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A SIMPLE MATHEMATICAL MODEL FOR ESTIMATING GENERAL JUMPING PREPAREDNESS OF SENIOR FEMALE VOLLEYBALL PLAYERS

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Abstract

The aim of this paper is to define a simple mathematical model for estimating general jumping preparedness of senior female volleyball players (SCOREpoint) by applying a set of 7 variables measured by standardized tests within the field measuring conditions. The sensitivity of this model is determined on the basis of achieved points and differences in general jumping preparedness among female volleyball players competing in elite international competitions, elite national competitions, state-level and regional-level competitions. Applied battery of tests has cumulatively explained 80.64% of the total variant of measurement. The defined model explained the criterion of general jumping preparedness of senior female volleyball players at the level of 100% (Adj. $R^2 = 1.000$), and with the minor error in prediction (Std. Err. Est. = 0.003 $SCORE_{point}$ points). The obtained model has the following form: SCOREpoint = -86.762 + (0.4595 · CMJ_{ARM} + 0.5158 · CMJ_{NoARM} + 0.4620 · SJ_{ConARM} + 0.4812 · $SJ_{ConcNoARM}$ + 0.5431 · CM_{BJ} + 0.5626 · SJ_{ConcBJ} + 0.138 · SLJ. The defined model has a satisfactory level of discrimination and it is proposed for further practical use.

Keywords: volleyball, jumping ability, mathematical model, general jumping preparedness

Introduction

Volleyball is a team sport played at all levels by both genders (e.g., youth, Olympic, professional) and places an emphasis on fast and explosive movements such as jumping, hitting, and blocking (Spence, Disch, Fred, & Coleman, 1980; Marques, Gonzalez-Badillo, & Kluka, 2006; Stojanović & Kostić, 2002; Sheppard et al., 2007; Rajić, Dopsaj, & Pablos-Abella, 2008). Volleyball is commonly described as a complex, high speed, explosive and powerful sport.

Success in a volleyball game depends to a great extent on the movement speed without the ball, the speed of the rhythm change and direction of movement, agility and jumping ability (Nešić, 2008; Suzović and Nedeljković, 2009). Repeated maximal or near-maximal vertical

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jumps, frequent change-of-direction sprints, diving to make a save, and repeated overt head movements when spiking or blocking are among the movements that make up the game (Black, 1995; Gandeken, 1999). A volleyball match can be played up to five sets, meaning that the duration of the match may be up to around 90 minutes. During that time a volleyball player performs 250-300 actions in which the explosiveness of the leg muscles dominates. Out of the total number of actions, jumps comprise 50-60%, fast movements and direction change in space amount to around 30% and falls make around 15%. The latest data point out that the average body height of a contemporary volleyball player is between 195 and 200cm (Ercolessi, 1999) and for female volleyball players from 185.41±7.88 cm for the Olympic level, up to 180.88±3.03 cm for the First League level and 174.25±3.07 cm for the regional-level (Second League – North). (Dopsaj, Nešić & Đokić, 2010). The average height of the vertical jump of the spike receiver, spiker and middle blocker is from 345 to 355cm and in the block from 320 to 335cm (Ercolessi, 1999). The explosive power and speed strength is dominant in spike and block actions and in most cases it is the key factor in winning points or the quality of defense actions in a block.

An average action in volleyball lasts about 6 seconds, and is followed by an average rest period of 14 seconds, not including player substitutions or timeouts (Gandeken, 1999). This action work-rest ratio suggests that athletes primarily use the adenosine triphosphate phosphocreatine system. There are about 50 rallies per a game. As a result, energy-system training for volleyball should consist of 50 or more repeats lasting 5-10 seconds. These efforts should consist of jumping, running, and/or diving, involving frequent changes of direction, followed by 10-15 seconds of rest (Black, 1995).

Bearing in mind that during a match volleyball players make jumps applying various jumping techniques (with and without arm swings), that they make jumps with a dominant vertical or horizontal component of movement direction of the gravity center of the body, and that the given elements are made in relation with various regimes of muscle contractions of leg stretchers (Stretch Shortening Cycle i.e. excentric-concentric muscle regime type of contraction, only concentric muscle type of contraction and different combination of contraction as well as isometric-concentric, excentric-isometric-concentric, pre-stretch deep jump impact-concentric etc.), it is supposed that from a methodological aspect, the sum of the results of various types and kinds of jumps would give a better general (summary) estimation about the level of general jumping preparedness of the female players in relation with the information obtained by an individual test. Also, the given kind of testing could be realized within the space-time conditions of usual trainings without disturbing the training rhythm, where the information on current level of development of the examined level of preparedness could be done by applying the method of field testing by means of the model load (Dopsaj, 2010).

