

Identification of Explosive Power Factors as Predictors of Player Quality in Young Female Volleyball Players

Zoran Grgantov, Mirjana Milić, and Ratko Katić

University of Split, Faculty of Kinesiology, Split, Croatia

ABSTRACT

With the purpose of determining the factor structure of explosive power, as well as the influence of each factor on situational efficiency, 56 young female volleyball players were tested using 14 tests for assessing nonspecific and specific explosive power. By factor analysis, 4 significant factors were isolated which explained the total of over 80% of the common variability in young female volleyball players. The first factor was defined as volleyball-specific jumping, the second factor as nonspecific jumping and sprinting, the third factor as throwing explosive power, while the fourth factor was interpreted as volleyball-specific throwing and spiking speed from the ground. Results obtained by regression analysis in the latent space of explosive power indicate that the identified factors are good predictors of player quality in young female volleyball players. The fourth factor defined as throwing and spiking speed from the ground had the largest influence on player quality, followed by volleyball-specific jumping and nonspecific jumping and sprinting, and to a much lesser extent, by throwing explosive power. The results obtained in this age group bring to the fore the ability of spiking and serving a ball of high speed, which hinders the opponents from playing those balls in serve reception and field defence. This ability, combined with a high standing vertical jump reach and spike approach vertical jump reach (which is the basis of the 1st varimax factor) enables successful performance of all volleyball elements by which points are won in complex 1 (spike) and complex 2 (serve and block). Even though the 2nd factor (nonspecific jumping and sprinting) has a slightly smaller impact on situational efficiency in young players, this ability provides preconditions i.e. preparation for successful realisation of all volleyball elements, so greater attention must be paid to perfecting it in young female volleyball players.

Key words: explosive power, female volleyball players, young players, player quality

Introduction

In many sports, performance depends on the ability of the player to generate the force rapidly. In volleyball, this is particularly prominent in those technical-tactical elements which gain most points in a game (spike, block, jump-serve). What is common to all these elements is that they are performed while jumping, which leads to the conclusion that explosive (jumping) ability underlies the successful performance of those elements. During forceful spiking and serving, explosive throwing (hitting) power is also manifested.

Volleyball is played on an 18x9 meters court, each team playing on a 9x9 m court. This is the reason why explosive sprinting movements, often in combination with sudden direction changes and stops, are performed at

short distance of 3 to 5 meters. Sometimes, usually in situations when a player must catch the ball which was played outside the playing court, that distance may be 5 to 10 meters, very rarely over 10 meters.

Salaj and Marković (2011)¹ point out that, »despite being addressed in a number of previous studies, the controversy regarding the generality *vs.* specificity of jumping, sprinting, and change-of-direction speed (CODS) abilities still remains unresolved. On the sample of eighty-seven male college athletes they confirmed the hypotheses that jumping, sprinting, and CODS represent separate and specific motor abilities, and that the jumping ability based on concentric and slow stretch shortening cycle (SSC) is relatively independent of the same abil-

ity based on fast SSC«. By contrast, Castro-Pinero et al. (2010)², using a sample of 94 girls and boys aged 6 to 17 years, established high correlations between certain test assessing jumping and throwing abilities, and repetitive and isometric upper body strength.

Katić et al. (2006)³ used factor analysis of motor tests in female volleyball players (under 15 /U-15/ and under 17 /U-17/ age category) to isolate two factors which are underlain with a force generation and regulation mechanism and a speed regulation mechanism. By regression correlation analysis, they have established that force and speed regulation mechanisms were good predictors of player quality in young players, with force regulation mechanism having a much greater impact on player quality in comparison to speed regulation mechanism.

Considering the abovementioned, this research concentrates primarily on tests assessing force regulation mechanisms with emphasis on jumping, throwing and sprinting explosive power. Nonspecific and specific tests assessing explosive power were used therein to obtain a more comprehensive latent structure of this important motor ability. Also, the influence of certain factors of explosive power on situational efficiency of young female volleyball players was investigated.

