METRIC CHARACTERISTICS OF THE STEP HOP TEST IN YOUNG FEMALE VOLLEYBALL PLAYERS

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Abstract
The main goal of the study was to analyse the metric characteristics of a specific volleyball agility test (SHT: Step-hop test) on a sample of 204 youth Croatian female volleyball players whose mean chronological age was 14.11±0.84 years with a training experience of 42.14±16.76 months. High values of the Cronbach's alpha coefficient (0.93) and low values (0.97 – 0.87 to include the values) of the coefficient of variation (0.004) confirmed good reliability of the step-hop test. Significant differences were found between the measured items by using the F-test, i.e., there was a noticeable trend of result improvement over the three consecutive test performances. The obtained value of the KS test and the values of coefficients of distribution Skewness (Skew) and Kurtosis (Kurt) indicated good sensitivity of the step-hop test. It was determined by factor analysis (principal components analysis) and correlation analysis that the step-hop test had the same object of measurement as the two tests for assessing agility in volleyball (side steps and 9-3-6-3-9) with validated metric characteristics. Univariate analysis of variance showed no significant inter-positional differences in the SHT performance. By applying an independent samples t-test significant differences were found between more successful and less successful young volleyball players at passer-hitter position. Based on the obtained results, the SHT can be recommended in the process of identification and selection of young female volleyball players at passer-hitter position. To improve the homogeneity of the test, players should be allowed more trials and the test should be modified so that every change of movement direction is initiated by the foot opposite from that which was last put on the floor in the previous movement.

***Key words**: factorial and pragmatic validity, reliability, step-hop test, volleyball players, team sport*

Introduction

Volleyball is a sport in which 76.6% of rallies last 12 seconds or less, and the average rally time is approximately 11 seconds. The range of durations includes rallies as short as 3 seconds and as long as 40 seconds. In addition, 44% of rest periods between rallies are 12 seconds or less, with the average rest time being 14 seconds (Shepard et al., 2007). During those rallies, volleyball players perform different activities such as: jumps, drops, multidirectional accelerations, quick changes of directions, stops and landings. Players at different positions (setter, opposite hitter, passer-hitter, middle blocker and libero player) use various movement patterns with different frequency during a competition (Marques et all., 2009). These time-motion activities are rarely performed as isolated activities. Much more frequently volleyball players must quickly shift from one movement activity to another, e.g., from acceleration to landing or jumping (Padulo et al., 2003). During their performance, volleyball players averagely cross 11 meters in one rally (Mroczek et al., 2014). One of the most important motor abilities for successful performance of those movement activities in a competition is agility (Morales, 2002; Grgantov et al., 2006; Katić et al., 2006; *Gortsila* et al., 2013; Schaal et al., 2013). Agility has its perceptive-cognitive and motor component (Sheppard & Young, 2006; Horička et al., 2014; Sekulić et al., 2014), which are sometimes also defined as reactive (random) and planned agility (Oliver & Meyers, 2009). While the perceptive-cognitive component is important for predicting the intentions of one's team members and opponents, and for choosing the next technical-tactical action and its location, the motor component of agility is necessary to reach the chosen position for the performance of that action in time. In several studies (Grgantov et al., 2006; Katić et al., 2006; Gabbett, & Georgieff, 2007; Milić et al., 2012; Milić et al., 2013; Sekulić et al., 2013), the motor, i.e., planned component of agility in volleyball has been tested by tests such as *Side steps, T-test, 9-3-6-3-9 m*, etc. However, these tests do not simulate adequately a time motion analysis based on volleyball game. Indeed the small area represents the limit of ecological validity [small distances under 3 meters, e.g., during serve reception or transition from block to field defence]. In these situations, volleyball players usually apply the "step-hop" technique. That is why Đurković et al. (2008), constructed a specific agility test which they named the step-hop test. However, the step-hop test has been validated on a relatively small sample of junior and senior volleyball players and the differences between volleyball players playing at different positions have not been analysed. Thus, the aim of this study was to analyse the metric characteristics of the step-hop test on a large sample of young female volleyball players and to determine whether it is good in discriminating

players at different player positions, as well as players of different quality within certain position.

