Sport Sci Health
DOI 10.1007/s11332-014-0196-7

ORIGINAL ARTICLE

Differences in anthropometry, somatotype, body composition and physiological characteristics of female volleyball players by competition level

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Received: 3 June 2014 / Accepted: 27 June 2014

Abstract
Purpose The aim of this study was to compare female volleyball teams with different performance level and to identify the physiological characteristics that discriminate them.
Methods Thirty-seven players (age 21.9 ± 4.8 years, mean ± standard deviation, body mass 66.3 ± 7.1 kg, stature 173.9 ± 7.3 cm) from teams A, B and C participating in the first, second and third Greek league, respectively, performed a series of anthropometric and physical fitness measures.
Results Players of team A and B were taller than players of C [10.8 cm (4.7; 16.9), mean difference (95 % confidence intervals), and 7.4 cm (1.6; 13.3), respectively]. Players of A also had lower body fat [−5.8 % (−9.3; −2.3)] and higher fat-free mass than C [6.5 kg (1.8; 11.3)]. The mean somatotype of A was ectomorphic mesomorph, B was balanced endomorph and C was mesomorphic endomorph. Players of B jumped higher in squat jump, countermovement jump without and with arm-swing than their counterparts of C [4.9 cm (1.4; 8.5), 4.3 cm (0.3; 8.3) and 5.1 cm (0.9; 9.2), respectively]. Players of A scored better than those of C with regard to the strength of the right hand [5.9 kg (1.2; 10.6)] and the sum of both hands [10.2 kg (1.4; 19.1)]. Peak power in Wingate anaerobic test was better in team B than C [1.0 W kg^{-1} (0.0; 2.0)]. Team A and B scored higher in mean power either in absolute values [79 W (11; 147) and 77 W (10; 143), respectively] or in relative to body mass values [1.0 W kg^{-1} (0.1; 1.8) and 1.0 W kg^{-1} (0.2; 1.8), respectively] than team C.
Conclusions These findings confirmed the importance of stature and jump ability for performance in volleyball. However, what is novel is that for the first time we identified differences in upper limbs' muscle strength and in lower limbs' muscle power among teams from different leagues, and based on these findings recommendations can be given on training goals and players' selection.

Keywords Women · Performance · Physique · Countermovement jump · Wingate anaerobic test

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Introduction

During the training process, volleyball coaches and trainers often make decisions on their players' selection and training considering the physical and physiological characteristics. For the selection of players at a given competitive level, it is necessary to examine whether a player has the proper profile (e.g. stature), whereas the knowledge of the optimal physiological profile (e.g. jumping ability) is important to set proper training goals.

Actually, profiling female players has been the subject of several research papers, whose common methodology was the comparison of teams and players of different competitive level [1–7]. Martin-Matillas et al. [1] have examined morphological differences among players of teams with different ranking in the first Spanish league and between players selected or non-selected for their national team. Schaal et al. [2] compared players of the first US collegiate league and high school teams with regard to anthropometry, vertical jump, agility and shuttle-run. Barnes et al. [3] focused on agility and jumping ability of collegiate players of US Division I, II, and III. Morphological differences between the first and second league were studied by Malousaris et al. [4] in Greece and by Gualdi-Russo et al. [5] in Italy. Fleck et al. [6] compared US national team and university games team, and Spence et al. [7] examined players who were selected or not for the US national team.

From the abovementioned studies, only two [4, 5] compared players from teams participating in different national leagues. However, they focused only on morphological characteristics. In addition, we noticed that among the studies which investigated physiological characteristics, there was a lack of information on the muscle power assessed by traditional laboratory methods (e.g. Wingate anaerobic test). Observing the relevant literature makes it clear that there is a gap in research concerning the comparison of physiological characteristics of players participating in leagues with different level. The knowledge of these differences may help coaches and trainers in the selection and training of their players. Therefore, the aim of this study was to compare players from the top three Greek leagues.

Materials and methods

Study design and participants

A cross-sectional design was used to examine the relationship of performance level in female volleyball with anthropometric, body composition, somatotype and physiological characteristics. To accomplish this aim, volleyball players from teams competing at different league were measured and compared. The anthropometric, body composition, somatotype and physiological characteristics were designated as dependent variables, whereas the league of competition was designated as independent variable. The study was carried out according to the ethical standards of Declaration of Helsinki of the World Medical Association in 1964 as it was modified in 2013 and approved by the local institutional review board. Informed consent was given by all players.

