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WITHIN-SESSION RELIABILITY AND VALIDITY OF OVERHAND BALL THROW TEST TO EVALUATE POWER ABILITY IN JUNIOR TENNIS PLAYERS

KÁROLY DOBOS[1*], PÉTER JÁNOS TÓTH[2]

ABSTRACT. Introduction: Coaches should be able to estimate successfully different physical attributes of junior tennis player's performance such as power, in order to monitor players' progress and to design the most appropriate training program. However, this process requires reliable and valid field tests. **Objective:** Aim of this study was to examine absolute and relative reliability of overhand_ball throw (OBT) test within testing session and to investigate its validity. **Methods:** 257 Hungarian junior boy and girl tennis players (aged 11-17) separated into four groups, performed OBT and serve speed (SS) tests of standardised protocol. **Results:** Dependent sample t-test revealed no significant (p= 0.31-57>0.05) difference between test and retest sample means within testing session and magnitude of effect size (dz=0.1-0.5) were trivial for all groups. Furthermore, all groups had low typical percentage error (CV= 3-4 %), and standard error of measurement values was consistently low (SEM= 0.12-0.18). Within test-retest consistency illustrated strong relative reliability (ICC= 0.98-0.99). Moreover, significantly large to very large positive correlations were found between OBT and SS (r= 0.57-0.81; p<0.01) tests. The coefficient of determination indicated that OBT explained 32-65% of the SS for groups. **Conclusions:** These findings suggest that absolute and relative reliability of OBT test is high within testing session and validity of OBT test is acceptable for measuring power ability of flat serve execution in junior tennis players.

Keywords: *field based test, serve speed, power ability*

Introduction – Objective

Power is an ability that is associated with force and velocity of movement (Fernández-Fernández, Ulbricht & Ferrauti, 2014). This ability to generate and transfer force rapidly may be a key element in determining success in many ball games. The strokes of tennis can be most frequently characterised by power

[1] *Department of Combat Sports, University of Physical Education, Budapest, Hungary.*
[2] *Student of Master of Recreation Programme, University of Physical Education, Budapest, Hungary.*
** Corresponding author: doboskaresztenisz@gmail.com.*

execution. This power execution (that involves a stretch – shortening cycle muscle contraction) manifests itself through different high-speed strokes such as flat serve, which is the most dominant and important stroke in modern junior tennis as well (Fernandez-Fernandez, Ellenbecker, Sanz-Rivas, Ulbricht & Ferrauti, 2013; Kovalchik & Reid, 2017).

Junior tennis players are at the beginning of their careers and their physical attributes are in the developmental stage, therefore coaches should be able to estimate different physical attributes of junior tennis player's performance successfully such as power, in order to monitor the players' progress and to design the most appropriate training program. In the literature, several field-based tests were designed to estimate the power ability generated by the total body or the upper and lower extremities. These widely used field based tests performed by different equipment and protocol, include, counter movement jumps, depth jumps, repeated jumps, different push-up variations, chest, side and overhead medicine ball throws and tosses (Beckham et al., 2019; Buchheit, Spencer & Ahmaidi, 2010; Fernández-Fernández, Ulbricht & Ferrauti, 2014; Fernandez-Fernandez, Villarreal, Sanz-Rivas & Moya, 2016; Genevois, Frican, Creveaux, Hautier, & Rogowski, 2013; Harris et al., 2011; Markovic, Dizdar, Jukic & Cardinale, 2004; Sayers & Bishop, 2017; Zalleg et al., 2018). From these, medicine ball throw tests are the most common ones to measure power ability of upper extremities in junior tennis players. These tests involve integrated, multidirectional movements and specific attributions, so they well demonstrate the movement pattern demands of tennis strokes. Furthermore, several studies demonstrated that the results of medicine ball throw tests and medicine ball exercises are associated with stroke-speed in junior tennis players (Fernández-Fernández et al., 2014, 2016; Genevois et al., 2013). However, it should be noted, that these tests are executed with two hands. In other words, execution of these tests requires bilateral movement. We know that during the execution of a flat serve, tennis players only use their dominant arms (unilateral movement), so it may be a good idea to apply such field tests performed with one hand, for example the overhand_ball throw (OBT) test. Furthermore, our several studies (Dobos, 2011, 2018) have proved that OBT test seems to be suitable for measuring power ability of the flat serve in junior tennis players.

