ORIGINAL

Relationships between motor abilities and volleyball performance skills in 15-year-old talent-identified volleyball players

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Data Interpretation
E Manuscript Preparation
F Literature Search
G Funds Collection

Dariusz Mroczek[ADEF], Edward Superlak[ABD], Adam Kawczyński[CEF], Jan Chmura[AD]

Department of Biological and Motor Sport Bases, Faculty of Sport Science, University School of Physical Education, Wrocław, Poland

abstract

Background
The aim of this study is to determine synergistic motor outcomes understood as sets of mutually dependent players' motor abilities affecting the efficacy of performance skills of young volleyball players.

Material/Methods
The study was carried out during a national volleyball tournament for 150 boys aged 14-15 years. The matches were recorded with two cameras placed 10 m behind the end line, 1.6 m above the floor. The following parameters were assessed: attack efficacy, block efficacy, serve efficacy. The first dependent variables were players' actions that most significantly affected the set outcome, i.e. serves, blocks and attacks.

Results
The greatest differences were found among players' serve results, where – with the exception of ineffective serves – the index of variability ranged from $v = 67.14$ (counter-effective serve) to $v = 80.23$ (effective serve).

Conclusions
The study showed that serving and attacking effectiveness is directly determined by standing jumping ability, while blocking efficacy is affected by the height of the running vertical jump.

Key words
volleyball, performance skills analysis, game efficacy

INTRODUCTION

The game of volleyball is characterized by a great number of changing situations in which players perform a variety of actions attempting to score points, while avoiding making errors and losing points, which obviously leads to a conflict of aims [1]. The match outcome depends on a variety of gameplay elements, and the score depends on the quality of attacks, blocks, serves and the number of the opponent's errors [2–11].

Volleyball players at the net usually perform their attacks and blocks high above the net. The players' maximal reach ability in running jumps in attacks and in standing jumps in blocks is decisive for their effective actions [12]. This ability is an important indicator in the process of selecting young volleyball players. Hermoso et al. [13] in their study of 14–15-year-old volleyball players revealed significant differences between won and lost volleyball sets, based on the degree of players' serve, dig and spike efficacy. Conti et al. [6] observed that scoring opportunities in elite volleyball youth teams were significantly affected by quick and powerful attacks.

A player's dynamic force and speed of locomotion are dominant in attacks and blocks, which in most cases decide about the set outcome [14]. Many authors [15, 16, 17] stress the importance of the vertical jump (one-foot or two-foot; standing or running; with or without a semi-squat) which requires a high level of explosive muscle force.

A successful preparation process of volleyball players requires constant gathering of information about the effectiveness of their actions during games. According to Miskin et al. [18], volleyball coaches should estimate different performance skills of individual players during sets and matches and then adjust the training cycle of the team concentrating on the development of the efficacy of key skills that significantly determine players' scoring abilities.

Authors of relevant studies have mostly focused on the determination of relationships between particular motor skills of volleyball players and their attacking, blocking and serving efficacy influencing the set outcome [15, 16, 17]. Many of these authors have stressed, first of all, the correlations between individual players' abilities and particular elements of volleyball gameplay. Stronger correlations have been mostly interpreted as motor determinants of players' high efficacy of actions.

However, the available literature lacks reports on relationships between whole sets of volleyball motor skills and performance efficacy. It seems that relationships between particular motor abilities and playing efficacy are multidimensional and involve different directions and strengths of correlations.

The aim of this study is the determination of synergistic motor outcomes understood as sets of mutually dependent players' motor abilities affecting the efficacy of performance skills of young volleyball players. We hypothesized that attack efficacy, block efficacy and serve efficacy are determined by particular motor abilities.

MATERIAL AND METHODS

SUBJECTS

The study was carried out during a national volleyball tournament for 150 boys aged 14–15 years. After completion of the tournament, expert coaches assessed the players' motor abilities and volleyball performance skills, and identified the most talented players for further training. It must be underlined that six experts coaches were chosen by the Polish National Volleyball Association. All experts were highly qualified, professional coaches contracted in Polish national and extra league teams.