For the purpose of this study, 37 volleyball players, who competed with their teams A, B and C to the first, second and third Greek league, respectively, volunteered to participate in this study. Participants from team A ($n = 11$) had 10.4 ± 5.5 years experience in playing volleyball and 11.1 ± 1.4 h weekly training volume, whereas those from teams B ($n = 13$) and C ($n = 13$) had 9.8 ± 4.7 years and 7.2 ± 1.7 h, and 10.3 ± 4.8 years and 5.1 ± 1.8 h, respectively. During the previous season, team A, B and C had played 26, 16 and 30 official games, respectively. Testing procedures were carried out on two consecutive days on September 2013 during the preparative period of season 2013–2014. The participants were familiar with testing procedures, because the present physical fitness battery was routinely administered to these teams in the past. On Day 1, the participants visited the laboratory, where they were examined for anthropometric characteristics, heart rate variability, flexibility, cardiorespiratory power, muscle strength and anaerobic power. On Day 2, the participants performed jump and sprint tests in teams' indoor court under standard environmental conditions (temperature 22–24 °C and humidity 50–54 %) between 9 and 11 am.

Protocols and equipments

a. Anthropometry. We used an electronic body mass scale (HD-351 Tanita, Illinois, USA) and a portable stadiometer (SECA, Leicester, UK) to measure body mass in the nearest 0.1 kg and stature in the nearest 1 mm with participants being barefoot and in minimal clothing, respectively. These measurements were used to calculate Body mass index (BMI) as the quotient of body mass (kg) to stature squared (m^2). Body fat percentage (BF) was calculated from the sum of 10 skinfolds [8], which were taken with a skinfold caliper (Harpenden, West Sussex, UK). Fat-free mass (FFM) was calculated as $FFM = body\ mass \times (1 - BF)$. Somatotype was assessed by the Heath-Carter method as it was described by Ross and Marfell-Jones [9]. Chronological age for each participant was calculated using a table of decimals of year [9].
b. Flexibility. The sit-and-reach (SAR) protocol [10] was employed for the assessment of lower back and hamstring flexibility. An advantage of 15 cm was set at the position of just reaching the toes. Two trials were given and the best score was recorded.
c. Heart rate variability (HRV). The participants were measured in supine position for 5 min for HRV [11]. Data were analyzed with the software Kubios 2.1 (Biosignal Analysis and Medical Imaging Group, University of Eastern Finland, Joensuu, Finland). The parameters that analyzed were the normal-to-normal interval (NN), standard deviation of the NN intervals (SDNN), heart rate (HR), square root of the mean squared differences of successive NN intervals (RMSSD), the proportion derived by dividing the number of interval differences of successive NN intervals greater than 50 ms by the total number of NN intervals (pNN50). HR was recorded continuously during all testing procedures in the laboratory and in

the field by Team2 Pro (Polar Electro Oy, Kempele, Finland).

d. Physical working capacity in heart rate 170 min^{-1} (PWC_{170}). We followed the Eurofit guidelines [12] to measure PWC_{170} 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. We instructed participants before the test to pedal with steady cadence 60 revolutions per minute, which was given by both visual (ergometer's screen showing pedaling cadence) and audio means (metronome set at 60 beats per minute). Three stages, each lasting 3 min, against incremental braking force to elicit HR between 120 and 170 beats per minute (min^{-1}) consisted this test. 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 and W kg^{-1}.

e. Handgrip strength test (HST). The participants were asked to stand with their elbow bent at $\sim 90°$ and instructed to squeeze the handle of the handgrip dynamometer (Takei, Tokyo, Japan) as hard as possible for 5 s [13]. Two trials were given for each hand and the best trial was recorded. HST was calculated as the sum of the best efforts for each hand in absolute values (kg) and relative to body mass values (kg kg^{-1} of body mass).