The aim of this paper is to define a simple mathematical model for estimation of general level of jumping preparedness of senior female volleyball players. The sensitivity of this model will be determined on the basis of achieved points and differences in general jumping preparedness among the female volleyball players who have been successful in volleyball on various levels: in elite international competitions (the Olympics), elite national competitions (Super League), and state-level (First League) and regional-level (Second League – North) competitions. In that way a simple and operational method of testing female volleyball players will be defined, and the obtained results can be used in the process of staged training tests of jumping readiness in the function of long-term training process.

Method

The main method used in this research is the field testing method (Dopsaj, 2010). As far as measuring is concerned, a method of direct measuring was used where the Abalak's method was applied (Zaciorski & Kraemer, 2006), that is, Belt Jump Test (Klavora, 2000) (Figure 1). Prior to each testing, the players were explained the purpose and ways of the measuring, and each of them gave an oral consent to participate in the study in accordance with the norms of the Ethical Committee of the Faculty of Sport and Physical Education of the University in Belgrade. All measuring were performed in the afternoons in training gyms with the same type of flooring (wooden parquet floor). All the measuring was done by qualified experts – three Physical Education teachers.

Figure 1. A device for measuring height of vertical jump (Abalak's method).

Sample of the examined players

Sample consisted of 59 female players (N): 15 players of the Olympic selection (OS), 12 players of the VC Radnički (SL) who participated in the competitions of the Super League of Serbia, 20 players of the VC Vizura (FL) who played in the First League of Serbia and 12 players of the VC Kikinda (SLN) who took part in the competitions of the Second League – North.

An average age and length of training period of the female volleyball players from the Olympic selection was 22.6±3.2 and 12.3±2.5 years. The players of the VC Radnički were 20.0±2.1 and 7.4±1.7 years of age. The players of the VC Vizura 19.4±2.6 and 8.4±3.0 and with the players VC Kikinda 18.4±2.7 i 6.2±2.9 years respectively.

All players had been informed about the subject, goal and objectives of the research and in cooperation with their trainers gave a voluntary consent to participate in the research.

Table 1

Basic descriptive indicators of the sample of all four teams

Volleyball players		Teams	N	Average age (mean±sd)	Training period (mean±sd)
	1	Olympic Selection	15	22.6±3.2	12.3±2.5
	2	Super league	12	20.0±2.1	7.4±1.7
	3	First league	20	19.4±2.6	8.4±3.0
	4	Second league -North	12	18.4±2.7	6.2±2.9

Variables samples

In order to define a simple mathematical model, tests were selected by the criterion of simplicity, informativeness and practical usage in function of application from the aspect of field measuring. From the aspect of motoric structure, the jumps were selected which are the most representative from the analytical, diagnostical and situational aspect in function of defining the profile of jumping ability in volleyball (Spence et al., 1980; Fleck et al., 1985; Klavora, 2000; Young et al., 2001; Sheppard et al., 2007; Marques et al., 2004; Ćopić, Dopsaj, Nešić, & Sikimić, 2010).

A battery of tests by which jumping ability was assessed, both in function of basic vertical and in function of basic horizontal component, contained the following 7 different types of jumps which represented individual variables of the measured space:

- Seven variables for assessment of different types of jumps are:
  - **double leg vertical countermovement jump with arm swing (CMJ_{ARM})** measured in cm (Figure 2)
  - **double leg vertical countermovement jump-no arm swing allowed (CMJ_{NoARM})** measured in cm (Figure 3)
  - **double leg concentric vertical squat jump (SJ_{ConARM})** measured in cm (Figure 4)
  - **double leg concentric vertical squat jump ($SJ_{ConcNoARM}$)** measured in cm (Figure 5)
  - **double leg vertical countermovement standing block jump (CM_{BJ})** measured in cm (Figure 6)
  - **double leg vertical squat standing block jump (SJ_{ConcBJ})** measured in cm (Figure 7)
  - **Standing long jump (SLJ)** measured in cm.

