Relationship between serve speed and performance of different motor test results

Az adogatás indítási sebességének kapcsolata a különböző motorikus teszteken nyújtott teljesítményekkel

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Abstract

The continuous monitoring and the development of the reactive strength of junior tennis players require standardized field tests and training exercises that model force and movement pattern of serve execution well. The aim of our research was to examine the correlation of the one-hand overhead throw (OBT) or two-hand overhead medicine ball throw (OMBT) with serve speed (SS) to aid a more effective performance improvement; furthermore, to estimate SS, using simple field tests based on regression models. 142 male (age: 15.55±1.20) and 115 female (age: 15.65±1.19) tennis players participated in the research; they executed three different (OBT, OMBT and SS) field tests. To find the correlation between performance at the field tests and the SS, the parametric Pearson's correlation analysis was used. Furthermore, simple linear regression analysis was used originating from the collinearity problem, to be able to analyse the effects of the predictor variables (reactive strength during the OBT and OMBT tests) on the dependent variable (SS). Significantly large and very large positive correlations were observed between SS and different ball throws (OBT, OMBT) in both genders (r=0.67-0.89; p<0.05). Coefficient of determination (R^2) values indicated that distance of OBT explained 68-80% of the variance of SS in both genders. Moreover, distance of OMBT explained 45-78% of the variance of SS in both genders. The results showed that motor tests measuring reactive strength of unilateral and bilateral movement forms can be well applied for monitoring the reactive strength of tennis players and can be used well during the preparation period as a means of training.

Keywords: field test, reactive strength, serve speed, tennis

Összefoglaló

A korosztályos teniszező reaktív erejének folyamatos monitorozásához és fejlesztéshez olyan sztenderdizált pályatesztekre és edzésgyakorlatokra van szükség, amelyek jól modellezik az adogatás végrehajtása során történő erőkifejtéseket és mozgás-mintázatokat. Vizsgálatunk célja az volt, hogy megvizsgáljuk az egykezes felső dobás (OBT) és a kétkezes tömöttlabda dobás (OMBT) tesztek kapcsolatát az adogatás sebességével (SS) abból a célból, hogy elősegítsük a hatékonyabb teljesítményfokozást. Továbbá, hogy ezen egyszerű pályatesztek alkalmazásával megbecsüljük az adogatás sebességét a regressziós modell segítségével. A vizsgálatban 142 fiú (15,55±1,20 év) és 115 leány teniszező (15,65±1,19 év) vett részt, akik a mérés során háromféle (OBT, OMBT és SS tesztek) pályatesztet hajtottak végre. A pályateszteken mutatott teljesítmények és az SS kapcsolatának feltárásához paraméteres Pearson-féle korreláció-analízist alkalmaztunk. Továbbá, a kollenaritás problémájából fakadóan egyszerű lineáris regresszió-analízist használtunk, hogy az adott prediktor változók (OBT and OMBT teszteken mutatott reaktív erőkifejtések) hatását a függő változóra (SS) tisztán elemezhessük. Mindkét nem esetében az OBT és OMBT teszteken mutatott reaktív erőkifejtések szignifikáns, nagyon erős korrelációs (r=0,67-0,89; p<0,05) kapcsolatot mutattak a SS-vel (p<0,05). Az OBT teszten mutatott reaktív erőkifejtés 68-80%-ban játszik szerepet a SS-ben. Az OMBT teszteken mutatott reaktív erőkifejtés pedig 45-78%-ban játszik szerepet a SS-ben. Az eredmé-

nyek azt mutatták, hogy az uni- és bilaterális mozgásformákat tartalmazó reaktív erőt mérő motorikus tesztek egyformán jól alkalmazhatók a teniszezők reaktív erejének monitorozására, valamint a felkészítés folyamatában edzéseszközként is jól alkalmazhatók.