f. Wingate anaerobic test (WAnT). The WAnT was performed on a cycle ergometer (Ergomedics 874, Monark, Sweden) [14]. Briefly, participants were asked to pedal as fast as possible for 30 s against a braking force that was determined by the product of body mass in kg by 0.075. Peak power (P_{peak}) was estimated as the average power over a 5 s period with the highest performance, which occurs usually in the first 5 s of the test. Mean power (P_{mean}) was calculated as the average power during the 30 s period. Both P_{peak} and P_{mean} were expressed as W and W kg^{-1}. HR was recorded at the end of the test.

g. Squat jump (SJ), countermovement jump without arm-swing (CMJ) and with arm-swing (CMJa), and 30 s continuous jumping Bosco test. The participants performed two trials for each jumping exercise and the best result was recorded [15]. Height of each jump was estimated using the Opto-jump (Microgate Engineering, Bolzano, Italy) and was expressed in cm. The Bosco test was conducted on the same equipment as the abovementioned jump tests. The participants were instructed to jump as high as possible for 30 s, while trying to retain short ground contact times [16]. They were also requested to keep their hands on their waist throughout the test. The mean power during the 30 s test was recorded in W kg^{-1}.

h. 10 m sprint. Participants performed two trials with 5 min break and the best was recorded. Each sprint was timed using a photocell system (Brower Timing Systems, Utah, USA). Two pairs of photocells were used, set at 0 and 10 m. The photocells were placed at the belt height so that the legs do not break the light beam according to manufacturer's guidelines and the participants started their attempts from a standing position 0.5 m behind the first pair of photocells.

Statistical analysis

Statistical analyses were performed using IBM SPSS v.20.0 (SPSS, Chicago, USA). Data were expressed as mean and standard deviations of the mean (SD). One-way analysis of variance (ANOVA) with a sub-sequent Bonferroni post hoc test (if difference among the groups was revealed) was used to examine differences in physical and physiological characteristics among the three volleyball teams. Mean difference together with 95 % confidence intervals (CI) was calculated when the post hoc was necessary. To interpret the effect size for statistical differences in the ANOVA we used eta square classified as small ($0.01 < \eta^2 \leq 0.06$), medium ($0.06 < \eta^2 \leq 0.14$) and large ($\eta^2 > 0.14$) [17]. The level of significance was set at $\alpha = 0.05$.

Results

The differences in anthropometry, body composition and somatotype among teams can be seen in Table 1. Players of team A and B were taller than players of C [10.8 cm (4.7; 16.9) and 7.4 cm (1.6; 13.3), respectively]. Players of A had also lower BF [−5.8 % (−9.3; −2.3)] and higher FFM than C [6.5 kg (1.8; 11.3)]. Players of A were less endomorphic than B [−1.2 (−2.2; −0.2)] and C [−2.1 (−3.0; −1.1)], and more ectomorphic than C [1.4 (0.2; 2.6)], while B were more ectomorphic than C [1.2 (0; 2.3)], too. The effect size in these differences was large. The mean somatotype of A was ectomorphic mesomorph, B was balanced endomorph and C was mesomorphic endomorph. There was no difference in heart rate variability and in aerobic power (Table 2).

The differences in jumping performance can be seen in Table 3. Players of B jumped higher (large effect size) in SJ, CMJ and CMJa than their counterparts of C [4.9 cm (1.4; 8.5), 4.3 cm (0.3; 8.3) and 5.1 cm (0.9; 9.2), respectively]. Players of A scored better (large effect size) than those of C with regard to the strength of the right hand [5.9 kg (1.2; 10.6)] and the sum of both hands [10.2 kg (1.4; 19.1)] (Table 4). Peak power in WAnT was better in team B than C [1.0 W kg^{-1} (0.0; 2.0)] (Table 5). Teams A and B scored higher in P_{mean} either in absolute values