Reliability and validity are the two most important criteria to judge the quality of measurement (Hopkins, 2000). Reliability refers to reproducibility and repeatability of the test results within (test stability within one testing session) and between (test stability between two testing sessions) the test sessions. Validity expresses the test's ability to measures what is supposed to measure (Hopkins, 2000; Stockbrugger & Haennel, 2001). One part of the previously mentioned field tests has indicated good reliability and validity as well as that this information is available (Beckham et al., 2019; Buchheit et al., 2010; Harris et al., 2011, Markovic et al., 2004; Sayers & Bishop, 2017; Zalleg et al., 2018). However, reliability and validity values of tennis specific medicine ball throw and OBT tests are not readily available, especially for a wide range of junior tennis population.

Therefore, aim of this study was to examine the absolute and relative reliability of the OBT test within the testing session and to investigate the validity of the OBT test as a practical tennis specific field test for assessing the power ability of flat serve execution on a wide range junior tennis population comprising both genders and different age categories.

Methods

Participants

Altogether 257 (aged 11-18) Hungarian youth tennis players participated in the research (Table 1.). They played 25-60 matches per year and participated an average 8-14 h of combined training (i.e. on and off court) per week. Tennis players were divided into 4 groups (1. under 14 boys (U14); 2. under 14 girls (U14); 3. under 18 boys (U18); 4. under 18 girls (U18)), based on the criteria of the American Tennis Association (USTA) and Roetert and Ellenbecker (2007).

Table 1. Individual characteristics and serve speed of junior tennis players (n=257*)*

Group	Age	Body weight (kg)	Body height (cm)	SS (km/h)
U14 boys (n=92)	12.55±1.20	38.03±6.21	150.60±7.10	131.89±8.22
U18 boys (n=50)	16.13±1.21	67.18± 5.23	179.43±5.24	171.06±7.42
U14 girls (n=75)	12.65±1.19	32.60±4.76	146.40±8.22	122.50±7.88
U18 girls (n=40)	16.27±1.17	62.27±4.12	167.22±4.31	151.10±6.52

SS=serve speed

Procedures

One week before each testing session players had a meeting when both the players and the parents were informed in an oral and written form about the testing procedure and aim of the research, and declarations of consent were asked from the parents. In addition, the testing protocol (OBT and serve speed (SS) tests) was presented in order to show how to execute them properly.

Players could participate the testing session with valid medical certificate and consent of their parents. The ethical standards were in harmony with the principles of the Helsinki declaration (Harriss, MacSween & Atkinson, 2019).

To avoid the effect of tiredness, testing session was carried out outdoors, in the summer season, at the same time (late morning) and in optimal weather conditions (17-25 C degrees), 48 hours after a heavy training or match. Four players were measured at the same time and before testing session height and weight of the players were measured (Table 1.), then they executed a general and a specific warm-up of 10-15 minutes. Warm-up comprised aerobic-type running, general mobilizing and stabilizing exercises. Reliability and validity of the tests were examined (the order of which was as follows: OBT and SS test), during which players had two OBT and eight flat serve attempts. After the warm-up and between the tests, players had 5-minute passive resting time, between the OBT attempts they could rest for 4 minutes and between the serves for 25 seconds.

Neither the measuring equipment, nor the person carrying out the task was modified during the testing session.

