{C}	$F_{4,57}$=2.82, p=.033, η^2=0.17
	Adults	65.9±9.5	62.4±9.3	70.2±10.8	69.1±11.6	64.8±6.0	63.7±6.9	$F_{4,53}$=1.74, p=.154
Body height (cm)	Adolescents	169.1±6.4	169.2±6.1^{L}	174.1±4.9^{SL}	168.6±5.1^{L}	166.7±4.3^{C}	160.8±4.7^{HCO}	$F_{4,57}$=9.82, p<.001, η^2=0.41
	Adults	172.2±7.3*	170.4±5.7^{C}	178.6±4.2^{HSL*}	177.0±6.5^{SL*}	169.0±5.3^{CO}	165.4±6.5^{CO}	$F_{4,53}$=11.27, p<.001, η^2=0.46
BMI (kg·m^{-2})	Adolescents	22.0±2.3	21.4±1.8	22.4±2.9	22.1±2.1	22.5±2.3	22.0±2.6	$F_{4,57}$=0.79, p=.538
	Adults	22.2±2.6	21.4±2.4	21.9±3.1	22.0±2.8	22.7±2.4	23.3±2.0	$F_{4,53}$=0.96, p=.438
BF (%)	Adolescents	25.0±3.6	24.5±3.8	26.0±3.8	24.3±3.6	25.3±1.9	24.2±4.7	$F_{4,57}$=0.65, p=.632
	Adults	23.8±4.6	21.8±5.1	24.1±4.3	23.3±3.9	25.2±4.1	25.8±4.8	$F_{4,53}$=1.52, p=.210
FFM (kg)	Adolescents	47.0±5.1	46.1±4.1	50.1±5.7^{L}	47.3±2.5	46.9±6.2	42.7±2.7^{C}	$F_{4,57}$=3.12, p=.022, η^2=0.18
	Adults	49.9±5.7†	48.6±5.9	52.9±5.8	52.7±6.8	48.3±3.6	47.1±3.9	$F_{4,53}$=2.79, p=.035, η^2=0.17

BMI=body mass index, BF=body fat percentage, FFM=fat-free mass. The letters H (hitters), C (centers), O (opposites), S (setters) and L (liberos), when presented as exponents, denote that the column's group differs from the respective group. The symbols *,† and ‡ denote significance level of difference of independent Student's t-test lower than .05, .01 and .001, between age groups, respectively.

Table 2. Physiological characteristics of female volleyball players according to their playing position

	Age group	Average	Hitters	Centers	Opposites	Setters	Liberos	Comparison
PWC$_{170}$ (W)	Adolescents	126±35	126±30	137±49	131±32	117±26	108±17	$F_{4,55}$=1.37, p=.255
	Adults	154±48‡	139±30	175±67	172±59	154±31*	131±30	$F_{4,45}$=1.79, p=.148
PWC$_{170}$ (W·kg^{-1})	Adolescents	2.00±0.51	2.06±0.49	2.00±0.65	2.11±0.59	1.88±0.41	1.93±0.39	$F_{4,45}$=0.57, p=.683
	Adults	2.31±0.51†	2.23±0.29	2.46±0.68	2.40±0.56	2.37±0.42*	2.07±0.47	$F_{4,45}$=0.98, p=.431
Step$_{end}$ (b·min^{-1})	Adolescents	155±12	156±10	156±18	153±9	155±12	156±17	$F_{4,42}$=0.29, p=.880
	Adults	149±14†	143±14†	147±14	154±12	149±15	154±12	$F_{4,52}$=1.29, p=.286
Step$_{rec}$ (b·min^{-1})	Adolescents	106±14	104±11	107±15	97±12	114±17	104±11	$F_{4,40}$=1.77, p=.153
	Adults	102±17	101±17	103±16	97±12	105±19	105±21	$F_{4,52}$=0.38, p=.823
P$_{peak}$ (W)	Adolescents	553±77	538±70	589±98	566±26	555±84	501±23	$F_{4,55}$=2.15, p=.087
	Adults	596±92†	597±112	628±87	602±69	590±76	551±94	$F_{4,53}$=1.03, p=.402
P$_{peak}$ (W·kg^{-1})	Adolescents	8.80±0.79	8.79±0.72	8.59±0.84	9.07±0.65	8.87±0.99	8.90±0.76	$F_{4,55}$=0.67, p=.613
	Adults	9.09±1.03	9.56±1.05*	9.01±0.93	8.79±0.75	9.14±1.18	8.67±1.06	$F_{4,53}$=1.47, p=.225
P$_{mean}$ (W)	Adolescents	408±56	404±50	412±71	426±37	414±65	370±27	$F_{4,54}$=0.98, p=.424
	Adults	446±65‡	435±68	471±67*	457±55	451±68	418±60*	$F_{4,50}$=1.15, p=.345
P$_{mean}$ (W·kg^{-1})	Adolescents	6.48±0.67	6.61±0.47	6.03±0.80	6.82±0.66	6.60±0.62	6.49±0.77	$F_{4,55}$=2.66, p=.043, η^2=0.16
	Adults	6.78±0.82*	6.99±0.85	6.66±0.79*	6.69±0.81	6.89±0.91	6.58±0.81	$F_{4,50}$=0.51, p=.730
SAR (cm)	Adolescents	26.4±6.4	27.7±5.8	25.3±6.1	23.7±9.3	26.6±6.9	27.2±4.7	$F_{4,56}$=0.65, p=.630
	Adults	24.0±7.7	24.4±6.5	21.6±8.9	24.1±7.0	25.6±8.5	25.1±8.4	$F_{4,53}$=0.47, p=.757
HGS (kg)	Adolescents	29.0±4.0	28.8±3.4	30.7±4.6	26.1±3.3	29.3±4.1	28.1±3.9	$F_{4,45}$=1.58, p=.197
	Adults	33.8±4.3‡	35.1±4.7‡	34.2±4.7	33.8±5.4†	32.4±3.4	32.2±2.4	$F_{4,53}$=1.04, p=.397
HGS (kg·kg^{-1})	Adolescents	0.47±0.07	0.47±0.06	0.46±0.09	0.42±0.07	0.47±0.07	0.51±0.08	$F_{4,55}$=1.32, p=.275
	Adults	0.52±0.08‡	0.57±0.08‡	0.49±0.07	0.50±0.10	0.50±0.07	0.51±0.04†	$F_{4,53}$=2.44, p=.058
CMJa (cm)	Adolescents	29.5±5.2	31.0±5.0	26.4±3.3	29.4±7.5	30.5±4.4	30.0±7.2	$F_{4,46}$=1.58, p=.197
	Adults	33.8±4.3*	35.2±4.7^{L*}	34.2±4.7‡	33.8±5.4	32.4±3.4	32.2±2.4^{H}	$F_{4,52}$=3.10, p=.023, η^2=0.24