Vertical jumping is probably the most important manifestation of explosive power in volleyball⁴. Volleyball-specific jumping can be measured in different ways⁵. Two most frequently used are the sargent test (high jump) measuring standing reach height on a wall scale^{3,6} or a self-contained measuring instrument – »vertec«⁷. Most frequently used volleyball-specific tests for both methods are standing vertical jump, spike approach vertical jump with two feet or one foot take-off. Such tests have the best pragmatic validity, but their results depend on various components which cannot be analysed in isolation (performance technique, explosive power, elastic power). Therefore, nonspecific tests have a goal of isolating particular components of jumping with the purpose of detecting strengths and weaknesses of an individual volleyball player. In this way, individual programmes for development of jumping can be created. Most frequently used nonspecific tests for assessing jumping are squat jump, countermovement jump without arm swing and countermovement jump with arm swing^{8,9}. Marković et al. (2004)¹⁰, in a study conducted on a sample of 93 kinesiology students, inferred: »it can be concluded that CMJ and SJ, measured by means of contact mat and digital timer, are the most reliable and valid field tests for the estimation of explosive power of the lower limbs in physically active men«.

Tests for assessing throwing (hitting) explosive power in volleyball can also be nonspecific and specific. The ability of hitting the ball of high speed in volleyball was tested mostly indirectly by nonspecific tests, measuring the strength and power of the upper body in tasks such as bench press or throwing the medicine ball of different weights in different ways^{6,11–13}, with such and similar tests being widely applicable in other related sports, e.g. karate¹⁴. Furthermore, most research conducted in thro-

wing sports which included treatments with exercises of strength and medicine ball throw achieved positive effects on the speed of the thrown (hit) ball¹⁵. However, due to the specificity of movement during spiking, in comparison to weight lifting and throwing a medicine ball, there is a requirement for specific methods of testing the explosive power of the upper body in volleyball players. The speed of the ball after spiking or serving, measured by radar, is thereby mostly used as an indicator of specific explosive power^{16–18}.

Palao and Valades (2009)¹⁸ suggested 6 tests in which specific power of spiking and serving is measured by radar, and due to its simplicity, the test of spiking from the ground is particularly appropriate for younger age groups. Sprinting explosive power in volleyball is usually assessed through 20 meters sprinting, whereas agility is assessed through shuttle run tests on shorter distances of 3 to 9 meters, e.g. 6x6 meters or 9–3–6–3–9 meters¹⁹. To reduce the measuring error, which may occur when using a stopwatch, it is advisable to use photocells in these tests²⁰.

The aim of this research was to determine the factor structure of nonspecific and specific tests for assessing explosive power which are underlain with force generation and regulation mechanisms. The special aim was to establish the influence of particular factors on situational efficiency of young female volleyball players.

Materials and Methods

Study subjects

The subject sample consisted of 56 female young volleyball players aged 13 to 15 years, with average height of 167.71 cm, body mass of 55.42 kg, relative body fat content of 23.61%, and reach height of 216.6 cm. All volleyball players are participants of »volleyball schools« from Kaštela and Trogir area.

Instruments

The variable sample included a set of 14 tests for assessing nonspecific and specific explosive power. Nonspecific explosive power was defined by a set of 9 tests composed of the following variables: throwing a 1 kg medicine ball from a standing position, throwing a heavier volleyball of 0.5 kg from a standing position, throwing a volleyball of 0.3 kg from a standing position to assess throwing explosive power of the arms; squat jump, countermovement jump without the arm swing, countermovement jump with the arm swing for assessing vertical jumping on the Opto-jump apparatus⁸; 5 m sprint from a standing start, 10 m sprint from a standing start to assess sprinting explosive power measured by photocells²⁰; 6x6 m run to assess agility measured by photocells.

The space of specific explosive power was defined by a set of 5 tests composed of the following variables: throwing speed of a 100 g ball, spiking speed of a volleyball from the ground to assess specific throwing (spiking) explosive power measured by Speedstar radar; standing

vertical jump on a wall measuring scale, spike approach vertical jump with one foot take-off on a wall measuring scale to assess specific vertical jumping.

Description of the nonspecific and specific explosive power tests used:

1. Throwing a 1 kg medicine ball from a standing position. The subject is positioned diagonally in front of the line which marks the beginning of the measuring scale. Medicine ball is held with both hands in front of the body, and lifted above the head imitating a circular arm swing in volleyball (right-handed from the right side of the body) and then thrown as far as possible along the measuring scale.