Methods

The sample recruited in this study included 204 youth female volleyball players from all over Croatia and the inclusion criteria was: participation in the open National Volleyball Championship in 2014. To make the sample as representative as possible, young volleyball players from all regions were included, especially members of the best national clubs. Mean *chronological age* of the subjects was 14.11±0.84 years, and mean *training experience* was 42.14±16.76 months. The subjects' mean height was 170.10±7.41cm and their mean body mass was 58.92±9.28 kg. Their mean *body mass index* was 20.31±2.67 kg/m^2 and mean *somatotype* was 4.60±1.48-2.74±1.32-3.51±1.39. All subjects had ID cards provided by the Croatian Volleyball Federation and verified by an authorized sports physician. Informed consent from parents was obtainted for children <18 yrs, according to the Declaration of Helsinski. The independent variable sample represented a set of three motor tests for assessing agility in young female volleyball players: *Side steps, 9-3-6-3-9 test, Step-hop test*. The description of these tests is as follows:

Side steps: The task is performed in a sports hall with a flat and firm surface and minimal dimensions of 6×3 m. Two parallel 1 m lines are marked on the floor, 4 m apart. A subject stands with both feet within the lines, sideways from the first line. On the mark, she moves as fast as she can sideways (step-touch), without crossing her legs, to the other line. When she steps on the line or crosses it with her outer foot, she stops and without changing body position, returns to the first line in the same way and then touches it with her foot or crosses over it. When a subject covers the 4-m distance for 6 times in the manner described and stands on the line or crosses it with her outer foot, the task is completed. Time is measured in hundredths of second from the moment she is given the mark "now" to the moment when she, after properly performing the task, touches the line. The task is performed 3 times with a pause sufficient for recovery.

Test 9-3-6-3-9: There are lines on the floor marking the 6, 9, 12 and 18 meter distance from the start line. A subject stands behind the start line in standing position and when she is given the mark "now", she touches the line which is 9 meters from the start line with her foot; she then goes back 3 meters and touches the line in the same way; she then runs 6 meters forward, again 3 meters back and finally sprints to the line which is 18 meters from the start line. The test is over when the subject crosses the line which is 18 meters from the start. The task is repeated 3 times with a pause sufficient for recovery.

Step-hop test The test is performed on a flat and non-slippery surface marked with a 3×3-m square which has 30×30-cm squares marked in its corners. A subject stands with both feet faced forward to the right side line of the square. Subject's feet are parallel. Her left foot is in the upper left square (0). When a subject is given the mark, she performs the first step with her right foot sideways, and then a hop with both feet, making sure that her right foot is touching the sides of the lower left square (1) when she hops. Then she steps with her right foot diagonally forward to the right and hops in a way that her right foot touches the upper right square (2). The next step sideways is performed with the left foot, followed by a hop, so that a part of the left foot touches the back right square (3). This is followed by a left foot step diagonally forward to the left and a hop. After performing the last hop, a subject stands in the same position in which she started the test (4). The goal of the test is to perform 2 predefined movement cycles in the shortest time possible, measured in seconds. The test is performed 3 times with a pause sufficient for recovery (Figure 1).

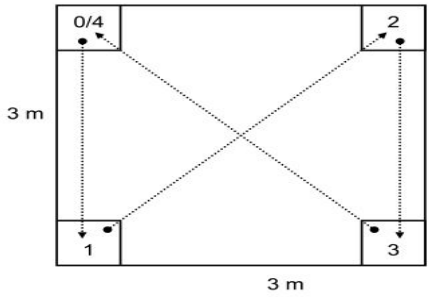

Figure 1. Schematic of the *Step-hop test*

The dependent variable sample was represented by two variables: *Playing position* and *Overall player quality*. According to the *Playing position* criterion, the volleyball players were divided into five groups: *Setters*, *Liberos*, *Passer-hitters*, *Opposite hitters* and *Middle blockers – 1st tempo attackers.Overall player quality* was determined on a five-point Likert scale (Grgantov et al., 2006).