Table 1 Anthropometry, body composition and somatotype

	Overall ($n = 37$)	Team A ($n = 11$)	Team B ($n = 13$)	Team C ($n = 13$)	Comparison
Age (years)	21.9 (4.8)	22.2 (5.3)	22.3 (4.9)	21.2 (4.6)	$F_{2,34} = 0.20$, $p = 0.823$, $\eta^2 = 0.01$
Body mass (kg)	66.3 (7.1)	68.3 (9.5)	65.9 (5.7)	64.8 (6.0)	$F_{2,34} = 0.75$, $p = 0.480$, $\eta^2 = 0.04$
Stature (cm)	173.9 (7.3)	178.9 (7.3)^{C}	175.5 (4.5)^{C}	168.1 (5.7)^{A,B}	$F_{2,34} = 10.73$, $p < 0.001$, $\eta^2 = 0.39$
BMI (kg m^{-2})	21.9 (2.2)	21.4 (2.5)	21.4 (1.9)	23.0 (1.9)	$F_{2,34} = 2.33$, $p = 0.113$, $\eta^2 = 0.12$
BF (%)	20.0 (4.1)	16.7 (3.9)^{C}	20.1 (3.5)	22.5 (2.8)^{A}	$F_{2,34} = 8.91$, $p = 0.001$, $\eta^2 = 0.34$
FFM (kg)	52.9 (5.2)	56.7 (6.0)^{C}	52.6 (3.9)	50.1 (4.0)^{A}	$F_{2,34} = 6.05$, $p = 0.006$, $\eta^2 = 0.26$
Endomorphy	4.2 (1.2)	3.0 (0.9)^{B,C}	4.2 (1.1)^{A}	5.1 (0.8)^{A}	$F_{2,34} = 14.3$, $p < 0.001$, $\eta^2 = 0.46$
Mesomorphy	4.0 (1.3)	4.1 (1.8)	3.6 (1.2)	4.5 (0.9)	$F_{2,34} = 1.6$, $p = 0.224$, $\eta^2 = 0.08$
Ectomorphy	2.9 (1.3)	3.5 (1.4)^{C}	3.3 (1.1)^{C}	2.1 (1.0)^{A,B}	$F_{2,34} = 5.4$, $p = 0.009$, $\eta^2 = 0.24$

Data are presented as mean with standard deviation in brackets. Capital letters A, B and C, when appear as exponents next to standard deviations, denote significant difference at $p < 0.05$ from team A, B and C, respectively

BMI body mass index, *BF* body fat, *FFM* fat free mass

Table 2 Heart rate variability and physical working capacity at 170 bpm

	Overall ($n = 37$)	Team A ($n = 11$)	Team B ($n = 13$)	Team C ($n = 13$)	Comparison
NN (ms)	866 (140)	816 (121)	910 (168)	865 (140)	$F_{2,34} = 1.38$, $p = 0.226$, $\eta^2 = 0.07$
SDNN (ms)	71.8 (31.0)	69.2 (39.3)	78.8 (32.1)	67.0 (22.2)	$F_{2,34} = 0.51$, $p = 0.605$, $\eta^2 = 0.03$
HR (min^{-1})	71.0 (11.0)	75.0 (10.4)	68.0 (12.3)	70.6 (9.9)	$F_{2,34} = 1.23$, $p = 0.306$, $\eta^2 = 0.07$
RMSSD (ms)	46.9 (23.2)	39.7 (16.2)	53.4 (29.2)	46.6 (21.4)	$F_{2,34} = 1.04$, $p = 0.363$, $\eta^2 = 0.06$
pNN50 (%)	25.0 (18.8)	18.4 (14.6)	29.9 (21.6)	25.8 (18.8)	$F_{2,34} = 1.15$, $p = 0.329$, $\eta^2 = 0.06$
PWC_{170} (W)	147.4 (28.1)	142.1 (29.7)	152.6 (21.6)	146.5 (33.4)	$F_{2,34} = 0.41$, $p = 0.665$, $\eta^2 = 0.02$
PWC_{170} (W kg^{-1})	2.23 (0.42)	2.08 (0.37)	2.33 (0.38)	2.26 (0.48)	$F_{2,34} = 1.11$, $p = 0.340$, $\eta^2 = 0.06$

Data are presented as mean with standard deviation in brackets

NN normal-to-normal interval, *SDNN* standard deviation of the NN intervals, *HR* heart rate, *RMSSD* square root of the mean squared differences of successive NN intervals, *pNN50* the proportion derived by dividing the number of interval differences of successive NN intervals greater than 50 ms by the total number of NN intervals, PWC_{170} physical working capacity in heart rate 170 min^{-1}