Description of selected field tests

OBT (Figure 1.): Player stood in a forward straddle position behind the throw-line with the ball in the dominant arm, in front of the thigh. The preparatory phase comprised hip and trunk rotations. At the same time, the ball was swung backwards behind the back with flexed knees. After this phase, player began to extend the knees, turned hips forward and swung the dominant arm forward. At the point of release, legs were almost fully extended, trunk a little bit tilted, dominant arm abducted to trunk with elbow slightly bent, wrist and ball above the head. During the execution of the throw and release of the ball, the player was not allowed to touch or cross the throw-line. The aim was to throw the ball as far as possible. The distance from the throw-line to the point, where the ball landed was measured in m. Two trials and their averages were recorded and used for statistical analysis. To gain the validity of the OBT test the best result was used. Furthermore, at the OBT test, a 103-gram small (diameter 8 cm) ball and a calibrated tape-measurer (marked at every cm) were applied. Additional information can be found about this test in the Nadori et al. (2005) book.

SS test (Figure 1): the test was intended to measure the speed of the flat serve and the power ability of the chest, dominant hand and shoulder. The player served from the deuce (right) court and executed eight flat serves into the 180x180 cm target, located in the corner nearest to the respective T-line of the tennis court. The player was instructed to execute the flat serve with maximal speed. Only the correctly executed flat serves and the speed of those balls, landing within the target area were measured in km/h and the best result was used for later analysis. The radar instrument measuring the speed of the serve was located in the centre, 4 m behind the baseline, at a height covering the contact point of the serve. For the SS test, the "Stalker ATS II" (Applied Concept, Inc., Dallas) serve speed measurer (within ±3 km/h of accuracy and operating frequency: 34.7 GHz [Ka-Band] ± 50 MHz) and "Slazenger Ultra Vis" (53-56 gram and 6.5 diameter) balls were used. Before each testing session, the radar gun was calibrated in accordance with the manufacturer's specifications and new balls were used. Players used their own tennis racquets. The intertrial reliability for serve velocity was 3.2% and the ICC for this test was 0.91–0.94 as used in previous researches (Fernandez-Fernandez et al., 2013; Hornery, Farrow, Mujika & Young, 2007; Kovacs & Ellenbecker, 2011) Additional information can be found about this test and instrument ("Stalker ATS II" radar) in previous researches (Ferrauti & Bastiaens, 2007; Fernández-Fernández et al., 2014, 2016).

Figure 1. Serve speed and overhand ball throw tests

Statistical analysis

First, normality of distributions was controlled with the Kolmogorov-Smirnov test. Absolute reliability was evaluated by dependent sample t-test to determine the differences between the test/retest sample means within the testing session. Effect size (ES) was estimated by Cohen's d test to assess the meaningfulness of difference. The magnitude of the ES was considered trivial (<0.20=trivial, 0.2-0.59=small, 0.6-1.19=moderate, 1.2-2.0=large, and>2.00=very large) (Hopkins, 2000). Coefficient of variance (CV) was calculated. Less than 10% of CV was considered an acceptable absolute reliability (Atkinson & Nevill, 1998; Clark, Bryant & Reaburn, 2006). Moreover, standard error of measurement (SEM) was calculated to assess the perfect absolute reliability of the OBT test. Furthermore, the intraclass correlation coefficients (ICC) were computed to determine relative reliability (Hopkins, Marshall, Batterham & Hanin, 2009; Weir, 2005). ICC value equal to or above 0.70 was considered acceptable (Hopkins, 2004; Weir, 2005).

To evaluate validity of the OBT test, the Pearson correlation coefficients (r), gained from the best between OBT and SS values were calculated. The magnitude of correlation was determined according to Hopkins (r<0.1=trivial; 0.1-0.3=small; 0.3-0.5=moderate; 0.5-0.7=large; 0.7-0.9=very large>0.9=nearly perfect) (Hopkins, 2000).

Finally, simple linear regression analyses were separately used for each group, in order to calculate coefficient of determination (R^2) and set up regression models. Level of significance for all statistical tests was accepted at ($p<0.05$) and statistical analysis of the data was carried out with the SPSS 21.0 software.

Results

The Kolmogorov-Smirnov test found that all data were normally distributed ($p> 0.05$) therefore the mean and the standard deviations were calculated.

Dependent sample t-test revealed no significant difference between test and retest sample means within testing session and the magnitude of the ES were trivial for all groups (Table 2.). All CV values of each group are below the accepted threshold of 10% and SEM values are low. Moreover, the ICC values for each group were higher than the acceptable threshold value 0.70 (Table 2.).