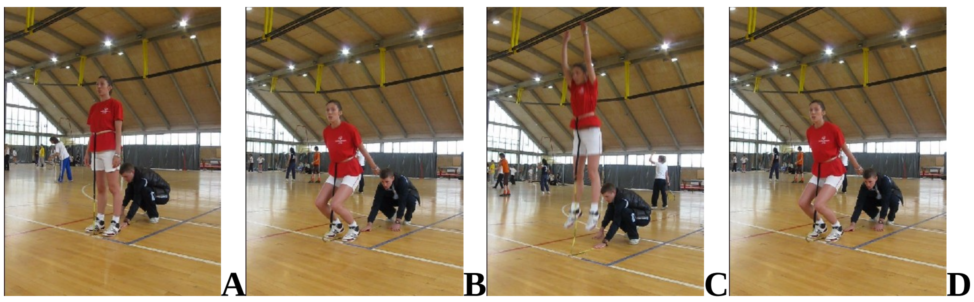


Figure 2. Double leg vertical countermovement jump with arm swing (CMJ_{ARM}).

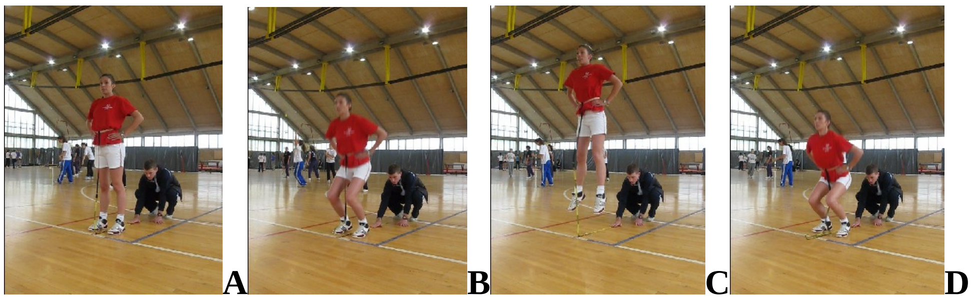


Figure 3. Double leg vertical countermovement jump-no arm swing allowed (CMJ_{NoArm}).

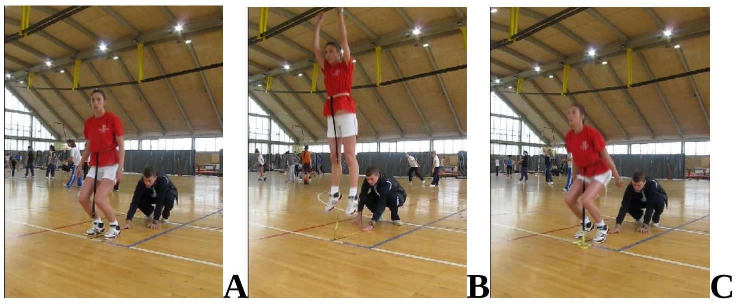


*Figure 4***.** Double leg concentric vertical squat jump (SJ_{ConArm}).

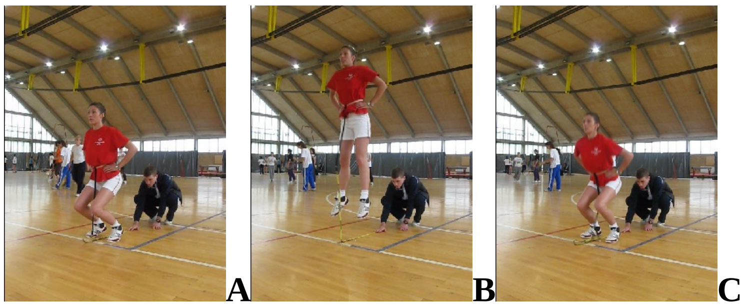


Figure 5. Double leg concentric vertical squat jump ($SJ_{ConcNoArm}$).

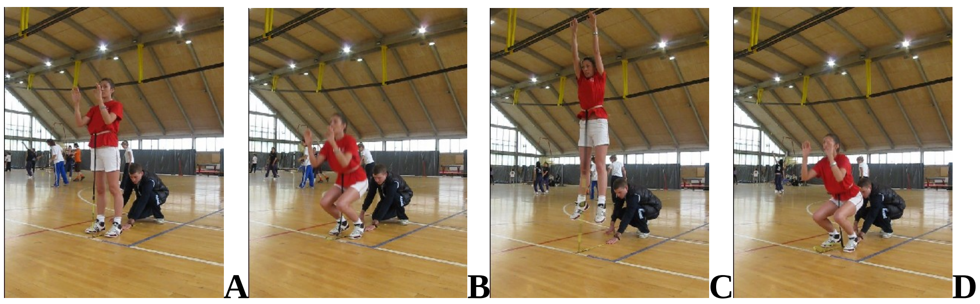


Figure 6. Double leg vertical countermovement standing block jump (CM_{BJ}).