After a long training process in sports clubs and in the Athletic Championship School of the Polish Volleyball Federation, the Poland national coach finally selected 12 players for the Poland Boys' Youth National Volleyball Team, including two setters, three middle blockers and seven hitters. In 2005 the Polish team won the Boys' Youth European Championship in Riga, Latvia.

The selected boys' training experience (i.e. their active and systematic participation in training and competitions) ranged from 3 to 4 years. The 12 elite players constituted a representative sample for the Polish population of volleyball players aged 15 years. Table 1 presents the players' anthropometric data. The players were informed about the purpose of the study before its commencement, and their parents or guardians gave their informed written consent to participate in the study. All matches during the tournament were recorded. In the present study only players who won Boys' Youth European Championship in Riga, Latvia, were involved in the effectiveness analysis.

Table 1. Anthropometric data of selected volleyball players

Player	Position	Body height [cm]	Body mass [kg]	Ponderal Index (PI)	Standing one-arm reach [cm]	Standing two-arm reach [cm]
1.	hitter	187	77	1.13	248	246
2.	hitter	188	70	1.05	252	247
3.	hitter	190	80	1.17	258	252
4.	hitter	187	74	1.13	242	238
5.	hitter	202.5	89	1.07	265	260
6.	hitter	185	65	1.03	246	241
7.	hitter	190	69	1.01	254	250
8.	middle blocker	197	90	1.18	262	256
9.	middle blocker	191	70	1	250	248
10.	middle blocker	191	63	0.9	254	251
11.	setter	184	68	1.09	242	238
12.	setter	179	69	1.2	237	234
Mean (M)		189.3	73.7	1.1	250.8	246.8
Standard deviation (SD)		6.1	8.8	0.1	8.4	7.8
Index of variability (v)		3.2	11.9	9.1	3.3	3.2

METHODS

The aim of the tournament was to select the best candidates for the Polish youth national team before the Boys' Youth Volleyball European Championship. During the qualifying stage expert volleyball coaches (qualifications described in methods) observed all the participating players and selected the most talented and skillful ones to teams that would advance to the final stage of the tournament. All the matches between the selected teams were then video recorded during the final stage of the tournament.

The subjects gave their written consent prior to the study, which was approved by the local Ethics Committee in University of Physical Education in Wrocław, Poland and accords with the Helsinki Declaration.

During the tournament the selected young players were subjected to exercise tests assessing the levels of their motor skills. The tests included:

- a running vertical jump with a one-arm swing;
- a standing vertical jump with a two-arm swing;
- a 3kg medicine ball throw;
- a 10-m run;
- a zig-zag run.

PROCEDURES

The matches were recorded with two Sony DCR-SR70E video cameras with a VCL-060X x 0.6 wide conversion lens. The two cameras were each placed 10 m behind the end line, 1.6 m above the floor. The analysis of the recorded footage consisted of re-playing of each action of the computer screen. The following efficacy scale was used to determine the players' volleyball performance skills:

Attack efficacy:
• Effective – action completed, point scored;
• Ineffective – attack defended, game continues;
• Counter-effective – action completed, error in attack, point awarded to the opposing team.
Block efficacy:
• Effective – action completed, attack blocked, point scored;
• Ineffective – attack defended after the ball is ineffectively blocked, game continues;
• Counter-effective – action completed, error in block, point awarded to the opposing team.
Serve efficacy:
Effective – action complete, "ace", point scored;
Ineffective – serve received by the opposing team, game continues;
Counter-effective – action completed, error in block, point awarded to the opposing team.

The following self-authorized formula was used to calculate the index of serve (overhand, jump float or power), jump block and attack efficacy, (i.e. ISE, IBE, IAE) being the quotient of the sum of effective actions and the sum of all actions performed by each player:

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$$IE = \frac{\sum \text{ of effective actions}}{\sum \text{ of effective actions} + \sum \text{ of ineffective actions} + \sum \text{ of counter-effective actions}}$$

The index of efficacy values ranged between 0.0–1.0. A higher index value (closer to 1.0) signified a higher level of player's efficacy. The indices were prepared by authors of the present study.

The tests measuring the players' motor abilities were chosen and approved by a group of independent expert coaches appointed by the Polish Volleyball Federation.