PWC170=physical working capacity at HR of 170 bpm, Step$_{end}$=HR at the end of the step test, Step$_{rec}$=the average HR at the first minute of recovery after the step test, P$_{peak}$=peak power, P$_{mean}$=mean power during the Wingate anaerobic test, SAR=sit-and-reach test, HGS=handgrip strength test, and CMJa=arm-swing countermovement vertical jump. The letters, when presented as exponents, denote that the column's group differs from the respective group. The symbols *,† and ‡ denote significance level of difference between age groups of independent Student's t-test lower than .05, .01 and .001, respectively.

and when *post-hoc* corrections were considered, positional groups differed only in one case (CMJa).

We found significant age-related differences in physical and physiological characteristics. Adult players were taller (3.1 cm (0.6;5.6), Cohen's d=0.45) and had higher fat-free mass than adolescents (2.8 kg (0.9;4.8), d=0.54). In addition, the older age group had better performance in cardiorespiratory power (e.g. in PWC_{170} 28 W (12;44), d=0.67), anaerobic power (e.g. in P_{mean} 39 W (16;61), d=0.63), handgrip muscle strength (4.7 kg (3.2;6.2, d=1.16) and CMJa (2.5 cm (0.5;4.5), d=0.48) than the younger group. However, these age differences were not similar for each playing position. For instance, the variation of the differences in body height ranged from 1.2 cm (-2.7;5.2, d=0.20) in hitters to 8.4 cm (1.8;15.0, d=1.52) in opposites.

Discussion and conclusions

The purpose of this study was to examine whether positional differences vary by age in female volleyball players. The main finding was that different physical attributes and physiological characteristics discriminate female volleyball players by playing position depending on age. Although positional differences in body height were found for both adolescents and adults, differences in body mass and fat-free mass were observed only in adolescents, whereas differences in CMJa were found only in adults.

With regard to physical traits and body composition of adult players, centers and opposites were taller than hitters, setters and liberos, while there was no difference between players in the various positions in BF. This is in line with a previous study on physical attributes and body composition which showed that liberos were shorter and lighter than hitters, centers and opposites, and that centers and opposites were taller than setters and hitters. However, our findings contradict the significant differences between centers and liberos, centers and setters, as well as between hitters and liberos with regard to FFM (Malousaris, et al., 2008). An explanation for this discrepancy might be that our sample included players from three divisions, whereas Malousaris, et al. (2008) included players from two divisions, thus the homogeneity of samples might influence the positional differences. Also, another study on a mixed sample of adolescent and adult players, who were classified into three playing positions, found that hitters were taller than setters and defense players, and that hitters and setters were heavier than defense players (Schaal, et al., 2013).

Furthermore, in the group of adolescent players, we found hitters, centers and opposites to be taller than liberos. Also, centers were taller than setters; centers were heavier and had higher percentage of FFM than liberos. These positional differences for body height in adolescent volleyball players were in agreement with the corresponding differences of their adult counterparts. On the contrary, positional differences for body mass were observed only in adolescents indicating that anthropometric characteristics might be more important for assignment of players to positions in the younger group than in the older.