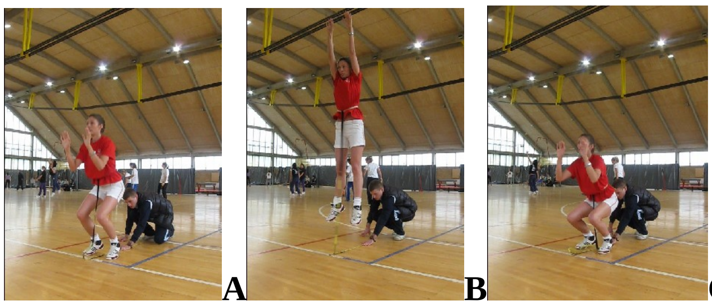

A B C

Figure 7. Standing long jump (SLJ).

Measuring methods

The measurement was performed by the Abalak's method, i.e. belt jump method in which the standard PVC measuring belt was fixed on the upper side in the position around the umbiculus (in front of the stomach) of the examined player, and from the lower side on the parquet in the front projection of the standing point. The belt was pulled through the measuring fixator from the lower side which was firmly fixed to the floor so that the belt could freely move (in the direction of pull-out movement) through it (Klavora, 2000). The examined players did a set series consisting of 6 vertical jumps, each jump was repeated twice, while the break between the jumps lasted 30 seconds. Each jump was made with maximal intensity with a task to jump back onto the same place. The position of jump-up and jump-down was marked on the parquet (Figure 1). In case an examined player jumped down out of the marked jump-down zone, that attempt was not recorded and the measuring was repeated. A better result in each jump type was recorded as the final score of that particular jump type. After that measuring, the examined players were tested on another place by the standing long jump test which was realized by a standardized procedure (Zaciorsky & Kraemer, 2006).

Statistical methods

Raw data were analyzed in the first phase by application of descriptive statistics in order to calculate the basic descriptive indicators, the mean values (mean) and the standard deviations (sd) in particular. For the purpose of calculating general difference between the jumping ability in function of examined sub-samples, the ANOVA was used (Hair, Anderson, Tatham, & Black, 1998). Definition of the Index of general jumping preparedness (SCOREpoint) was made by applying the method of mathematical analogy where the value of position of the factor score of each examined player was turned into an analogue point score defined from 0 points (as hypothetical minimum) to 100 points (as hypothetical maximum). In the consequent statistical process of defining a mathematical model the value of the SCORE point represented a criterion variable, while the individual score obtained by application of the battery of 7 jumping tests stood for a system of predictable variables. The final form of the model was defined by application of the Multivariant regressive analysis. All analyses were done in the statistical package SPSS 12.0 and the difference criterion was defined on the level p=0.05 (Hair et al., 1998) .

Results

Table 2 presents the KMO results of measuring of the sample adequacy where it is possible to see that the raw data belong to a homogenous group with the reliability level from 88.30% (p=0.000). In that way it was proved that they can be validly analyzed by the method of multi-variant statistics, and that they can be validly interpreted as well.

Table 2

The results of KMO measurement of the sample adequacy KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.883
Bartlett's Test of Sphericity	Approx. Chi-Square	442.55
	df	21
	Sig.	0.000

Table 3 shows the communalities of the variables, and it is evident that all the used variables are highly projected on to the common measuring variance, i.e. they belong to the same measurement space. In such a way it can be claimed that the given set of tests can be treated as a battery of tests for evaluation of general level of jumping abilities. Of all single test tasks, CMJ_{ARM}, with its extraction level of 84.3%, has the greatest projection onto the common measurement space, while $SJ_{CONCNOARM}$ at the extraction level of 70.4%, has the lowest level.

Table 3

Communalities of the used variables for general jumping preparedness evaluation

Communalities		
	Initial	Extraction
CMJ_{ARM}	1.00	0.843
CMJ_{NOARM}	1.00	0.830
SJ_{CONARM}	1.00	0.840
$SJ_{CONCNOARM}$	1.00	0.704
CM_{BJ}	1.00	0.838
SJ_{CONCBJ}	1.00	0.827
SLJ	1.00	0.763

Extraction Method: Principal Component Analysis.

