Morphological features as weel as the strength and speed performance of female volleyball players at high sports level

Cechy morfologiczne organizmu i sprawność siłowo-szybkościowa siatkarek występujących na wysokim poziomie sportowym

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Summary

Introduction: Contemporary volleyball requires athletes to present a high level of development of strength and speed capabilities. Effectiveness in this discipline is also significantly determined by the level of development of the basic features of the somatic structure, including primarily body height and armspan. The main aim of the study was to assess the level of development of the most important morpho-functional characteristics specific for female volleyball players occurring at the second level of national league games against the background of non-playing females.

Materials and methods: 13 female athletes representing the 1st league volleyball club took part in the study. The control group consisted of 11 females not playing any form of sports. Basic measurements of the somatic structure were carried out: body height, body weight and its tissue components. In addition, explosive power of the lower limbs (CMJ) was measured and the Wingate test was performed. Based on the statistical analysis, the most important features of somatic structure and indicators of motor skills characterizing the 1st league female volleyball players were selected.

Results: The greatest differentiation between female volleyball players and non-playing females in terms of morphological characteristics was recorded for lean body mass (LBM [kg], $Z = 6.63$, $p < 0.01$). However, in terms of cardiovascular indicators, the largest differences were found in the power peak, average power and counter movement jump (CMJ) and relative CMJ power. The following was calculated: $Z=2,59$, $p<0,001$; $Z=3,22$, $p<0,001$; $Z=2,75$, $p<0,001$, $Z=2,54$, $p<0,001$).

Conclusions: Own study has shown and confirmed the high importance of selected morpho-functional being favorable in terms of high performance in women's volleyball. Testes based on jumping (e.g. CMJ) assessing the motor potential of lower limbs of female volleyball players have practical value in the context of recruitment, selection and control of women's volleyball training. The Wingate test, as a diagnostic tool, can be used as a supplement for volleyball specific tests.

Keywords: volleyball, anaerobic power of the lower limbs, body tissue components, selection and control of women's volleyball training

Introduction

Anaerobic performance is crucial for the successful implementation of short-term supramaximal intensity. These types of efforts involve processes that allow athletes to develop high power in a short time. The energy necessary to perform muscle contraction in this type of effort is derived almost exclusively from the energy anaerobic metabolism based on the breakdown of ATP, phosphocreatine and anaerobic glycolysis [1, 2].

Anaerobic performance (maximum non-lactic-acid strength and maximum lactic-acid strength) determines the possibility of achieving high sports results in many disciplines [3, 4]. Volleyball is a dynamic discipline in which maximization of the motor preparation process, individual level of athlete's involvement in the game as well as a high level of technical and tactical skills,

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which are largely conditioned by psychomotor skills, are important [5]. In the light of the analysis of the scientific literature, it can be concluded that the most important somatic features in volleyball include: body height and armspan. In addition, contemporary volleyball (at high sports level) requires athletes to present a high level of strength and speed capabilities (speed, jumping, jumping endurance, explosive power) [6, 7]. Volleyball is a discipline in which the energy demand of effort is covered by the following sources: in 40% anaerobic non-lactic-acid, in 10% anaerobic lactic-acid and in 50% aerobic [8].

One of the most important and most common motor activity in volleyball is the vertical jump – performed during attacking or blocking. It has been shown that the vertical jumps performed by volleyball players who are more effective in the game are carried out at a higher level of performance compared to less effective athletes, and that they are the basic indicator enabling the assessment of the volleyball player's fitness preparation [7]. The publications cited above indicate that the assessment of motor skills of volleyball players should include motor tests, whose time-space structure is similar to motor activities occurring in the volleyball (jumps) as well as tests enabling the assessment of energetic motor potential determining the effective conduct of volleyball players.

The main purpose of this study, in the light of the analysis of literature in the field of motor preparation in volleyball, was to assess the level of strength and speed capabilities of Polish female volleyball players playing at the second level of league games. Aiming to achieve the goal, a hypothesis has been developed, that the level of strength and speed capabilities of female volleyball players will be significantly higher compared to non-playing females.

On the other hand, on the basis of a comparative analysis of the basic features of somatic structure as well as strength and speed performance between female athletes and non-playing females, an attempt was made to determine the characteristics that most determine, at this sports level, a high level of motor performance (in terms of fitness tests used).