2. Throwing a 0.5 kg ball from a standing position. Test is performed as previously described, but with a heavier volleyball weighing 0.5 kg.

3. Throwing a 0.3 kg volleyball from a standing position. The subject throws the ball standing in a diagonal position, in the same way as previously described tests.

4. Squat jump on the Optojump device: The subject is positioned in a squat (90-degree angle between the lower and upper leg, holding the trunk as upright as possible, with arms akimbo). After keeping that position for 3 seconds, the subject tries to jump as high as possible by extending his/her legs. Landing is performed with legs extended as much as possible.

5. Countermovement jump with no arm swing on the Optojump device: The subject stands on the optojump pad with legs extended and arms akimbo. He/she rapidly changes that position into a squat (position described in the first test) and immediately jumps high by extending his/her legs. Landing as described in the first test.

6. Countermovement jump with an arm swing on the optojump device: The same as the 2nd test, but with an arm swing (movement backwards and then forward) instead of arms akimbo, balanced with squat and take-off. Landing as described in previous tests.

7. 5 m sprint from a standing start measured by photocells. Photocells are set on the starting and finishing line. The subject (on a 0.5 m distance from the first pair of photocells) runs the 5 meter distance from a high start.

8. 10 m sprint from a standing start measured by photocells. Test is performed as the previous one, but on a 10 m distance.

9. 6x6 meter run measured by photocells. Photocells are set on the serving line of the volleyball court, and on the line between the attack zone and the defence zone, on a 6 m distance. The subject (on a 0.5 m distance from the first pair of photocells), from a high start, runs the distance between the serving line and the attack line 6 times, having to touch the lines by his/her foot each time he/she changes direction.

10. Standing throwing speed of a 100g ball. The subject is positioned diagonally 5 meters from the examiner (for the right-handed left leg forward). He/she holds the ball in his/her right hand next to the body. The examiner

stands behind a 135 X 90 cm goal. The goal is positioned on an elevation (tables) 75 cm high so that the examiner, who is standing behind the goal holding the radar, is protected from being hit with a ball. The examiner, sitting on a chair holds the radar approximately 1 m high and points it towards the throwing position. The trajectory of the ball in relation to the ground, similar to the angle during the game when deep parts of the opponents' court are hit by spiking, is obtained by setting the target lower than the ball throwing position. The subject tries to throw the ball as fast as he/she can with his/her dominant hand towards the radar. The test is repeated until the subject throws the ball 6 times into the goal.

11. Spiking speed from the ground. As in the previous test, the subject is positioned diagonally 5 meters from the examiner (for the right-handed left leg forward). He/she holds a volleyball in his/her hands. The ball is thrown above and slightly in front of the hitting shoulder, and spiked as hard as possible towards the radar. The test is repeated until the subject spikes 6 balls into the goal.

12. Standing vertical jump reach on a wall measuring scale. Without moving his/her feet, through a half-squat, with a forceful arm swing, with his/her hitting arm, the subject reaches the highest possible point on the wall measuring scale, which is then read and noted down by the examiner.

13. Spike approach vertical jump reach with two feet take-off on a wall measuring scale. Vertical jump following a volleyball approach is performed after three steps, with a two feet take-off by forceful arm swing performed at the last step in order to achieve maximum vertical jump.

14. Spike approach volleyball jump reach with one foot take-off on a wall measuring scale. The subject performs a one foot take-off at the last step after the volleyball approach (left-right-left for the right-handed) and, as in the previous test, reaches the highest possible point on the wall measuring scale with his/her hitting arm, which is then read and noted down.

All results in specific and nonspecific explosive power tests are condensed in such a way that maximum values are analysed.

Situational efficiency of female volleyball players is the criterion variable in this research. It was assessed on a 1 to 5 Likert scale based on 2 criteria²¹:

Team quality: Teams were ranked according to quality into 3 groups. The 1st group included 4 top-placed teams from the regional competition, the 2nd group included teams placed 5th to 8th, and the 3rd group included teams placed 9th to 12th in the regional championship.