Significantly large to very large positive correlations were found between the OBT and SS (Table 3.) tests. Based on the linear regression analyses of the OBT explained 32-65% of the variance of SS for groups (Table 4).

Table 2. Within session absolute and relative reliability of overhand ball throw test for junior boy and girl tennis players (n=257)

Groups	Tests (m)	Retest (m)	p	dz	Mean±SD	SEM	CV%	ICC
U14 boys (n=92)	31.63±1.30	31.66±1.22	0.44	0.01	31.64±1.26	0.12	3	0.99
U18 boys (n=50)	46.33±1.88	46.44±1.84	0.57	0.05	46.38±1.86	0.18	4	0.99
U14 girls (n=75)	24.83±1.21	24.89±1.22	0.56	0.05	24.86±1.21	0.17	4	0.98
U18 girls (n=40)	30.50±1.29	30.55±1.27	0.31	0.04	30.52±1.28	0.12	4	0.99

dz=Cohen's d for dependent sample t-test; SD=standard deviation, SEM=Standard error of measurement; CV=Coefficient of variation; ICC=Intraclass Correlation Coefficient

Table 3. Pearson's correlation coefficients between overhand ball throw and serve speed test for junior boy and girl tennis players (n=257).

	OBT and SS U14 boys (n=92)	OBT and SS U18 boys (n=50)	OBT and SS U14 girls (n=75)	OBT and SS U18 girls (n=40)
r (95 % CI)	*0.81 (0.73-0.87)	*0.57 (0.35-0.75)	*0.79 (0.70-0.85)	*0.78 (0,64-0,87)

r=correlation coefficient; CI=confidence interval; OBT=_overhand ball throw; SS=serve speed *denotes significant correlations at *p<0.05

Table 4. Simple linear regression analysis of junior tennis players (n=257)

Group		B	SEM	β	t	p
U14 boys (n:92)	Intercept	57.69	5.64		10.22	<.001
	overhand ball throw	2.34	0.17	0.81	13.37	<.001
U18 boys (n:50)	Intercept	119.56	5.78		10.77	<.001
	overhand ball throw	1.11	0.23	0.56	4.69	<.001
U14 girls (n:75)	Intercept	53.63	6.48		8.27	<.001
	overhand ball throw	2.76	0.25	0.78	10.85	<.001
U18 girls (n:40)	Intercept	103.34	6.33		16.32	<.001
	overhand ball throw	1.56	0.20	0.78	7.69	<.001

Dependent variables: serve speed
(U14 boys) R^2=0.65; adj R^2=0.65; F (1-90)=178.95; p<0.05
(U18 boys) R^2=0.32; adj R^2=0.31; F (1-48)=22.02; p<0.05
(U14 girls) R^2=0.62; adj R^2=0.62; F (1-73)=117.75; p<0.05
(U18 girls) R^2=0.60; adj R^2=0.59; F (1-38)=59.26; p<0.05

Discussion

Aim of the present study was to analyse the absolute and relative reliability within the testing session and the validity of the OBT test in a wide range junior tennis population. Main finding of the present study revealed that the absolute and relative reliability of the OBT test was high within the testing sessions and the validity of the OBT test was acceptable for measuring power ability in the flat serve execution.