Table 4 shows the result of separate cumulative variance projected onto the first factor. The used battery of tests has cumulatively accounted for 80.64% of the total measurement variance, which means that at the level of 80.64%, it defined the general jumping preparedness of female volleyball players of senior/varsity age.

Table 4

Cumulative level of explained measurement variance

Total Variance Explained						
Component	Initial Eigenvalues			Extraction Sums of Squared		
	Total	% of	Cumulative %	Total	% of	Cumulative %
1	5.65	80.64	80.64	5.65	80.64	80.64

Extraction Method: Principal Component Analysis.

Table 5 shows the results of multiple regression analysis where the SCOREpoint represented the value of criteria variables, and the results of the separate tests showed the predictive variables.

Table 5

Results of multiple regression analysis

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95,0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-86.7620	0.005		-18939.46	0.000	-86.771	-86.753
	CMJ_{ARM}	0.4595	0.000	0.163	2625.68	0.000	0.459	0.460
	CMJ_{NoARM}	0.5158	0.000	0.161	2871.742	0.000	0.515	0.516
	SJ_{CONARM}	0.4620	0.000	0.162	2912.801	0.000	0.462	0.462
	$SJ_{CONCNoARM}$	0.4812	0.000	0.149	3255.311	0.000	0.481	0.482
	CM_{BJ}	0.5431	0.000	0.162	2914.241	0.000	0.543	0.543
	SJ_{CONCBJ}	0.5626	0.000	0.161	2990.454	0.000	0.562	0.563
	SLJ	0.1381	0.000	0.155	3551.424	0.000	0.138	0.138

Model Summary[b]

Model	**R**	**R Square**	**Adj. R Square**	**Std. Error of the Estimate**
1	1.000[a]	1.000	1.000	0.003

a. Predictors: (Constant), CMJ_{ARM}, CMJ_{NoARM}, SJ_{CONARM}, $SJ_{CONCNoARM}$, CM_{BJ}, SJ_{CONCBJ}, SLJ

b. Dependent Variable: SCOREpoint

Table 6 presents the results of ANOVA; there are statistically significant differences in comparison with the index of general jumping preparedness (SCOREpoint) between the analyzed groups, i.e. female players from high-level international competitions (the Olympics), high-level national competitions (Super League), and state-level (First League) and regional-level (Second League – North) competitions; at a level of F – 17.38, p = 0.000.

Table 6

The results of ANOVA index of general jumping preparedness (SCOREpoint) in comparison with the tested groups of examined players

Tests of Between-Subjects Effects					
Dependent Variable:SCOREpoint					
Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Team	13963.216	3	4654.405	17.380	0.000
a. R Squared = 0.487 (Adjusted R Squared = 0.459)					

Table 7 and Graph 1 show the basic descriptive data of the SCOREpoint with determined differences between groups of tested female volleyball players from high-level international competitions (the Olympics), high-level national competitions (Super League), and state-level (First League) and regional-level (Second League – North).