Materials and study methods

In own study (descriptive character) 13 female athletes representing the 1st league volleyball club (24.07 years of age), and having an average body height of 178.76 cm and an average body weight of 74.71 kg took part. The study was conducted in 2018 during the pre-season. The control group consisted of non-competitive sports female students of the State Higher Vocational School in Tarnów (n = 11, 20.4 years old), who systematically participated in physical education classes. Their average body height was 163.8 cm, with an average body weight of 55.88 kg.

Due to the fact that the size of the control group was small, in order to determine its representativeness, the so-called computer test of significance of one or two means was carried out [9]. The average of our own control group was compared with the average of the population of young women of large numbers, similar age and similar level of physical activity, tested by Kopiczko and Bogucka [10]. This study [10] and comparisons carried out with the significance test of one or two means [9] indicate that at the level of development of the analyzed morphological characteristics of own control group and the population of Polish first-year female students at the age of 21.4 years, there were no significant differences (height and weight p-value were: 0,87 and 0,84 respectively). Based on the analysis, it was assumed that the control group observed in own study may constitute a valuable „background", from the point of view of training practice and recruitment, for the group of assessed female volleyball players. In addition, it should be emphasized that the control group was not selected from the general population of athletes (female volleyball players in this case). Nevertheless, in the light of the adopted study goal, which in the context of recruitment and selection, was the search for important elements of the motor potential of female volleyball players and methods of their diagnosis, the choice of the control group recruited from the general population seems to be justified.

Somatic measurements

The following measurements of basic body composition features were made [11]: body height (WC [cm]), body weight (MC [kg]), body fat percentage (FM [%]) and lean body mass (LBM [kg]). The measurements of somatic features were made with the use of an anthropometer and the TANITA BF-350 Body Composition Analyzer. BMI was calculated based on the above measurements.

Motor skills measurements

The persons in the study were divided into two groups (6 and 7 persons in the female volleyball group, 6 and 5 people in the non-playing group). Motor skills measurements were carried out as follows:

1. a 10-minute warm-up was performed,
2. followed by a CMJ test (each of the test subjects performed it twice, at 1 minute interval),
3. then, after waiting about 2 minutes after the last CMJ, a cycloergometer test was carried out.

Tests based on the assessment of anaerobic motor achievements

The explosive power of the lower limbs of the females in the study was measured by the vertical jump (CMJ) – each jump was performed twice, the higher result was recorded in cm. The study used the Optojump Next measuring system (Microgate, Bolzano, Italy). Based on the jumping results, the maximum jumping power (CMJ Pmax [W/kg]) was calculated using the equation developed by Sayers [12].

Ergometric measurements

In addition, the Wingate test was performed using the Monark 847E cycloergometer to determine the anaerobic capacity of the females in the study [13]. The right choice of external load is an important consideration for the study using the Wingate test. In the previous study, in the groups of women, an external load was applied for the lower limbs at the level of: 8.6% of body weight [14, 15], 6.7% of body weight [16] or 7.5% of body weight [17]. In own study, the test protocol presented by Nikolaidis et al. was used [18]. This protocol was to enable comparison of the results of own study with the results of the Nikolaidis team. The external load during the test was 7.5% of the body weight under study. The effort time was 30 seconds and started from the „0" position, i.e. from stillness. The following basic parameters were recorded: relative total work W_{tot} [J/kg], which enables the assessment of anaerobic capacity and peak power P_{max} [W/kg], which informs about the maximum mechanical muscle power. In addition, the following supplementary indicators were recorded: relative average effort power $P_{śr}$ [W/kg], time to obtain power peak $TuzP_{max}$ [s], power loss indicator WS% P [%].

Statistical analysis

Standard activities were used and performed in statistical analysis of the collected data. Basic descriptive statistics were calculated: arithmetic mean, standard deviation, confidence intervals for means. The compliance of the distribution of the analyzed variables with the normal distribution was assessed by the Shapiro-Wilk test with the assumption that at $p<0.05$ the hypothesis about the compatibility of the distribution of the tested variable with the normal distribution should be rejected. For the purpose of comparative analysis and assessment of the diversity of the intergroup level of development of the examined somatic features and functional characteristics of the female athletes, the t-Student test was carried out for independent tests or, in the case of heterogeneity of variance, the Cochran-Cox test. The homogeneity of variance in the variables was checked by Levene's test. The level of statistically significant results for the t-Student test or Cochran-Cox test was $p\leq0.05$. For variables that did not meet the requirements of the Shapiro-Wilk test, a non-parametric of difference significance Mann-Whitney U test was carried out, in which the level of $p<0.05$ was assumed as significant (the assumption concerns one variable: Tuz_{max} [s], special designation in Table 1). In order to present the size of the differences – in the scope of the analyzed variables – between female volleyball players and non-playing women, the results were normalized (Z-score) in relation to the mean and standard deviation of non-playing females. The Z-score value was interpreted as an indicator allowing to assess the potential significance of a given variable in the context of the possibility of effective competition in women's volleyball.