Table 3 Jumping performance

	Overall ($n = 37$)	Team A ($n = 11$)	Team B ($n = 13$)	Team C ($n = 13$)	Comparison
SJ (cm)	24.5 (4.1)	24.8 (6.6)	26.8 (3.7)^{C}	21.9 (4.0)^{B}	$F_{2,34} = 6.15$, $p = 0.005$, $\eta^2 = 0.27$
CMJ (cm)	25.7 (4.3)	25.7 (3.8)	27.9 (4.6)^{C}	23.6 (3.7)^{B}	$F_{2,34} = 3.64$, $p = 0.037$, $\eta^2 = 0.18$
CMJa (cm)	30.6 (4.6)	30.7 (4.9)	33.1 (3.5)^{C}	28.0 (4.2)^{B}	$F_{2,34} = 4.72$, $p = 0.016$, $\eta^2 = 0.22$
Bosco (W kg^{-1})	27.3 (4.6)	29.2 (3.9)	27.2 (4.8)	25.3 (4.5)	$F_{2,31} = 2.08$, $p = 0.142$, $\eta^2 = 0.12$

Data are presented as mean with standard deviation in brackets. Capital letters A, B and C, when appear as exponents next to standard deviations, denote significant difference at $p < 0.05$ from team A, B and C, respectively

SJ squat jump, *CMJ* countermovement jump, *CMJa* countermovement jump with arm-swing, *Bosco* mean power during 30 s Bosco test

[79 W (11; 147) and 77 W (10; 143), respectively] or in relative to body mass values [1.0 W kg^{-1} (0.1; 1.8) and 1.0 W kg^{-1} (0.2; 1.8), respectively] than team C. The effect size was large for each comparison.

Discussion

The main finding of this study was that anaerobic power and muscle strength discriminated female volleyball players according to their performance level, which was indicated by the comparison among teams participating in different divisions. We observed differences in a series of jumping tests (squat jump, countermovement jump with and without arm-swing), handgrip strength test and in the Wingate anaerobic test.

With regards to the anthropometric, body composition and somatotype characteristics, the results confirmed the existing literature. The players of the first division had superior characteristics than the other players as we

Table 4 Neuromuscular performance

	Overall ($n = 37$)	Team A ($n = 11$)	Team B ($n = 13$)	Team C ($n = 13$)	Comparison
SAR (cm)	25.4 (7.8)	28.8 (6.6)	25.3 (9.5)	22.8 (6.2)	$F_{2,34} = 1.85$, $p = 0.172$, $\eta^2 = 0.10$
RH (kg)	33.4 (5.1)	36.2 (4.8)^{C}	34.0 (5.3)	30.3 (3.4)^{A}	$F_{2,34} = 5.18$, $p = 0.011$, $\eta^2 = 0.23$
LH (kg)	32.0 (4.9)	34.4 (6.2)	32.0 (3.9)	30.0 (3.9)	$F_{2,34} = 2.52$, $p = 0.095$, $\eta^2 = 0.13$
SUM (kg)	65.4 (9.3)	70.6 (10.1)^{C}	66.1 (8.7)	60.4 (6.9)^{A}	$F_{2,34} = 4.28$, $p = 0.022$, $\eta^2 = 0.20$
SUM (kg kg^{-1})	0.99 (0.14)	1.04 (0.13)	1.01 (0.14)	0.94 (0.13)	$F_{2,34} = 1.80$, $p = 0.181$, $\eta^2 = 0.10$
10 m sprint (s)	2.06 (0.09)	2.03 (0.08)	2.04 (0.07)	2.11 (0.09)	$F_{2,27} = 2.56$, $p = 0.096$, $\eta^2 = 0.16$

Data are presented as mean with standard deviation in brackets. Capital letters A, B and C, when appear as exponents next to standard deviations, denote significant difference at $p < 0.05$ from team A, B and C, respectively

SAR sit-and-reach test, *RH* right handgrip strength, *LH* left handgrip strength, *SUM* sum of RH and LH