Kulcsszavak: adogatás sebesség, pályateszt, reaktív erő, tenisz

Introduction

Tennis is a technically and tactically dominated ball game that requires very high levels of motor abilities already at the age of junior tennis players (Dobos, 2011, 2018a; Dobos and Nagykáldi, 2016, 2017). It is a common viewpoint of professionals that from among motor abilities, it is reactive strength (special motor ability Nádori, 1991) that has an outstanding role in reaching a high-level competitive performance. Reactive strength is a force exertion, during which muscles first lengthen (eccentric contraction), then pre-stretch in the active state, then suddenly shorten (explosive concentric contraction) (Váczi, 2015). This force exertion can be observed during the execution of the serve, which is the most important and the most dominant stroke in tennis (Fernandez-Fernandez et al., 2013). Besides all these, it is also an ability of elite junior tennis players to generate high-speed balls that has become one of the fundamentals of successful competition performance (Cross and Pollard, 2009; Dobos et al., 2021). That is why, in our opinion, continuous monitoring of reactive strength in junior tennis players and its development should have a key role during the preparation and competition period.

However, all these require standardized field tests and training exercises that model the proper force and movement patterns used during the execution of serve well. It means that effective performance improvement cannot be reached without the knowledge of its proper active movement patterns verified by scientific research, and the knowledge of how to apply proper training exercises and field tests adapted to it (Benkovics, 2019).

Several scientifically accepted field tests involving different protocols and means measure reactive strength (standing long jump, different take-offs, depth jumps, series of jumps, medicine ball throws, puts, etc.) are at our disposal. (Beckham et al., 2019; Buchheit et al., 2010; Fernandez-Fernandez et al., 2014, 2016; Genevois et al., 2013; Harris et al., 2011; Markovic et al., 2004; Quinn and Reid, 2003; Roetert and Ellenbecker 2007; Sayers and Bishop, 2017; Ulbricht et al., 2013; Zalleg et al., 2018).

Based on special literature and suggestions, throwing tests (involving different throws, putts, heaves) are the most frequently applied field tests to monitor the reactive strength of junior tennis players, as they model the stretching-shortening based contraction types (reactive strength) and tennis-specific movement patterns well. Several papers have proven (Dobos, 2011, 2018a; Dobos and Nagykáldi, 2017; Dobos and Tóth, 2021; Fernandez-Fernandez et al., 2014, 2016; Ulbricht et al., 2013) correlation (relation) of different above-head unilateral and bilateral (one and two-sided) throws with serve speed (SS). According to our supposition, the field test of unilateral movement, the one-hand overhead ball throw (OBT) is more suitable for monitoring reactive strength during serve than the two-hand overhead medicine ball throw (OMBT), because during the execution of the serve, the role of the dominant-side upper limb is unambiguous.

Therefore, the aim of the research was to examine the correlation of OBT or OMBT with SS to aid a more effective performance improvement, as well as to estimate the SS, using simple field tests based on regression models.

Material and methods

Participants

Altogether 257 junior tennis players of both sexes (boys=142, girls=115) voluntarily took part in this study (**Table 1.**). All of them were aged 11-17 and had practised tennis for more than a minimum of 4 years. They played 30-60 matches per year and participated an average 8-14 h of combined training (i.e. on and off court) per week with a focus on the development of on-court technical/tactical tennis behaviour, as well as an improvement of tennis specific physical abilities (balance, reactive strength, agility and multidirectional speed, aerobic and anaerobic endurance, flexibility). All players possessed correct serve and throws techniques. Furthermore, all players were nationally ranked in the top 50 players for their respective age group and 20 of them were members of national teams. Two groups were formed (boys/girls) for this study.

Procedures

One week prior to each testing a one-hour familiarization session was conducted where the testing protocol (OBT, OMBT and SS tests) was presented

Table 1. Individual characteristics of junior tennis players
1. táblázat. Korosztályos teniszezők alapstatisztikai mutatói (n=257)

Group (Csoport)	Age (Életkor) év	Body weight (Testtömeg) kg	Body height (Testmagasság) cm
Boys (fiúk) (n=142) Mean±SD (Átlag±szórás)	15.55±1.20	66.19±8.05	177.68±7.10
Girls (leányok)(n=115) Mean±SD (Átlag±szórás)	15.65±1.19	61.92±7.11	168.40±8.22

Figure 1. Serve speed and overhead ball throw tests
1. ábra. Adogatás sebesség és egykezes felső dobás teszt (Dobos and Nagykáldi, 2017; Dobos, 2018b)

in order to show how to execute them properly and to familiarize participants with the applied field tests. In addition, during the familiarization session players and parents were informed in oral and written form about the aim of the study, and declarations of consent were asked from the parents.