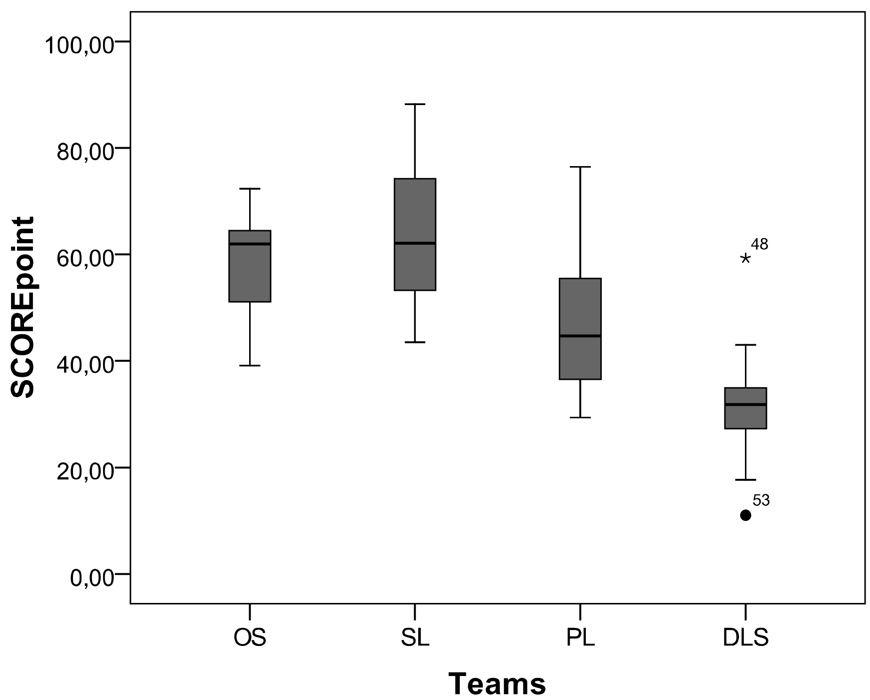
Table 7

Results of the descriptive statistics

VOLLEYBALL	**OS** (N=15)	**SL** (N=12)	**PL** (N=20)	**DLS** (N=12)
	mean± sd	mean± sd	mean± sd	mean± sd
SCOREpoint	60.62±10.38†	67.12±13.70$▲	48.83±12.02	35.00±11.55

OS vs DLS†; **SL** vs PL$; **SL** vs DLS▲ p> 0.05▲;

Graph 1. The overview of the basic descriptive indicator (mean±sd) SCOREpoint with determined differences between the groups of athletes from elite international competitions (the Olympics), elite national competitions (Super League), and state-level (First League) and regional-level (Second League – North).



At the end, the finally defined simple mathematical model for evaluation of general jumping preparedness (SCOREpoint) has the following form:

SCOREpoint	$= -86.762 + (0.4595 \cdot CMJ_{ARM} + 0.5158 \cdot CMJ_{NoARM} + 0.4620 \cdot SJ_{CONARM} + 0.4812 \cdot SJ_{CONCNoARM} + 0.5431 \cdot CM_{BJ} + 0.5626 \cdot SJ_{CONCBJ} + 0.138 \cdot SLJ)$

Discussion

A simple mathematical model was defined on basis of the obtained results which explained the measurement space i.e. a criterion of general jumping preparedness of senior female volleyball players at the level of 100% (Adj. $R^2 = 1.000$, Table 5). In other words, it explained this with the negligible prediction error (Table 5, Std. Err. Est. = 0.003 $SCORE_{point}$). The results also showed that the defined model has a satisfactory level of discrimination, for it turned out there is a statistically significant criterion difference in comparison with the tested group that represented players selected with respect to different competition level – high-level international competitions (the Olympics), high-level national competitions (Super League), and state-level (First League) and regional-level (Second League – North) competitions, at a level of F – 17.38, p = 0.000 (Table 6).

Results of an interaction of influences of separate variables of various types of jumps have showed that the greatest influence on general jumping ability (the largest value of coefficient of regression influence) has $SJconc_{BJ} = 0.5626$, followed by $CM_{BJ} = 0.5431$ and so on, while the smallest one has SLJ = 0.1381 (Table 5). It is obvious that the largest impact on total variability of general jumping preparedness is by types and variants of jumps that within a given motoric task bear also a specific structure of movement, that is, they directly represent a specific volleyball jumping technique. Examples of these are double leg vertical squat standing block jump (SJ_{ConcBJ}, Image 7) and double leg vertical countermovement standing block jump (CM_{BJ}, Image 6).

On the other hand, the smallest impact on any given indicator have the jumps that dominantly represent the motoric task that defines the general level of preparedness when it comes to jumps without any additional jump technique. Those are double leg vertical countermovement jump with arm swing (form of excentric-concentric action of leg stretching muscles with circular arm motion CMJ_{Arm}, Picture 2), and Standing long jump with arm swing (form of excentric-concentric exertion of leg-stretching muscles with circular arm motion and dominantly horizontal body movement – SLJ).

In this way it was also shown that the selected battery of jumps is valid both in respect with its composition and structure since it is not only of statistically significant validity in evaluating the general jumping preparedness, but also sensitive enough when considering the level of separate impact of result attained in jumps with motoric structure that bears informational complexness of jumping techniques specific to volleyball.

Since the results have shown that the defined model has a satisfactory level of discrimination it is recommended for practical use, for the purpose of a simple testing method in the process of evaluating given preparedness with respect to phases of preparation of senior female volleyball players.

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