Individual player's quality within the team: Coaches will classify players within their teams into 3 groups according to this criterion: the 1st group includes players (1–3) who are playmakers in their teams, the 2nd group (3–6) includes remaining players of the starting line-up and players who enter the game contributing to the re-

sult, and the 3rd group includes players who enter the game very rarely or not at all.

Data analysis

Data analysis methods involved calculating the descriptive statistical parameters: arithmetic mean (\bar{X}), standard deviation (SD), minimum (Min) and maximum (Max) result, coefficient of asymmetry (Skew), coefficient of kurtosis (Kurt) and establishing the MaxD value for determining the normal distribution of variables by KS-test. Factor analysis was conducted to analyze the structure of nonspecific and specific explosive power, with varimax rotation of principal components of the inter-correlation matrix. In the obtained latent space, regression analysis of player quality prediction was performed on the reduced and identified factors.

Results and Discussion

The results of descriptive statistics of the morphological variables, as well as of tests for assessing nonspecific and specific explosive power in 56 young female volleyball players are presented in Table 1. Analysis of distribution parameters shows there were no significant deviation from the normal distribution in any of the variables, which means that all variables are suitable for further

multivariate statistical analysis. Testing the normality of distribution was conducted using a Kolmogorov-Smirnov test with the critical value of 0.18.

A better comprehension of the true value of the obtained results can be achieved by comparing the obtained mean values with the results attained from other research investigating young female volleyball players. Maximum values can serve volleyball practitioners as model values.

When comparing the results in variables for assessing anthropometric characteristics (height, body mass, body fat percentage) with the results of other research in female volleyball players of approximately the same age²², similar values can be observed. It is evident that there has still not been a more noticeable selection of subjects according to the longitudinal dimensionality of the skeleton and the subcutaneous adipose tissue. Grgantov et al. (2006)²², by comparing results in four age groups (from young pre-competition players to juniors), concluded that a more prominent selection of volleyball players into competitive teams does not occur until the transition from the younger U-15 age group (14-15 years) into the U-17 age group (16–17 years).

By analysing mean values of results in tests for assessing specific spiking (throwing) explosive power, it can be observed that young female volleyball players achieve

TABLE 1
DESCRIPTIVE STATISTICS OF VARIABLES (MORPHOLOGICAL, NONSPECIFIC AND SPECIFIC EXPLOSIVE POWER) OF FEMALE VOLLEYBALL PLAYERS AGED 13 TO 15 (N=56)

Variables	\bar{X}	SD	Min	Max	KS	Skew	Kurt
Body height (cm)	167.71	7.01	153.00	192.50	0.10	0.80	2.10
Standing reach height (cm)	216.6	9.14	199.50	248.50	0.12	0.75	0.63
Body mass (kg)	55.42	7.82	41.60	74.70	0.11	0.60	-0.16
Body fat percentage (%)	23.61	5.68	9.40	33.90	0.09	-0.24	-0.38
Spiking speed from the ground (km/h)	54.89	8.74	32.00	75.00	0.09	-0.06	0.31
Throwing speed of a 100 g ball (km/h)	65.66	7.38	52.00	87.00	0.09	0.38	0.26
Throwing a 1 kg medicine ball (m)	8.96	1.55	5.70	12.30	0.06	0.02	-0.62
Throwing a 0.5 kg ball (m)	12.47	1.83	9.40	17.90	0.09	0.25	-0.12
Throwing a 0.3 kg ball (m)	13.59	1.81	10.20	18.30	0.09	0.23	-0.52
Standing vertical jump reach (cm)	252.34	10.82	230.00	285.00	0.08	0.42	0.35
Spike approach vertical jump reach with two feet take-off (cm)	254.07	11.39	229.00	288.00	0.06	0.38	0.52
Spike approach vertical jump reach with one foot take-off (cm)	248.75	11.50	225.00	287.00	0.11	0.52	1.27
Squat jump (cm)	23.15	3.20	16.40	31.30	0.07	0.06	-0.16
Countermovement jump without arm swing (cm)	23.75	3.38	16.90	32.40	0.06	0.16	-0.09
Countermovement jump with arm swing (cm)	29.65	4.38	20.70	38.40	0.08	0.06	-0.62
5 m sprint (s)#	1.27	0.06	1.14	1.39	0.12	0.21	-0.41
10 m sprint (s)#	2.19	0.09	2.03	2.41	0.08	0.29	-0.54
6x6 m run (s)#	11.41	0.62	10.15	12.79	0.09	-0.10	-0.12