The battery of motor skills tests used in the study included:
- running jump with a one-arm swing (dynamic force of the legs) – the best result out of three trials was recorded down. Each player began the test with a 3-4 m run-up, and then took a two-foot vertical jump and attempted to touch with the dominant extended arm the highest possible point on the measurement stand [cm].
- standing jump with a two-arm swing (dynamic force of the legs) – the best result out of three trials was recorded down. Each player began the test by standing on both feet. After lowering the body center of mass (bending the knees, leaning the body forward and taking a two-arm swing) the player performed a vertical jump and attempted to touch with extended arms the highest possible point on the measurement stand [cm]. If the players' hands touched the stand in an non-parallel manner, the measurement point touched by the higher hand was taken into account.
- running jumping ability(dynamic force of the legs) – the difference between the height of one-arm reach in a running jump and standing one-arm reach [cm];
- standing jumping ability (dynamic force of the legs) – the difference between the reach of two arms in a standing vertical jump and standing two-arm reach [cm];
- 3 kg medicine ball throw (dynamic force of the arms) – the 3 kg ball was thrown overhead forward using both arms. During the throw a player was kneeling on a mattress and maintained the body balance. The best result out of three trials was recorded down [m];
- 10 m run – a player began the test in prone position with the shoulders along the starting line. On a signal with a downward movement of the starting flag the player stood up and began running crossing the starting line and the 10 m finishing line, each marked by two pairs of photo-sensors. The best result out of three trials was recorded down [sec].
- zig-zag run (Fig. 1) (7 m x 7 m "envelope" test) [sec] – a player began the test in prone position with the shoulders along the starting line, and with the hands at the line of the shoulders:
  - the timer was started once the player began extending his arms;
  - the player ran forward toward the net and then ran backward away from the net facing the net all the time;
  - the timer was stopped once the player had crossed the center line.

The running route was marked with five flags 7 meters apart. The covered distance was measured in seconds.
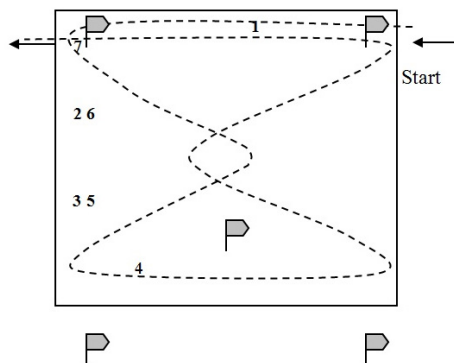
Fig.1. The zig-zag test route

STATISTICAL ANALYSIS

Multiple regression analysis was used to determine the relationships between several independent variables and a dependent variable. The independent variables included the motor abilities test results, while the dependent variables were the indices of efficacy of particular volleyball performance skills. The most appropriate subset of independent variables for a given dependent variable was found by calculating R^2 values and standardized regression coefficients (ß) for each subset pattern.

In the analysis of collinearity for regression equation expressions, with parametrization with sigma-limits, a partial correlation was estimated for each variable, between a given variable and a dependent variable (after having considered the impact of all remaining independent variables), t-test values and the level of statistical significance p ($0.0001 < \alpha < 0.05$).

RESULTS

VOLLEYBALL PERFORMANCE SKILLS

The first dependent variables were players' actions that most significantly affected the set outcome, i.e. serves, blocks and attacks (Tab. 2). The greatest differences were found among players' serve results, where – with the exception of ineffective serves – the index of variability ranged from v = 67.14 (counter-effective serve) to v = 80.23 (effective serve).

The relatively lowest variability, however within the widest range, was found among attack results: from $v = 14.07$ (effective attack, low variability) to v = 66.42 (counter-effective attack, very high variability). In terms of block efficacy the differences ranged from $v = 42.74$ to $v = 55.59$. The variability index for the counter-effective block exceeding 100% ($v = 133.19$) requires some explanation. No counter-effective blocking actions were recorded by six players, while in the case of the other six players they ranged from 1 to 6. Thus the standard deviation ($S = 2.11$) was higher than the mean value ($M = 1.58$).