Testing sessions were conducted outdoors (temperature 17-25 C), in spring and autumn season in early afternoon (from 14 to 16 pm). To avoid the effect of tiredness, testing sessions were carried out 48 hours after a heavy training or match. During 1 occasion, 4 players were measured. Before each testing, the player's age, body height and body mass were recorded. Each testing sessions started with a standardized warm-up of aerobic-type running, general mobilizing, stabilizing exercises and two trials on each test. Afterward the three standardized field tests were performed, during which the players had 3 OBT, 3 OMBT and 8 flat serve trials. Four-minute passive rests were provided after the warm-up and between the tests, and 2 minutes of rest were allowed in OBT and OMBT tests among the trials. In the SS test, the resting time was 25 seconds. Furthermore, neither the measuring equipment, nor the persons carrying out the work were modified during the testing session.

The study was approved by the Ethical Committee and conformed to the recommendations of Declaration of Helsinki (Harriss et al., 2019).

Description and characteristics of selected field tests

OBT (**Figure 1.**): the test was intended to measure the unilateral reactive strength of the upper body. The player stood in a forward straddle position behind the throw-line with the ball in the dominant arm, in front of the thigh. The countermovement phase consisted of the player's rotating the hip and trunk. Then the ball was swung backwards behind the back with flexed knees. Then the player began to extend the knees, turned hips forward and swung the dominant arm forward. At the

Figure 2. Overhead medicine ball throw test
2. ábra. Kétkezes tömöttlabda dobás (Dobos, 2018b)

Table 2. Descriptive statistics of the assessed variables
2. táblázat. A mért változók leíró statisztikai adatai (n=257)

	Serve speed (SS) (Adogatás sebesség) km/h		Overhand ball throw (OBT) (Egykezes felső dobás) m		Overhead medicine ball throw (OMBT) (Kétkezes tömött labda dobás) m	
	Boys (Fiúk)	Girls (Leányok)	Boys (Fiúk)	Girls (Leányok)	Boys (Fiúk)	Girls (Leányok)
Number (Elemszám)	142	115	142	115	142	115
Mean±SD (Átlag±szórás)	146.42±25.59	133.55±21.45	37.45±9.59	27.33±4.44	10.62±3.38	9.33±2.63

point of release, legs were almost fully extended, trunk a little bit tilted, dominant arm abducted to trunk, dominant arm's elbow slightly bent, wrist and ball above the head. During the execution of the test 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 meters (Dobos and Tóth, 2021). The best results were used for statistical analysis. At the OBT test, an 80-gram small (diameter 8 cm) ball and a calibrated tape-measurer (marked at every cm) were applied.

OMBT (**Figure 2.**): the test was intended to measure the bilateral reactive strength of the upper body. The player stood behind the line in forward straddle with the ball above the head in both hands. During gaining momentum, the medicine ball was brought back behind the head, knees were flexed and trunk extended. Then the player began to extend the knees, flexed the trunk and swung the arm forward. At the point of release, legs and trunk were almost fully extended, elbow extended, wrist and ball above the head. During the execution and after the release, the player was not allowed to touch or cross the line. The aim was to throw it as far as possible, with the distance being measured in meters (Dobos et al., 2021). The best result recorded was used for statistical analysis. At the OMBT test, a 1 kg medicine ball and a calibrated tape-measurer (marked at every cm) were used.

SS (**Figure 1.**): the test was intended to measure the serve speed of the flat serve and the neuromuscular power ability of the total body. During the test the players used their own tennis racquets (aiding the movement execution at the highest level (Fernandez-Fernandez et al., 2013; Ulbricht et al., 2013), and executed 8 flat serves from the baseline (right-handed from the right side and left-handed from the left side) 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. The highest speed ball landing in the target area was used later for statistical analysis.

The Stalker ATS II" radar instrument (within±3 km/h of accuracy and operating frequency: 34.7 GHz [Ka-Band] ± 50 MHz) was used for measuring the serve speed located in the centre, 4 m behind the baseline, at a height covering the contact point of the flat serve. Furthermore, new 53-56 gram and 6.5 diameter "Slazenger Ultra Vis" balls were used.