TEST = 0.18

variable with opposite metric orientation, \bar{X} – arithmetic mean, SD – standard deviation, Min – minimum result, Max – maximum result, KS – Kolmogorov-Smirnov test, Skew – coefficient of asymmetry, Kurt – coefficient of kurtosis

ved averagely 10 km/h greater speeds in ball throwing tests in comparison to spiking. Possible reasons for such results might be the following:

- smaller volume and weight of the ball as opposed to a volleyball
- throwing the ball implies a simpler and more natural movement as opposed to spiking, and it is possible that some players might not have yet adopted the spiking technique, which therefore hinders them from achieving better results in that test. This is supported by the differences in minimum results in the spiking and the throwing test, which are greater than the difference between average results.

Unfortunately, the authors could not find a research in the available literature to which they could compare results of young female volleyball players in ball throwing speed. With regard to the spiking speed from the ground, Melrose et al. (2007)⁷ found the same average spiking speed of 58 km/h on a sample of young female players as Matirolli et al. (2010)²³ on a sample of younger male players. These speeds are somewhat larger in relation to the speeds obtained in this research, which is probably due to smaller and more homogenous (more rigidly selected) samples which were analyzed in those studies.

In the space of nonspecific throwing explosive power, a related research could also not be found in the available literature to which obtained results could be compared. Further research is needed in female and male volleyball players of different age and situational efficiency to obtain data regarding pragmatic validity of these tests. As could be expected, subjects threw lighter balls further.

By comparing mean values in volleyball-specific jumps on a wall scale, it can be observed that young female volleyball players have a slightly higher average jump height (1.7 cm) in spike approach vertical jumps with two feet take off in relation to standing vertical jumps. Similar differences were also reported by Katić et al. (2006)³ on a sample of female volleyball players of approximately the same age. This is probably due to the somewhat insufficient development of leg muscle power which is required to »transform« the horizontal approach speed into the highest vertical jump possible, and to the insufficient refinement of the performance technique. Technical errors in young volleyball players can be noticed in the approach, jump, and take-off phase in which movements of the trunk and the legs must be precisely synchronized with movements of the arms which serve an important function in the take-off phase (swing), but also in the flying phase and preparing to hit the ball, where they help in keeping the balance of the body.

The abovementioned reasons are even more emphasized in spike approach vertical jumps with one foot take-off in which the subjects achieved averagely 4 cm smaller values in comparison to standing jumps. A somewhat difficult approach and reach during jumping on a wall scale with a one foot take-off must also be added to

previously mentioned reasons. Taking into account that one foot jump spiking is performed during games in women's volleyball, the authors believe that all young players should practice this technical-tactical element more frequently during training sessions, but also state that single foot exercises should be introduced into strength and jumping training.

Tests assessing nonspecific vertical jumping were performed on an opto-jump apparatus. Differences in mean values in squat jumps (SJ) and countermovement jumps (CMJ) are only slightly higher than 0.5 cm and smaller in relation to the data obtained in adult athletes^{4,24,25}. Reasons for this can be tracked to the insufficiently developed ability of transformation from eccentric to concentric muscle action in young female volleyball players, or to the use of countermovement in the SJ test.

Harman et al. (1990)²⁶ point out small counter movements, often invisible to the eye, which can be observed through ground reaction forces, which are slightly smaller than the body weight. It can be assumed that these movements are more prominent in young athletes, which points toward the necessity of practising the test from the static squat position. In contrast to the abovementioned, obtained differences between countermovement jump (CMJ) and countermovement jump with an arm swing (CMJ-A) were nearly 6 cm.

Lees et al. (2004)²⁷ emphasized the importance of the arm swing for the increase of the jump height. This influence is based on a number of factors which, combined, enable the storage of a large quantity of energy during the eccentric phase of the jump, as well as during the first part of the concentric (propulsive) phase. This energy allows greater acceleration of the body and greater jump height during the final part of the propulsive phase. Taking into consideration that movement in the CMJ-A is characteristic to volleyball players and it is performed in every training session (as opposed to other 2 tests which they have encountered for the first time during this measuring), such big differences are to be expected.