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Table 2. Efficacy of serving, blocking and attacking performance skills

Volleyball action	Level of efficacy	Mean M	Standard deviation S	Min	Max	Index of variability v
Serve	effective	3.58	2.87	0	9	80.23
	ineffective	15.17	4.95	9	27	32.65
	counter-effective	3.67	2.46	0	9	67.14
	index of serving efficacy (ISE)	0.13	0.09	0	0.25	69.87
Block	effective	2.92	1.62	0	6	55.59
	ineffective	10.17	4.34	3	16	42.74
	counter-effective	1.58	2.11	0	6	133.19
	index of blocking efficacy (IBE)	0.23	0.14	0	0.5	59.42
Attack	effective	11.42	5.87	2	24	51.41
	ineffective	9.58	4.44	4	15	46.34
	counter-effective	4.08	2.71	0	9	66.42
	index of attacking efficacy (IAE)	0.45	0.06	0.29	0.53	14.07

The highest mean number of points was scored by spiking (M = 11.42 pts), followed by serving (M = 3.58 pts.) and by blocking (M = 2.92 pts.) (IAE = 0.45; IBE = 0.23; ISE = 0.13).

MOTOR ABILITIES

The regression analysis permitted the selection of the most appropriate subset of motor abilities that were significantly correlated with effective serves, blocks or attacks (Tab. 3).

Table 3. Regression coefficients (R^2) for particular subsets of motor abilities and volleyball performance skills

Volleyball action	Index of efficacy	R^2	Motor abilities test						
			Running jump height with a one-arm swing	Standing jump height with a two-arm swing	Running jumping ability	Standing jumping ability	3kg medicine ball throw	Zig-zag run	10 m run
Serve	effective	0.68	-0.60			0.65	-0.73		
	ISE	0.79				0.36	-1.13		
		0.77	-0.45			0.53	-0.89		
Block	IBE	0.88	2.04		-0.91				
Attack	effective	0.66				1.32		1.04	
	IAE	0.81			0.63				

Effective serves performed by the players were strongly correlated (R^2 = 0.68) with a subset of three motor abilities: standing jumping ability, running jump with a one-arm swing and the dynamic force of the shoulder girdle (for the last two abilities the correlation was negative). All three types of serve efficacy (as indicated by the IE) were correlated with a subset of two motor abilities: standing jumping ability, the dynamic force of the shoulder girdle (R^2 = 0.79) and the running jump with a one-arm swing (R^2 = 0.77).

The block efficacy (IBE) was significantly correlated ($R^2 = 0.88$) with a subset of running jump with a one-arm swing and running jumping ability. Effective scoring with attacks was correlated ($R^2 = 0.66$) with the standing jumping ability and the zig-zag run test results. However, the index of attack efficiency (IAE) was greatly determined only by the running jumping ability ($R^2 = 0.81$).

Table 4 shows correlations between dependent variables (efficiency of volleyball performance skills) and independent variables (motor abilities) at $\alpha < 0.05$.

The serve efficiency was significantly correlated with standing jumping ability (0.69), but was not correlated with the height of the running jump with a one-arm swing (-0.68) or the dynamic force of the shoulder girdle muscles (-0.77). The negative effect of the last motor ability was confirmed by its strong correlation with the index of serve efficiency (-0.89) and a high t-value (-5.42).

Table 4. Correlations between efficiency of volleyball performance skills and motor abilities

Volleyball action	Motor abilities test	Partial correlation	t	p
	Effective serve			
	Running jump with a one-arm swing	-0.68	-2.63	0.0301
Serve	Standing jumping ability	0.69*	2.66	0.0286
	3 kg medicine ball throw	-0.77	-3.36	0.0099
	Index of serving efficacy (ISE)			
	3 kg medicine ball throw	-0.89	-5.42	0.0006
	Index of blocking efficacy (IBE)			
Block	Running jump with a one-arm swing	0.93*	7.02	0.0001
	running jumping ability	-0.84	-4.46	0.0021
	Effective attack			
	Standing jumping ability	0.81*	3.91	0.0045
Attack	Zig-zag run	0.74	3.07	0.0153
	Index of attacking efficacy (IAE)			
	Running jumping ability	0.82*	4.06	0.0036

* statistically significant differences ($p < 0.05$)

The partial correlation value indicated a strong correlation between the index of block efficacy (IBE) and the height of the running jump with a one-arm swing (0.93; t = 7.02), but not between the IBE and the running jumping ability (-0.84; t = -4.46). The attack efficacy was significantly determined by a high level of the standing jumping ability (0.81), while it was not significantly correlated with the zig-zag rune test results (0.74). The general attack efficacy (IAE) was largely dependent on the running jumping ability (0.82).