Table 5 Wingate anaerobic test

	Overall ($n = 37$)	Team A ($n = 11$)	Team B ($n = 13$)	Team C ($n = 13$)	Comparison
P_{peak} (W)	636 (97)	652 (105)	669 (82)	592 (94)	$F_{2,33} = 2.40$, $p = 0.106$, $\eta^2 = 0.13$
P_{peak} (W kg^{-1})	9.6 (1.1)	9.7 (0.8)	10.1 (0.9)^{C}	9.1 (1.1)^{B}	$F_{2,33} = 3.37$, $p = 0.047$, $\eta^2 = 0.17$
P_{mean} (W)	470 (72)	499 (57)^{C}	497 (67)^{C}	420 (63)^{A,B}	$F_{2,30} = 5.89$, $p = 0.007$, $\eta^2 = 0.28$
P_{mean} (W kg^{-1})	7.1 (0.9)	7.4 (0.7)^{C}	7.5 (0.7)^{C}	6.5 (0.9)^{A,B}	$F_{2,30} = 6.23$, $p = 0.005$, $\eta^2 = 0.29$
FI (%)	46.8 (8.3)	42.3 (10.1)	47.5 (6.5)	50.0 (6.9)	$F_{2,30} = 2.65$, $p = 0.087$, $\eta^2 = 0.15$
HR (min^{-1})	173.0 (10.0)	179.6 (7.9)^{C}	171.6 (10.3)	168.7 (9.0)^{A}	$F_{2,30} = 4.09$, $p = 0.027$, $\eta^2 = 0.21$

Data are presented as mean with standard deviation in brackets. Capital letters A, B and C, when appear as exponents next to standard deviations, denote significant difference at $p < 0.05$ from team A, B and C, respectively

P_{peak} peak power, P_{mean} mean power, *FI* fatigue index, *HR* heart rate

observed differences with regards to stature, BF, FFM and somatotype. These findings were in line with previous research which indicated greater values in stature and FFM, and lower BF for players of higher performance level [1, 4, 7]. For instance, in a previous research on Greek players, those of the first division were taller, leaner with greater FFM than their second division counterparts [4]. Also, players who were selected for the US national team were taller and heavier than those who were not selected [7]. In addition, in the highest Spanish league, top level players (those of teams with better ranking) were taller, had higher muscle mass and ectomorphy, and had lower level of adiposity markers, and the players selected for the national team of Spain were taller, heavier, had higher muscle mass and lower endomorphy [1]. Greek and Italian players of the first league were less endomorph and mesomorph, and more ectomorph than those of the second league [4, 5], and both were less endomorph and mesomorph, and more ectomorph than Italian "amateur" female volleyball players [18]. Therefore, with the decreasing performance level of female volleyball teams, an increase in endomorphic and mesomorphic components and a decrease in ectomorphic component were noticed.

An interpretation for the low BF in the elite team is that it results from training at a higher level; therefore, a low BF might be a consequence of playing at a superior level and not a prerequisite. Low BF might be associated with high FFM. Taking into account that the three components of somatotype are calculated from other anthropometric parameters (e.g. stature, body mass and skinfolds), it was not a surprise to observe that the differences in endomorphy and ectomorphy were in agreement with corresponding differences in other anthropometric measures.

All teams that participated in this study exhibited very good level of aerobic power; compared with age-matched population norms (107 W or 1.8 W kg^{-1}) [19], they had higher PWC_{170} in W by 32.8–42.6 % and in W kg^{-1} by 15.6–29.4 %. The lack of differences in aerobic power and HRV among the three teams might be explained by the physiological demands of volleyball, which is a team sport characterized by high intensity and short duration actions (e.g. spiking and blocking). Thus, volleyball players should not be expected to present aerobic adaptations like those of endurance athletes (i.e. increased activity of parasympathetic nervous system and low heart rate at rest). Moreover, eccentric exercises usually included in training might result in increased sympathetic activity [20]. A very good level of aerobic power seems necessary to meet the demands of training and to recover between the high intensity actions during match-play, but this parameter cannot discriminate volleyball players by level. The present study is not the only one to find no superior aerobic performance in the better players. Spence et al. [7] compared players who were selected for the US national team with those who were not, and found that the latter had higher maximal oxygen uptake than the former.