Mean values of 29.58 cm obtained by CMJ-A test are similar to the values obtained by Nikolaidis et al. (2011)⁹ in female volleyball players of approximately the same age, whereas for comparing results in the remaining 2 tests, the authors did not find a study conducted on a sample of young female volleyball players. Values obtained in these tests are slightly higher in relation to the values obtained by Vicente-Rodriguez et al. (2004)²⁸ on a sample of female handball players of the same age (SJ 20.2 cm; CMJ 22.0 cm).

Keeping in mind that in previous research^{19,22}, agility tests were measured using a stopwatch and not photocells, results obtained in the 6x6 m test cannot be compared with previous research results. Moreover, tests of 5 m and 10 m sprinting, to the authors' knowledge, have not yet been used on a sample of young female volleyball players of this age group. The authors recommend the use of photocells in the assessment of agility and explosive power movements in future research, due to good

TABLE 2
VARIMAX FACTORS OF NONSPECIFIC AND SPECIFIC EXPLOSIVE POWER (V) OF YOUNG FEMALE VOLLEYBALL PLAYERS
AGED 13 TO 15 (N=56)

Variables	V1	V2	V3	V4
Spiking speed from the ground	0.3119	0.3119	0.3641	0.7307
Throwing speed of the 100 g ball	0.0096	0.2308	0.1779	0.8782
Throwing a 1 kg medicine ball	0.2333	-0.0140	0.8176	0.1240
Throwing a 0.5 kg ball	0.2469	0.1013	0.8452	0.2799
Throwing a 0.3 kg ball	0.1436	0.0567	0.8479	0.2921
Standing vertical jump reach	0.9615	0.0786	0.1702	0.0673
Spike approach vertical jump reach with two feet take-off	0.9515	0.1052	0.2197	0.0697
Spike approach vertical jump reach with one foot take-off	0.9376	-0.0195	0.2070	0.1127
Squat jump	-0.0021	0.8636	-0.0822	0.1771
Countermovement jump without arm swing	0.0571	0.9191	-0.0803	0.1442
Countermovement jump with arm swing	0.2451	0.7893	0.0640	0.1832
5 m sprint [#]	0.0003	-0.8214	-0.2038	0.0401
10 m sprint [#]	0.0594	-0.7571	-0.2982	-0.1110
6x6 m run [#]	-0.1123	-0.4457	-0.5673	0.1956
Eigenvalues	5.4258	3.0822	1.7069	1.0789
% of Variance	38.7558	22.0155	12.1922	7.7067
Cumulative %	38.7558	60.7713	72.9635	80.6701

[#]variable with opposite metric orientation

metric characteristics of the tests and greater precision of measurement.

By factor analysis in the space of nonspecific and specific explosive power, 4 significant factors were isolated, which explain the total of over 80% of the common variability in young female volleyball players (Table 2). Considering high projections of tests assessing standing vertical jump reach and spike approach vertical jump reach with two feet or one foot take-off, the first factor can be named volleyball-specific jumping. The second factor is characterized by high projections of all jumping tests on the optojump device, as well as of 5 and 10 meter sprinting tests. Therefore, it can be interpreted as nonspecific jumping and sprinting. Because of the high projections of medicine ball throw tests on the 3rd factor, it can be named throwing explosive power. The fourth factor is characterized by high projection of »spiking speed from the ground« and »throwing speed of a 100 g ball« tests and it can be interpreted as volleyball-specific throwing and spiking speed (from the ground).

Obtained factors specify the characteristics in the manifestation of types of explosive power in young female volleyball players, which also has a dominant impact on their player quality.