A grade of 1-5 was assigned to each player regarding 2 criteria (Table 1):
1 Team ranking in the competition: All teams (16 volleyball teams) participated in the open Croatian National Championship and, based on their ranking in the championship, they were classified into 3 categories (1th-9th place; 10th-19th place; 20th-30th place).
2 Player quality within the team (assessed by the coaches). Each coach divided the players of her/his team into 3 groups:

the most successful – the most efficient players
average – other starters and non-starters who contribute to game quality
the least successful – non-starters who very rarely or never enter the game

All players who were assigned grades of 1-3 were categorized into the less successful group, and all players who were assigned grades 4 and 5 were categorized into the more successful players group.

Categorization of individual player performance level is presented in Table 1.

Table 1. Categorization of individual player performance level

		Overall player quality		
Competition ranking	Members of the national team	The most successful players in the team	Average players in the team	The least successful players in the team
(1-9)	5	5	4	3
(10-19)	5	4	3	2
(20-30)	5	3	2	1

In the first phase of the research, the researcher contacted the volleyball clubs and set up the time and place of the testing. The coaches contacted the parents of the volleyball players and explained the reasons for conducting this study and obtained signed consents from parents allowing their under aged children to participate in the study. Apart from the parental consent for the conduction of the study, the researchers also obtained permission from regional volleyball federations and the Croatian Volleyball Federation. All tests were conducted in the morning time (between 10 and 12 am) to avoid any influence of circadian variation (Ammar et al., 2015). Before the testing, participants performed a standardized 15-minute warm-up. Participants started the warm-up with 3 minutes of jogging followed by 7 minutes of dynamic stretching exercises (Chaouachi et al., 2015) and then performed specific agility drills for 5 minutes. Two days before the testing, volleyball players did not have training with a significant load so fatigue did not affect the testing results (Gheller et al., 2015). All measurements were taken by a sports scientist. The data analysis included calculation of metric characteristics of all motor tests: reliability (by calculating the Cronbach's alpha coefficient, CA, and the coefficient of variability, CV), homogeneity (by using univariate analysis of variance – ANOVA) and sensitivity (by calculating the coefficients of asymmetry and peakedness of result distribution, SKEW and KURT).

The data was showed as arithmetic mean (AM), central value, median (M), minimum result (Min), maximum result (Max), standard deviation (SD) and MaxD value for determining significant deviation from normal distribution of variables by Kolmogorov-Smirnov test (KS test). Factorial validity of the step-hop test was analysed by principal components analysis (Preacher et al, 2002) and correlation analysis. The results of the step-hop test were compared to the results obtained by applying two agility tests (Side steps and 9-3-6-3-9) of validated metric characteristics on a sample of young female volleyball players (Katić et al., 2006). Pragmatic validity was tested by using the *t*-test to determine the differences between more successful and less successful young female volleyball players within each playing position, and by using Univariate analysis of variance (ANOVA) with post *hoc test* of differences (Tukey *Unequal N* HSD test) to determine inter-positional differences with the level of significance set at $p \leq 0.05$. The data were analysed by the Statistica Ver.12.00 software package.

Results and discussion

Reliability of the battery of tests for assessing motor abilities which included 3 tests for assessing agility was determined by the Cronbach's Alpha (CA), as coefficient of internal consistency between the measured items. Inter-item variability was determined by the coefficient of variation (CV), and analysis of inter-item homogeneity of the applied motor variables was tested by the F-test (Table 2).