The team of the second league scored better than that of the third league in the three jump tests, whereas there was no difference in the 30 s continuous jumping test. It has been shown in a previous study that a team of first division scored higher than that of third league in countermovement jump [3]. Also, in a comparison between the US national team and a university games team, it was shown that the former had better vertical jump [6]. We observed that the similar jumping ability in teams from the first and second league in the present study had been previously reported by Barnes et al. [3]. This trend might be attributed to that a minimum jumping ability is necessary to play at a certain level, but after that threshold has been reached, more jumping ability is not necessary. Another explanation might be that since the tallest players have been selected for the first league, relatively short players should possess high jumping ability to balance their stature "deficit". On the other hand, the lowest scores of the team C might be partially due to increased body mass index and body fat percentage, which have been shown to correlate inversely with CMJa [21].

We observed better performance in isometric strength in team A than in team C, which was statistically significant for the right handgrip muscle strength and the sum of two hands in kg, but not for left handgrip strength and the sum of two hands in kg per kg of body mass. Accordingly, we did not find statistical difference in flexibility and 10 m sprint, although a common trend was observed in all these parameters: better scores in team A than in team B, and both better than in team C. With regards to the sum of two hands in kg per kg of body mass, the lack of statistical significance might be attributed to the increased body mass in team A compared to the other teams, i.e. the difference in muscle strength was explained partially by the difference in body mass. This finding was in agreement with the research of Koley and Pal Kaur [22] who showed significant positive correlations of handgrip strength with body dimensions. It might be supported that the lack of statistical differences in flexibility and sprint should be attributed to the lack of sensitivity or sport-specificity of these tests that would allow them to discriminate among the three performance levels. On the other hand, medium to large effect size was noticed even in the cases of non-significance indicating that this should be attributed rather to the sample size than to lack of differences.

The results of the Wingate anaerobic test revealed similar trend as in jumping ability; better anaerobic performance in teams A and B than in team C, suggesting that a good level is necessary to compete at high level, but there is no need for the higher score to compete at the top level. Compared with normative data on intercollegiate high-level female athletes [23], teams A and B had P_{peak} and P_{mean} in W above average, and average P_{peak} and P_{mean} in W kg^{-1}, whereas team had average P_{peak} in W and in W kg^{-1}, and P_{mean} in W, and below average P_{mean} in W kg^{-1}. These findings were in the same direction as those of muscle strength and jumping tests, revealing the importance of muscle strength and power for female volleyball. In a previous research on young volleyball players, Grgantov et al. [24] identified four factors explaining over of 80 % of their common variability: volleyball-specific jumping, nonspecific jumping and sprinting, throwing explosive power and volleyball-specific throwing and spiking speed. A secondary but interesting finding in the Wingate anaerobic test was the effect of performance level on the heart rate response, where the highest score was recorded in team A. An interpretation for this might be a better adaptation of the best teams to high intensity training by increased sympathetic function.

In addition to the superior values observed in the top teams, we would also expect to find lower scores of standard deviations in these teams than in the team C [25]. Standard deviation is a measure of variability that indicates the homogeneity of a group. Nevertheless, a trend revealing more homogeneous teams in the top leagues with regards to physical and physiological characteristics was not verified. Although positional roles were not taken into account in the present study, the lack of homogeneity might be partially attributed to the high specialization of players by positions.

An explanation of the superior scores in the top teams might be the differences in weekly training volume. Although players of all teams had similar experience in playing volleyball (~10 years), those of team A had almost double weekly training compared with those of team C, with players of B being in the middle. In contrast with stature, which is important for players' selection [26] but cannot change with training, all other parameters are subjected to the training effect. For instance, increase in muscle mass and fat-free mass, and decrease in body fat percentage have been reported during a season [27]. Moreover, increase in muscle strength and power, assessed by bench press, squat test, overhead medicine ball throw and countermovement jump, has also been noticed during a season [28]. In addition to countermovement jump, squat jump, spike and block jumps have also been found to change [29]. It has been shown that such seasonal changes might be due to the content of muscle strength training [30]. The seasonal variation of physical fitness among teams of different level, as well as the effect of competition level on injury prevalence [31, 32], need further research.

Conclusions

These findings confirmed the importance of stature and jump ability for performance in volleyball. However, what is novel is that for the first time we identified differences in physiological characteristics among teams from different leagues, and based on these findings, recommendations can be given on training goals and players selection.

Conflict of interest There are no conflicts of interest in this paper.

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