The first varimax factor named volleyball-specific jumping accounts for the major part of the common variability (over 38%) and it is the main feature of young female volleyball players. Namely, vertical jump reach height is very important in the realisation of all volleyball elements which are performed above the net. The manner in which the tests that form this factor are per-

formed resembles the performance of the volleyball approach and two feet take-off, but also of one foot jump spiking, which is specific to women's volleyball. Moreover, it must be kept in mind that jump serves (either a float serve or a top-spin) prevail in modern senior volleyball, and it can therefore be assumed that a certain number of volleyball players of this age have already started practising them in training, and some of the players even performing them during games. Apart from the serve, a block is another very important element in the complex 2 of the volleyball game, in which standing vertical jump reach height comes to the fore, but also reach height (particularly in middle blockers) after moving in a shuffle step, cross step or a running step. Two feet take-off is usually used for this, but when players are not positioned for the block in time, they sometimes use a one foot take-off, trying to jump not only for height, but also for distance towards the outside blocker. The overhand pass is also sometimes performed while jumping, but it is mostly specific to the setter position, primarily in junior and senior competition, whereas young players mostly use the simpler and more appropriate technique for their age – overhand pass from the ground.

The second varimax factor named nonspecific jumping and sprinting is the second important feature of young female volleyball players. Namely, explosiveness of lower extremities is the basic motor ability in the realisation of virtually all volleyball elements. Sprinting is particularly important to reach the ball in time during serve reception, court defence and setting ball for attack, but also for the performance quality of the approach for

spike, serve or block. Therefore, jumping and sprinting, as described by the second factor, precede specific jumping ability, as described by the first factor. Clearly, the performance of the overall spiking, blocking or serving technique will be better at explaining the motor efficiency than the performance of only the first part of the technique. It must be pointed out that the beginning of performance, i.e. the starting strength, will have the greatest impact on the efficiency of the whole technique, i.e. realisation of the abovementioned elements.

The third varimax factor named throwing explosive power is the third most important in motor functioning of young female volleyball players. Explosive power of the upper extremities is the basic ability for the realisation of primarily spiking and serving technique, but also of overhand pass at greater distance.

The fourth varimax factor named throwing and spiking speed from the ground is the fourth most important in motor functioning of young female volleyball players. The manner in which the ball is thrown (hit) in tests assessing this factor is very similar to movements of the hitting arm in volleyball players during spiking and serving. Therefore, it can be stated that the start speed and explosiveness of the arms is the basis for the realisation of the spike and serve, but also in the manifestation of throwing explosive power.

Mutual conditioning of throwing explosive power as defined by the third factor and the throwing and spiking speed as defined by the fourth factor can be observed. Here, it must be pointed out that throwing explosive power will have a dominant influence on spike and serve efficiency due to greater speed of the hit ball.

Results of the regression analysis in the latent space of explosive power indicate that identified factors are good predictors of player quality in young female volleyball players (Table 3). The fourth factor defined as volleyball-specific throwing and spiking speed from the ground has the greatest impact on player quality, followed by volleyball-specific jumping, and nonspecific jumping and sprinting, whereas throwing explosive power has a much smaller impact.

The results clearly indicate that spiking and serving, as crucial elements in winning the points when the team possesses the ball, have a dominant impact on player quality in young players, as well as blocking, being the only element in volleyball by which a point can be won after the opponents have made a contact with the ball. Authors emphasize the importance of the second varimax factor which is underlain with explosiveness of the legs and sprinting, providing preconditions i.e. preparation for successful realisation of all volleyball elements, particularly realisation of the block, spike and field defence, and in a manner established by previous research. However, in order to reach a more comprehensive prediction of player quality, it is necessary to assess the speed of the serve as it has been observed in previous research that efficiency of the serve is a significant determinant of the game outcome in all age categories, especially in young female volleyball players^{6,22}.

TABLE 3
RESULTS OF REGRESSION ANALYSIS FOR THE CRITERIA OF PLAYER QUALITY IN THE FACTOR SPACE OF NONSPECIFIC AND SPECIFIC EXPLOSIVE POWER OF YOUNG FEMALE VOLLEYBALL PLAYERS AGED 13 TO 15 (N=56)

Factor	r	β	p
1. Volleyball-specific jumping	0.597	0.442	0.000
2. Nonspecific jumping and sprinting	0.566	0.408	0.000
3. Throwing explosive power	0.372	0.238	0.006
4. Throwing/spiking speed from the ground	0.627	0.478	0.000
ρ		0.804	
δ		0.647	$p < 0.000$

r – coefficient of correlation, β – regression coefficient, ρ – multiple correlation, δ – coefficient of determination, # variable with opposite metric orientation