Results

Table 1 shows the results of the groups under study. It can be noted that the group of female volleyball players presented a higher level of development in most of the analyzed variables. Only in terms of the indicator informing about the level of work done non-playing females presented a higher level compared to the athletes. Table 1 also presents the results of the intergroup difference significance test and values of normalized Z-score differences. These data show that in most cases the size of the observed differences was statistically significant. The exceptions were the fat level (FM%) and the size of the power loss indicator (WS% P). Among the variables describing the somatic structure, the greatest differentiation between female volleyball players and non-playing females was recorded for lean body mass (LBM [kg]: Z=6,63, p=0,01). However, in terms of effort indicators, the greatest differences were found in the power peak range (P_{max} [W/kg]: Z=2.59, p=0.001), average power ($P_{śr}$ [W/kg]: Z=3.22, p=0.001) and CMJ (CMJ [cm]: Z=2.75, p=0.001) and relative power of CMJ (CMJ P_{max} [W/kg]: Z=2,54, p=0,001). It is interesting that non-playing females presented a statistically significantly higher level of work done during a cycloergometer test (W_{tot} [J/kg]: Z=-1,60, p=0,001).

Discussion

It is widely believed that body height is a decisive factor in volleyball sports performance. However, in recent years it has often been shown that male teams with a lower level of development of somatic parameters have been performing well, but compensating for the lack of athletic preparation, speed and special skills [6]. The second important feature that was identified in the analysis was lean body mass (LBM). LBM is an approximate measure of muscle mass and one of the predispositions of structural strength abilities [19]. In turn, the level of muscle strength affects the ability to generate anaerobic power, which is the product of strength and speed [20]. Thus, LBM is a structural predisposition having a significant impact on the performance and motor effectiveness realized in specific volleyball motor activities.

The above statements indicate that during recruitment and selection in volleyball, these two characteristics should be taken into account, with greater weight being given to lean body mass. Own study indicates a significant, but smaller importance of body height in women's volleyball against the background of the level of LBM development. As mentioned earlier, in men's volleyball, the importance of body height in the context of high motor effectiveness seems to decrease in favor of other predispositions determining motor skills. Perhaps the same tendency is beginning to be observed within female groups. However, this hypothesis should be scientifically verified.

Table 1.

Statistical characteristics of the groups in the study, p-values of difference significance tests and Z-score

variable	on-playing females					female athletes					p-value	Z-score
	$\tilde{x}$	95% CI		SD	CV	$\tilde{x}$	95% CI		SD	CV		
WC [cm]	163.80	159.67	167.93	6.15	3.76	178.76	174.39	183.13	7.23	4.04	**p<0.001**	**2.43**
MC[kg]	55.88	51.09	60.68	7.14	12.77	74.71	71.65	77.77	5.06	6.77	**p<0.001**	**2.64**
FM[%]	22.45	17.81	27.10	6.92	30.80	21.38	19.39	23.37	3.29	15.40	0.6218	-0.16
BMI	20.77	19.55	21.98	1.81	8.72	23.43	22.34	24.51	1.80	7.67	**p<0.001**	**1.47**
LBM[kg]	42.91	41.31	44.50	2.37	5.53	58.64	56.84	60.44	2.98	5.08	**p<0.01**	**6.63**
CMJ [cm]	27.35	25.13	29.56	3.30	12.07	36.45	33.85	39.05	4.30	11.81	**p<0.001**	**2.76**
CMJ P_{max} [W/kg]	38.26	35.81	40.71	3.65	9.53	47.53	45.39	49.66	3.53	7.42	**p<0.001**	**2.54**
W_{tot} [J/kg]	181.30	170.45	192.15	16.16	8.91	155.52	149.70	161.33	9.62	6.19	**p<0.001**	**-1.60**
Psr [W/kg]	6.04	5.68	6.40	0.54	8.90	7.78	7.49	8.07	0.48	6.19	**p<0.001**	**3.22**
P_{max} [W/kg]	7.77	7.29	8.25	0.71	9.17	9.61	9.24	9.98	0.61	6.36	**p<0.001**	**2.59**
$TuzP_{max}$ [s]	*9.21*	*7.00*	*11.43*	*3.29*	*35.76*	*5.99*	*5.32*	*6.67*	*1.12*	*18.65*	***p<0.001***	***-0.98***
WS%_P [%]	20.63	17.83	23.43	4.17	20.20	17.80	15.98	19.63	3.02	16.97	0.0671	-0.68