Despite the large difference in age between adolescent and adult players, we observed no differences in BMI and BF, and small difference in FFM between them, whereas the same trend was noticed when examining positional differences. These findings suggest that muscle mass is not a discriminant factor for success in volleyball. This makes sense, as relative force is more relevant than absolute force in this sport, so perhaps training the neural aspects is more relevant than increasing muscle mass. Therefore, neither age nor positional effect was observed for body composition. The differences in body height of adult players by playing position correspond to the large diversity of players' somatotype associated with different playing positions in the game as previously observed by Buśko et al. (2013). In the aforementioned study, liberos and setters had the lowest ectomorphy and the highest endomorphy, whereas the hitters and opposites had the highest ectomorphy and the lowest endomorphy and mesomorphy.

In physiological characteristics, significant positional difference was found only with regard to countermovement jump (CMJa), in which hitters jumped higher than liberos. No differences were found for opposites and setters (+1.4 cm, $p>.05$); an explanation might be that the role of opposites demands of them to be powerful attackers; on the other hand, setters should have adequate jumping capacity in order to perform many submaximal jumps during a match. Tentatively, these results lead us to suggest that technical and tactical aspects might be more relevant than jump height for opposite hitters. The importance of CMJa was previously highlighted by the large correlations recently found between this measure with block and attack jump (Sattler, Sekulic, Hadzic, Uljevic, & Dervisevic, 2012). Jumping is an integral part of volleyball, so considerable training time is allocated to developing this component (Newton, Rogers, Volek, Hakkinen, & Kraemer, 2006).

Moreover, we examined the differences between age groups and we found better CMJa in adult than in adolescent players. This finding was not in agreement with previous research, which did not observe any statistical differences; e.g. 38.8 cm in 15.8 year olds, 40.7 cm in 18.0 year olds and 39.0 cm in 22.5 year olds (Buśko, Michalski, Mazur, & Gajewski, 2012); 27.7 cm in U14, 28.5 cm in U18 and 30.0 in over-18 years old players (Nikolaidis, et al., 2012). However, this disagreement should be attributed to different methodology (sample size, age and protocol). In general, CMJa in the adult players was similar to that of Portuguese (34.2 cm; Gonzáléz-Rave, Arija, & Clemente-Suarez, 2011) and Spanish professional players (34.3 cm; Marques, Tillaar, Vescovi, & Gonzalez-Badillo, 2008), and lower than Polish players (39.0 cm; Buśko, et al., 2012). Therefore, the overall jumping performance of participants in this study and age-related differences were in agreement with most of previous research.

We tested aerobic power by assessing HR responses to submaximal exercise on cycle ergometer and step test. Despite the small age differences, i.e. better performance in PWC_{170} in W and in $W \cdot kg^{-1}$, and in HR at the end of the step test for the older group, no positional difference was found. Based on the game demands, we expected that setters would achieve better aerobic capacity than attackers. For instance, setters are capable of setting even balls that are very far away from them, an aspect that increases the distance they have to run. On the other hand, it seems that there is no need for superior aerobic capacity in this sport, since actions last only few seconds and there are many breaks to allow recovery. This finding was in agreement with a recent study that showed no difference in aerobic capacity among teams of different competition level (Nikolaidis, Afonso, & Busko, 2015).

Overall, the sport-specific requirements of different age groups seem to impose distinct demands on players. Our data show that adult setters are aerobically fitter than their younger counterparts. Also, adult hitters and centers have to jump higher than the younger players in the same positional role, as verified with the CMJa testing. Notwithstanding, few statistically significant differences exist between adults and adolescents for the applied tests in female volleyball. Being an imminently tactical sport, it is likely that tactical evaluations would provide more significant differences (e.g. distinct game models for each age group; Afonso, et al., 2010). Furthermore, perhaps different sets of tests could provide more discriminative information (Schaal, et al., 2013). The finding of no differences in physiological characteristics among adolescent players, as opposed to hitters scoring higher on CMJa among adult players, could reflect a lack of position-specific training, resulting in all players possessing similar physiological capacity regardless of their playing position. Also, this difference could be due to a more systematic placing of players with high jumping ability (i.e. CMJa) in positions (i.e. hitters) close to the net.

There are some important practical applications of our findings. First, they can be used as reference by coaches to assign players into positions, especially in countries with similar quality level as Greece (which was ranked 46th out of 131 countries in FIVB Senior World Ranking, January 2014). Second, they provide normative data for specific positions by age that might be used in future research. Finally, these findings highlight the need for age-tailored training programs taking into account the positional variation of physical and physiological characteristics.

In conclusion, the differences in physical and physiological characteristics between playing positions in female volleyball players are age-dependent. Therefore, coaches and trainers working with adolescent players should develop training programs considering the age-specific positional differences. Our findings could serve as a base for talent identification in volleyball, since adult players in this study were taken from players competing in the top Greek leagues. Moreover, the ability to make tailored position-specific training programs among adult and adolescent volleyball players might be enhanced by knowledge about age-related positional differences.

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