DISCUSSION

The results of the analysis showed that volleyball players' efficacy determined to a large degree, although in various ways, the players' levels of motor abilities.

The study revealed that the effective performance of attacks, blocks and serves was correlated with various motor abilities and formed specific subsets with these abilities. An effective serve performance is correlated with a set consisting of the standing jumping ability, the running jump with a one-arm

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swing and 3 kg medicine ball throw; an effective block performance –with a set of the height of the running jump with a one-arm swing, the running jumping ability and the speed of locomotion with changing directions (zig-zag run).

Studies on relationships between attack, block and serve efficacy in volleyball with players' motor abilities have been carried out by a number of authors [16, 19]. According to Dopsaj et al. [20], power, strength and speed are important determinants of spike and block jumps and are decisive for the set outcome. Significant correlations between effective blocks and the set outcome in male volleyball players were also revealed by Palao et al. [21].

In their study of relationships between motor abilities and volleyball performance Dopsaj et al. [14] concluded that players' dynamic force and locomotion speed are dominant in attacks and blocks and in most cases are decisive for the set outcome.

On the other hand, a study of 14–15 and 16–17-year-old female volleyball players by Katić et al. [12] showed that attacks and blocks were the best predictors of game scores, and their analysis of regression revealed a correlation between players' force and speed; however, the former had a greater impact on the set outcome than the latter. Conti et al. [6] concluded that youth volleyball gameplay becomes more offensive in result of the performance of attacks by players with high levels of dynamic force, and the force and the speed of attacks do increase chances of scoring. Marcelino et al. [9] noted that the spike is the best index of the volleyball set outcome, followed by the block. The best volleyball teams do have the largest number of serve errors, but also gain more points by the opponent's serve errors. The study results of Zetou et al. [5] confirm that "ace" volleyball serves are important tools of victory of aggressive teams.

Particular volleyball actions can be assigned respective indices of efficacy. In the present study these indices were 0.45 for attacks, 0.23 for blocks, and 0.13 for serves. Similar volleyball efficacy indices (in %) were examined by Monteiro et al. [11], and they amounted to 13.67% for the serve (corresponding to the results of the present study), 29.17% for the spike, and 6.49% for the block. The last two indices were lower than their counterparts in the present study.

Lidor and Ziv [22] in their multidimensional assessment of determinants of volleyball game play in young players emphasized the significance of the vertical jump for the set outcome and recommended selection of appropriate tests to assess young volleyball players' skills and abilities.

CONCLUSIONS

The results of the present study can be directly used in the development of training programs by volleyball coaches of young players. They clearly indicate that serving and attacking effectiveness is directly determined by the standing jumping ability, while blocking efficacy is affected by the height of the running vertical jump. This necessitates the consideration of diversified of hitter, middle blocker and setter selection criteria in volleyball. A hitter and setter must possess a high level of standing jumping ability, while a middle blocker a long arm reach in a running vertical jump.

The authors hope that this pioneering study will encourage others to design and apply more innovative and efficient methods of measuring motor abilities and volleyball performance skills.

PRACTICAL IMPLICATION

The obtained results allow giving important information to trainers. Effective serve does not depend on a large dynamic force of the shoulder girdle; actually, the progressive development of the shoulder girdle can even cause a decrease in the effectiveness of the serve. This should be taken into a consideration while planning training for a player.

The study confirmed the practical rule, very often used by trainers, that the position of the player in the middle block, is reserved for a person with the best result in the running vertical jump. This parameter has a significant impact on the high performance reliability for activities in the block.

The most reliable players in attack turned out to be those with the highest values of the jumping ability (immediately and with the run up) and the speed of shift. Therefore, it is the dynamic force of the players' lower limbs that has the most significant impact on the effectiveness of attack not the standing jumping ability. It is possible to suggest that the position of the receiving or attacking player should be assigned to players with this particular motoric abilities.

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