Table 2. Metric characteristics of motor tests

Motor tests	**CA**	**CV**	**$AM_1 \pm SD_1$**	**$AM_2 \pm SD_2$**	**$AM_3 \pm SD_3$**	**F-test**
Side steps (s)	0.97	0.03	9.28± 1.02	9.05± 0.88	8.97± 0.95	48.69*
9-3-6-3-9 test (s)	0.87	0.04	8.68± 0.77	8.49± 0.58	8.46± 0.57	23.20*
Step hop test (s)	0.93	0.04	10.58 ±1.21	10.11 ±1.02	9.89± 1.07	114.40*

Legend: CA - Cronbach's alpha. CV - coefficient of variation of measured items. AM_1 - arithmetic mean of the first measuring. AM_2 - arithmetic mean of the second measuring. AM_3 - arithmetic mean of the third measuring. SD_1 - standard deviation of the first measuring. SD_2 - standard deviation of the second measuring. SD_3 - standard deviation of the third measuring. F-test - test value at testing significance of differences between AM of the first, the second and the third measuring. * - significance of differences at the level of $p \leq 0.05$.

It can be seen from the table that the values of the Cronbach's alpha coefficient were high and the values of the coefficient of variability were low, which indicates that all motor variables for assessing agility had a high level of relative and absolute reliability (consistency of results in the repeated measuring). There were significant differences between the items of the three measurements of all the used motor variables, which indicates heterogeneity of items of all agility tests, as well as the trend of result improvement over the three consecutive test performances. The most prominent improvements were noticed in the step-hop test. There were several reasons for this. As all measurements were conducted in the same day, not enough time was spent on specific warm-up for each test (volleyball players were not allowed enough trials). This was particularly obvious in the step-hop test as subjects were not familiar with it, as opposed to the, e.g., side steps test which is a part of the mandatory battery of tests for assessing motor abilities in primary and secondary schools in Croatia, and the 9-3-6-9 test, which is frequently used in volleyball clubs, both as a test and as an exercise of specific warm-up in introductory-preparatory part of training. It is the authors' opinion that the complexity of the step-hop test is additionally contributed by the unusual

way of changing the movement direction during diagonal movements from the lower left to the upper right square and from the lower right to the upper left square (marked by the arrow connecting the squares 1 and 2 and the arrow connecting the squares 3 and 4 in Figure 1). Namely, the usual way of performing all movement changes is to initiate the movement in the new direction by the opposite foot from that which was last put on the floor, and in this test both diagonal movements are performed by the same foot which was last put on the floor. This posed a significant problem to a certain number of players during test performance because they had to reorganize the pre-existing movement stereotypes. Due to this, it can be speculated that this test has elements of a coordination test, rather than just agility. Because of the heterogeneity that had been noticed, the minimum value (the best result) was used as the final result of the motor abilities tests (*side steps*, *9-3-6-3-9 test* and *step-hop test*), as variables were inversely scaled. The results of descriptive statistics are presented in Table 3: arithmetic mean (AM), median (M), minimum (Min) and maximum (Max) result and standard deviation (SD) of the three motor variables which explain the motor ability of agility in young female volleyball players. Sensitivity was tested by coefficients of Skewness (Skew) and Kurtosis (Kurt) of result distribution. The normality of distribution was tested by the Kolmogorov-Smirnov test with critical value of 0.12 which represents the maximal allowed size of maximal difference between cumulative observed and theoretical relative frequencies.

Table 3. Descriptive indicators and sensitivity of motor variables of youth female volleyball players (N=204)

Variables	AM	M	Min	Max	SD	KS	Skew	Kurt
Side steps (s)	8.84	8.71	6.97	11.26	0.87	0.08	0.46	-0.50
9-3-6-3-9 (s)	8.34	8.28	7.07	10.24	0.56	0.06	0.58	0.61
Step hop (s)	10.11	10.09	7.70	12.90	1.00	0.05	0.11	-0.05
						KS-test = 0.12		

Legend: AM - arithmetic mean. M - median. Min - minimum result. Max - maximum result. SD - standard deviation. KS - Kolmogorov-Smirnov test. Skew - coefficient of distribution Skewness. Kurt - coefficient of distribution Kurtosis.