Explanation: *italics - Mann-Whitney U test result*

Volleyball is widely recognized as a sport discipline in which often repeated high-intensity efforts dominate which are secured by aerobic and anaerobic energy sources [7, 8, 21]. Due to the above, there is a constant need to update and verify the level of development of strength and speed capabilities as well as anaerobic capacity of athletes presenting high sports level. In the study conducted in groups 1st and 2nd league female volleyball players in Slovenia, jump-based tests were performed (CMJ, SJ, BJ – block jump, AJ – attack jump). The average CMJ value in the first league team was 45.3 cm, with 42.5 in the second league team [22]. Marques and his colleagues, studying the Portuguese top league female volleyball team, noted a much lower CMJ test result: 35.56 cm [23]. In the study of Nikolaidis et al. the average level in the CMJ test amongst Greek female volleyball players was 25.9 (± 5.1) cm. In addition, the level of maximum anaerobic power and average power in the Wingate test (with an external load of 7.5% of body weight) were checked in that study. The average values of maximum power and average power expressed in relative units were 9.07 (± 0.97) and 6.73 (± 0.82) W/kg, respectively [24]. In other study also conducted under the direction of Nikolaidis, a group of professional female volleyball players was noted to perform CMJs 33.8 ± 4.3 cm and achieve a similar maximum power and average power in the Wingate test, which were: 9.09 ± 1.03 and 6.78 ± 0.82 W/g [18].

In own study, the level of development of explosive power of the lower limbs was assessed using the CMJ test and anaerobic endurance with the Wingate test. Comparing own results and the achievements of the observed female volleyball players with the results of other studies, it can be concluded that the level of development of their explosive power was satisfactory [18, 23, 24]. The results obtained by female volleyball players in own study in the Wingate test regarding maximum power and average effort power were comparable (slightly higher values were found in own study) with the results obtained by the female athletes in other studies [18, 24]. On this basis, it can be concluded that in terms of the level of development of motor potential, the female athletes competing at the Polish volleyball 1st league level are a well-selected group as a result of sports recruitment and selection. In the light of the above statement and the motor requirements set for adepts in this discipline (6.8), it can be said that this type of cross-sectional study, the purpose of which is to assess the level of strength and speed potential, has significant application value.

The data collected in the course of own study shows that the absolute CMJ test result and CMJ power based on the Sayers formula (Z-score: 2.76 and 2.54 respectively) as well as maximum power and average power in the Wingate test (Z-score 2.59 and 3.22, respectively) have a great informative value in the selection and recruitment process practice. Own results are the basis for the statement that the most important and thus high diagnostic value in women's volleyball are not so much the maximum values of power indicators as the possibility of maintaining high power values for a longer period of time. The high average power effort indicator of the female volleyball players outstanding during the course of the analysis may seem surprising especially against the background of indicators more related to speed capabilities, i.e. CMJ, P_{max}, but in the context of volleyball game analysis, which is intermittent and in which active and passive phases occur successively, it is understandable. The active phase time of volleyball players is on average 9–10 seconds (at 2.2 to as much as 55 seconds). In addition, a large number of various actions and cyclical substitutions in volleyball team