Within session reliability of OBT test

In all groups and genders the OBT test had typically low percentage error (CV3-4%) and the SEM values were also low consistently (0.12-0.18). Furthermore, the test-retest consistency showed strong reliability (ICC=0.98-0.99) and there was no difference between test and retest sample means, ES were trivial (dz=0.1-0.5). Thus, both measurements showed almost similar results, the errors were also low. Some values differed from the average in a very small percentage; they showed a positive direction and a significant correlation ($p<0.05$). As a result, it can be said that the repeated testing was not influenced by experience, practice and tiredness. Therefore, absolute and relative reliability of the OBT test within the testing session is acceptable. Moreover, our results trend is consistent with the recent previous tennis specific studies; Fernandez- Fernandez et al., (2016) and Kramer, Huijgen, Elferink-Gemser and Visscher (2016) have reported acceptable ICC values (0.86-0.99) at overhead medicine ball throw test executed with two hands in junior tennis players. In addition, reliability results of the present study are also in line with other previous investigations, which have frequently showed high absolute (CV=2.6-5.3%; SEM=0.12-0.012) and relative reliability (ICC=0.87-0.99) in medicine ball throw test performed with two hands from sitting and standing position in different samples (Beckham et al., 2019; Harris et al., 2011 Sayers & Bishop, 2017; Stockbrugger & Haennel, 2001).

Validity of the OBT test

The best result of the OBT showed a significantly large to very large positive correlation (0.57-0.81) of the best value of SS in each group ($p<0.05$). The results indicated that the power manifested in the OBT could be well transferred to the movement pattern of the flat serve. Thus, the main groups of muscles participating in the flat serve mostly control the OBT movement. For example: movement of the dominant arm and shoulder, as well as the chest muscles (the pectorals), play a key role in the acceleration of tennis racket or ball (Fleisig, Nicholls, Elliott & Escamilla, 2003; Roetert & Kovacs, 2011). At the point of release in the OBT test, the abduction degree of the dominant shoulder (100°±10°) is similar to the contact point of the flat serve (Reid, Elliott & Alderson, 2008). Furthermore, the direction vector of force in both movement is decisively horizontal and the execution of the movement (using dominant hand) is unilateral from point of view of upper body. Moreover, this result was in line with the previous research, demonstrating that medicine ball exercise and distance of medicine ball throw executed with one and two hands correlates to the strokes speed (r=0.79-0.87) in junior tennis players (Dobos, 2011, 2018; Fernandez-Fernandez et al., 2013; Genevois et al., 2013). In addition, based on the F test and on its related significance ($p<0.05$) level and on low SEM, it can be said that the regression model is suitable to explain the dependent variable.

Regarding the coefficient of determination (R^2) in the U18 boy group the best result of OBT explained 32% of the variance of the best value of SS that is smaller than that of the other groups (60-65%). The possible explanation is that besides the previously mentioned similarities, the biomechanical features and specialities of racket handling can much better contribute to the technical execution in the older boy group. This suggestion was confirmed by Reid, Giblin and Whiteside (2015), and Wagner et al. (2014), who found that during the acceleration phase of the peak trunk twist and elbow extension, velocities were significantly higher in the OBT, yet the peak shoulder internal rotation and the angular velocities of the wrist flexion were significantly greater in the flat serve. However, in spite of the mechanical differences, the OBT test probably could be more suitable for assessing the power ability of the flat serve execution in contrast to medicine ball throw executed with two hands, because the OBT test well simulates those physical attributes (explosive force generation) and mechanical components (unilateral movement, decisively horizontal force exertion, role of similar muscle groups) manifested during the flat serve motion (Wagner et al., 2014). Therefore, according to the authors' opinion, the execution of OBT might form a proper basis of the serving motion. Furthermore, based on the large to very large significant positive correlation coefficient values, the OBT test is considered valid.

A limit of this study was that we analysed the absolute and relative reliability of the OBT test only within the testing session, therefore further investigation is needed to examine it between the testing sessions. However, to the author's best knowledge it was the first study to detect OBT test reliability within the testing session and its validity in a wide-range of junior tennis population (U14-U18 boys and girls, n=257) to allow for the sport science practitioners and coaches to get a real, available information about it.

Conclusions

The OBT test is reliable within the testing session and is a valid test to assess power ability in the flat serve execution. The serve speed is determined by the ability of the lower extremities, chest, dominant hand and shoulder muscles to generate power actions (Kovacs & Ellenbecker, 2011). The OBT test well simulated these explosive force generations especially in the chest, dominant hand and shoulder muscles, therefore the OBT test is suggested as a tennis-specific field based test that can be part of tennis players' general preparation and be used as a tool of power performance diagnostics in junior tennis population.

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