Conclusion

Young female volleyball players aged 13 to 15 find themselves in transition from a phase which emphasized the development of basic (nonspecific) motor abilities and elementary technical-tactical skills into a phase which will be dominated by position-specific training. Factor structure obtained by tests assessing explosive power implies that explosive power was not a unique construct in the analyzed age group of volleyball players, but that there were four factors existing within, which were extracted according to the topological and sport-specific criterion. According to the topological criterion, 2 factors were differentiated, predominated by jumping and sprinting explosive power (which dominantly engage the leg muscles) and 2 factors which are based on throwing (hitting) explosiveness (which primarily includes arm muscles). According to the specificity criterion, there were 2 factors describing volleyball-specific jumps and hits, while the 2 remaining factors were based on nonspecific volleyball jumps, sprints and throws. Given that the extracted factors have a significant impact on situational efficiency of young players it might be recommended to volleyball coaches to pay greater attention to the development of explosive power. Volleyball-specific and volleyball-nonspecific exercises should be used therein. Furthermore, topological specificity of explosive power should also be taken into consideration by using jumping and sprinting within the training to develop explosive power of legs, but also using throwing and hitting to develop explosive power of arms. In all abovementioned movements core muscles play a very important role in transferring the force from the lower to the upper body and vice-versa. This is particularly emphasized during swift transitions from an approach into a spike or block jump, but also in the contact of the ball and the hand during blocking and spiking. The authors suggest further research of explosive power structure in female and male volleyball players. There is especially a lack of lon-

itudinal studies which would analyze the structure of this important motor ability in the period from the start of practicing volleyball up until the peak of the sports career.

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R. Katić

University of Split, Faculty of Kinesiology, Teslina 6, 21 000 Split, Croatia
e-mail: ratko.katic@gmail.com

IDENTIFIKACIJA FAKTORA EKSPLOZIVNE SNAGE ODOJKAŠICA MLAĐEKADETSKOG UZRASTA U PREDIKCIJI IGRAČKE KVALITETE

SAŽETAK

S ciljem utvrđivanja faktorske strukture eksplozivne snage, kao i utjecaja pojedinih faktora na situacijsku uspješnost, 56 odbojkašica mladekadetskog uzrasta testirano je s 14 testova za procjenu nespecifične i specifične eksplozivne snage. Faktorska analiza izolirala je 4 značajna faktora koji ukupno objašnjavaju preko 80% zajedničkog varijabiliteta odbojkašica mladekadetskog uzrasta. Prvi faktor je definiran kao specifična odbojkaška skočnost, drugi faktor kao nespecifična skočnost i startna ubrzanja, treći faktor kao eksplozivna snaga tipa bacanja, a četvrti faktor interpretiran je kao brzina bacanja i smećiranja s podloge. Rezultati regresijske analize u latentnom prostoru eksplozivne snage pokazuju kako su identificirani faktori dobri prediktori igračke kvalitete kod odbojkašica mladekadetskog uzrasta. Najveći utjecaj na igračku kvalitetu ima četvrti faktor definiran kao brzina bacanja i smećiranja s podloge, zatim specifična odbojkaška skočnost, te nespecifična skočnost i startna ubrzanja i u znatno manjoj mjeri eksplozivna snaga tipa bacanja. Dobiveni rezultati kod mladih kadetkinja u prvi plan ističu sposobnost smećiranja i serviranja velikom brzinom, što protivnicama otežava odigravanje tih lopti u prijemu servisa i obrani polja. Ta sposobnost, u kombinaciji s visokim dohvatom u skoku iz mjesta i nakon odbojkaškog zaleta (koji su u osnovi 1. varimaks faktora) omogućava uspješno izvođenje svih odbojkaških elemenata kojima se osvajaju poeni u kompleksu 1 (smeč) i u kompleksu 2 (servis i blok). Iako 2. faktor (nespecifična skočnost i startna ubrzanja) ima nešto manji utjecaj na situacijsku uspješnost mladih kadetkinja, ta sposobnost osigurava početne uvjete to jest dobru pripremu za uspješnu realizaciju svih odbojkaških elemenata te se kod mladih odbojkašica velika pažnja mora posvetiti njihovom usavršavanju.