formation on the court requires high motor activity for a longer period of time [6]. In the light of the above statements, it is obvious that shorter actions lasting a few seconds are determined by the capabilities in terms of speed of achieving power and the level of maximum power. The analysis of differences between female athletes and non-playing women (Z-score) indicates that during recruitment to volleyball team, one should perform tests based on the assessment of effectiveness in jumps (e.g. CMJ). In addition, you can assess the maximum power and average power of longer efforts with maximum intensity. In order to assess the effectiveness of longer efforts of the female volleyball players the Wingate test was done. However, it seems that great care should be taken when interpreting the results of this test (despite the fairly large differences in results observed during the tests). This is due to the fact that the measurement on the cycloergometer is not volleyball-specific (but it allows to determine the strength and speed potential). Therefore, when measuring special performance in women's volleyball, tests should be done that are not the result of a single movement, as is the case with the CMJ, but the result of cyclical effort lasting relatively longer (the Bosco jumping test can be suggested here). Based on the results of own study and reports resulting from the analysis of the literature, it can be stated that during recruitment and selection process, fitness tests based mainly on jumps, should be done e.g. CMJ (for special fitness assessment). It seems that the Wingate test also has diagnostic value (there are data published in the literature that constitute a reference point), but it should be pointed out that it is not volleyball-specific, which means that it can only be the supplement to jump-based tests.

Conclusions

1. Own study ha shown and confirmed the high importance of selected morpho-functional characteristics determining speed performance and game effectiveness in women's volleyball. The obtained results were in line with current world reports in this field, as well as with the basic requirements of the level of motor development in contemporary volleyball.
2. A female volleyball player competing at a high level at this sports level (Polish 1st league) should be characterized by a high level of development of active tissue, i.e. muscle mass, as well as a high level of strength and speed of lower limbs.
3. Testes based on jumping (e.g. CMJ) assessing the motor potential of lower limbs of female volleyball players have practical value in the context of recruitment, selection and control of women's volleyball training.
4. The Wingate test, as a diagnostic tool, can be used as a supplement for volleyball specific tests.

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Streszczenie

Wstęp: Współczesna siatkówka wymaga od zawodników prezentowania wysokiego poziomu rozwoju możliwości siłowo-szybkościowych. Efektywność w tej dyscyplinie jest także istotnie determinowana poziomem rozwoju podstawowych cechy budowy somatycznej, w tym przede wszystkim wysokością ciała oraz zasięgiem ramion. Głównym celem badań była ocena poziomu rozwoju najistotniejszych cech morfo-funkcjonalnych charakteryzujących siatkarki występujące na drugim poziomie krajowych rozgrywek ligowych na tle kobiet nietrenujących.

Materiał i metody: W badaniach wzięło udział 13 zawodniczek reprezentujących I-ligowy klub siatkarski. Grupę kontrolną stanowiło 11 kobiet nietrenujących żadnej formy sportu. Przeprowadzono pomiary podstawowych cech budowy somatycznej: wysokość ciała, masę ciała i jej komponenty tkankowe. Ponadto zmierzono siłę eksplozywną kończyn dolnych (CMJ) oraz przeprowadzono test Wingate. Na podstawie analizy statystycznej wyselekcjonowano najistotniejsze cechy budowy somatycznej i wskaźniki sprawności motorycznej charakteryzujące I-ligowe siatkarki.

Wyniki: Największe zróżnicowanie pomiędzy siatkarkami a nietrenującymi w zakresie cech morfologicznych odnotowano dla masy ciała szczupłego (LBM [kg], $Z=6{,}63$, $p<0{,}01$). Natomiast w zakresie wskaźników wysiłkowych największe różnice stwierdzono w zakresie piku mocy, mocy średniej oraz wyskoku CMJ i mocy względnej wyskoku CMJ. Obliczono odpowiednio: $Z=2{,}59$, $p<0{,}001$; $Z=3{,}22$, $p<0{,}001$; $Z=2{,}75$, $p<0{,}001$, $Z=2{,}54$, $p<0{,}001$).

Wnioski: Badania własne wykazały i potwierdziły wysokie znaczenie wybranych cech morfo-funkcjonalnych sprzyjających wysokiej efektywności gry w siatkówce kobiet. Testy bazujące na skokach (np. CMJ) oceniające potencjał motoryczny kończyn dolnych siatkarek, mają wartość praktyczną w kontekście naboru, selekcji oraz kontroli treningu w siatkówce kobiet. Test Wingate, jako narzędzie diagnostyczne, może być stosowany jako uzupełnienie do prób o charakterze specyficznym w siatkówce.

Słowa kluczowe: siatkówka, moc anaerobowa kończyn dolnych, komponenty tkankowe ciała, selekcja i kontrola treningu w siatkówce kobiet