Analysis of distribution indicators of motor variables of the total sample of youth Croatian female volleyball players showed that there were no significant deviations from normal distribution in any of the variables, which means that all variables were suitable for further multivariate parametric statistical analysis. The values of the coefficient of asymmetry (Skew) indicate that the *side steps* and the *9-3-6-3-9 test* showed slight positive skew of result distribution. The coefficients of distribution peakedness (Kurt) which ranged from -0.51 to 0.60 indicate good sensitivity of all the applied measuring instruments (tests) of motor abilities. Factorial validity of the *Step-hop test* analysed by principal components analysis (factor analysis) and correlation analysis is presented in Table 4. The results of the applied Step-hop test were compared to the results obtained by applying two agility tests (*Side steps* and *9-3-6-3-9*) with validated metric characteristics on a sample of young female volleyball players (Katić et al., 2006).

Table 4. Factor and correlation analysis of the applied motor variables for assessing agility

		Correlation analysis		
Variables	F_1	Side steps	9-3-6-3-9 test	Step hop test
Side steps (s)	-0.84	1.000	0.536	0.490
9-3-6-3-9 test (s)	-0.81	0.536	1.000	0.426
Step hop test (s)	-0.78	0.490	0.426	1.000
Eigenvalues	1.97			
% of Variance	0.66			

Legend: F_1- factor isolated by principal components analysis

All three tests that were applied for assessing agility in young female volleyball players were isolated on the same significant factor which explained 66% of total variability. All tests had high projections on the obtained factor. This confirms factorial validity of the step-hop test for assessing agility. Moreover, significant coefficients of intercorrelation of all the applied instruments of motor measures of agility are visible in the correlation matrix. These correlation values were moderately positive and indicated that the step-hop test had only 24% of common variability with the side steps test and 18% with the 9-3-6-3-9 test. This points to different manifestations of agility required for performance of these tests. With the purpose of determining pragmatic validity of the step-hop test, the total sample of 204 young female volleyball players was divided according to playing position into 5 groups (setters, opposite hitters, passer-hitters, middle blockers and liberos), and each group was defined according to the criterion of overall player quality by two new groups – more successful and less successful players. The results of pragmatic validity obtained by using t-test to assess the differences between more successful and less successful players within each playing position, and by using univariate analysis of variance (ANOVA) with *post hoc* test of differences (Tukey *Unequal N* HSD test) to assess the inter-positional differences with the level of significance set at $p \leq 0.05$, are presented in Table 5. By analysing Table 5 it can be seen that there were no significant inter-positional differences in the validated measuring instrument for assessing

agility. There was a significant intra-positional difference only in passer-hitters, with the level of significance at p= 0.037.

Table 5. Inter-positional and intra-positional differences of the validated *Step hop test*

Variable		Setters N=35	Opposite hitters N=33	Passer - hitters N=57	Middle blockers N=43	Liberos N=36
		AM±SD	AM±SD	AM±SD	AM±SD	AM±SD
Step hop test	Less successful	11.10±1.51	9.02±0.94	8.50±0.69*	9.00±0.96	9.01±0.91
	More successful	10.02±1.55	9.84±0.97	9.55±0.93*	9.71±0.98	9.82±0.98

Legend: N- the number of subjects. AM - arithmetic mean. SD - standard deviation. ‡ - significant inter-positional difference of variable by univariate analysis (ANOVA), post hoc analysis by Tukey *Unequal N test* with the level of significance set at p≤ 0.05. * - significant intra-positional difference with the level of significance set at p≤ 0.05.

Even though univariate analysis of variance showed no statistically significant inter-positional differences in the performance of the step-hop test, it can be noticed that the players at passer-hitter position were averagely the most agile. Moreover, it must be taken into consideration that the lack of statistically significant differences does not mean that the differences found do not have practical significance during competition (Batterham and Hopkins, 2006). This particularly comes to the fore in volleyball in which players have very little time to react to visual cues and reach the ball and play, so in practice, even movement which is a split second faster can make the difference between successful and unsuccessful performance (Grgantov et al., 2006; Katić et al., 2006). By analysing the intra-positional differences, it can be seen that more successful volleyball players playing all positions performed the step-hop test faster in comparison to the less successful players. Even though statistically significant differences were found only at the passer-hitter position, the fact that at other positions more successful players performed the test faster in the range of a third of a second at libero position, to almost an entire second at setter position, and that the differences were at the border of statistical significance for all positions except for libero, should not be ignored. The best results of passer-hitters in the step-hop test can be explained by the fact that players at that position move by step-hop technique very often during a game, most frequently during serve reception and quick transition from block to field defence. Significant differences between more successful and less successful players at this position could also be explained in the same way (Nikolaidis et al., 2015). It is logical that those players who reach the ball faster by using those movements have an easier task during play and therefore a higher probability of successful performance.

Conclusion

This study determined good reliability and sensitivity of the step-hop test for assessing agility on a sample of young female volleyball players. Due to the difficulties noticed during test performance and the emphasized learning process, the authors suggest for the test to be modified so that both diagonal movements are initiated by the foot opposite to that which was last put on the floor. To additionally reduce the influence of learning on test results it is necessary to allow more trials for subjects who are doing the test for the first time, if possible not at the same session at which the testing is conducted. The test also showed good factorial validity for assessing agility in young female volleyball players. Even though more successful volleyball players at all positions had better results than less successful ones, these differences were statistically significant only at the passer-hitter position. Thus, it can be concluded that the step-hop test has satisfactory pragmatic validity only for the passer-hitter position, whereas to obtain possible proof of pragmatic validity at other positions, further research with application of a modified test is necessary. Based on the results of this study, the step-hop test can be particularly recommended for application in the process of identification and selection of talented young female volleyball players playing at passer-hitter position.

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METRIČKE KARAKTERISTIKE STEP HOP TESTA KOD MLADIH ODBOJKAŠICA

Sažetak

Osnovni cilj istraživanja bio je analizirati metričke karakteristike agility testa specifičnog za odbojku (ShT: step hop test) na uzorku od 204 mladih hrvatskih odbojkašica čija je kronološka dob bila 14.11 ± 0,84 godina sa trening iskustvom 42.14 ± 16,76 mjeseci. Visoke vrijednosti koeficijenta Cronbachove alfe (0,93) i niske vrijednosti (0,97-0,87 za uključiti vrijednosti) od koeficijenta varijacije (0.004) potvrdile su dobru pouzdanost step-hop testa. Utvrđena je statistički značajna razlika između izmjerenih objekata pomoću F-testa, tj, bio je uočen trend poboljšanja rezultata tijekom tri uzastopna testa. Dobivena vrijednost KS testa i vrijednosti koeficijenta distribucije asimetričnosti (Skew) i kurtoze (Kurt) pokazuje dobru osjetljivost step hop testa. Određeno je faktorskom analizom (analize glavnih komponenata) i korelacijskom analizom da je step hop test imalo isti predmet mjerenja kao dva testa za procjenu agilnosti u odbojci (bočnim stepenicama i 9-3-6-3-9) s validiranim metričkim karakteristikama. Jednosmjerna analiza varijance pokazala je da nema značajnih inter-položajnih razlika u performansama SHT. Primjenom nezavisnog uzorka t-testa su pronađene značajne razlike između uspješnijih i manje uspješnih mladih odbojkaša na dodavač-udarač položaju. Na temelju dobivenih rezultata, SHT može se preporučiti u procesu identifikacije i selekcije mladih odbojkašica na dodavač-udarač položaju. Kako bi se poboljšala homogenost testa, igračima bi trebalo biti dopušteno više suđenja, a test bi trebao biti izmijenjen tako da je svaka promjena smjera kretanja pokrenuta od strane stopala suprotno od onoga koje je zadnji put staviljeno na pod u prethodnom pokretu.

Ključne riječi: *faktorska i pragmatična valjanost, pouzdanost, step hop test, odbojkaši, timski sport*

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