Before each testing session, the Stalker ATS II" radar gun was calibrated in accordance with the manufacturer's specifications.

Additional information can be found about these selected tests (OBT, OMBT and SS) and instruments ("Stalker ATS II" radar) in previous research studies (Dobos 2018b; Dobos et al., 2021; Dobos and Tóth, 2021; Fernandez-Fernandez et al., 2013, 2014, 2016; Nádori et al., 2005; Quinn and Reid, 2003; Roetert and Ellenbecker 2007, Ulbricht et al., 2013).

Table 3. Pearson's correlation coefficients of junior tennis players
3. táblázat. Pearson-féle korrelációs koefficiens *p<0,05 (n=257)

Variables (Változók)			Pearson's correlation coefficients
Boys (Fiúk)	Serve speed (SS) (Adogatás sebesség) km/h	Overhand ball throw (OBT) (Egykezes felső dobás) m	0,89*
	Serve speed (SS) (Adogatás sebesség) km/h	Overhead medicine ball throw (OMBT) (Kétkezes tömött labda dobás) m	0,88*
	Overhand ball throw (OBT) (Egykezes felső dobás) m	Overhead medicine ball throw (OMBT) (Kétkezes tömött labda dobás) m	0,89*
Girls (Leányok)	Serve speed (SS) (Adogatás sebesség) km/h	Overhand ball throw (OBT) (Egykezes felső dobás) m	0,82*
	Serve speed (SS) (Adogatás sebesség) km/h	Overhead medicine ball throw (OMBT) (Kétkezes tömött labda dobás) m	0,67*
	Overhand ball throw (OBT) (Egykezes felső dobás) m	Overhead medicine ball throw (OMBT) (Kétkezes tömött labda dobás) m	0,62*

Table 4. Result of simple linear regression analysis of junior boy tennis players
4. táblázat. Az egyszerű lineáris regresszióselemzés eredményei (fiúk) (n=115)

Model	Regression Coefficient	Standard error of measurements	Standardized regression coefficiant	*t*	p
	B	SEM	β		
	(Regressziós együttható)	(Sztenderd hiba)	(Sztenderdizált regressziós együttható)		
Intercept Overhand ball throw (OBT) Egykezes felső dobás (m)	57.15	3.88	0.89	14.71	<0.05
	2.38	0.1		23.72	<0.05
1. modell R^2=0.80 adj R^2=0.79 F (1-141)=562.89 p<0.05					
Intercept Overhead medicine ball throw (OMBT) Kétkezes tömött labda dobás (m)	75,07	3,29	0.88	22.81	<0.05
	6.71	0.29		22.74	<0.05
2. modell R^2=0.78 adj R^2=0.78 F (1-141)=517.36 p<0.05					

Legends: R^2=coefficient of determination/determinációs együttható, adj. R^2=adjustment coefficient of determination (módosított determinációs együttható, t=t-test (*t*-próba), F=F-test (F-próba)

Statistical analysis

First, normality of distributions was controlled with using the Kolmogorov-Smirnov test. The distribution for each variable was normal (0.44-0.77; p>0.05), therefore the mean and the standard deviations were calculated, and parametric statistical test (Pearson correlation coefficients) was applied.

The Pearson correlation coefficients (r) were calculated to identify measured variables (unilateral and bilateral reactive strength of the upper body) related to SS and to reveal correlation among the (independent or predictor) variables for each group. The magnitude of correlation was classified according to Hopkins (2000) (trivial=0-0.1; small=0.1-0.3; moderate=0.3-0.5; large=0.5-0.7; very large=0.7-0.9; almost perfect=0.9 and perfect=1.0). Finally, a simple regression model was separately used for each group in order to calculate coefficient of determination (R^2) and set up regression models. Significance was established at p<0.05 and data analyses were performed with the SPSS 21.0 software.

Results

Significantly large and very large positive correlations were observed between the SS and the different ball throws (OBT, OMBT) for each group (r=0.67-0.89; p<0.05). Between the predictor variables (OBT, OMBT tests) large and very large positive correlations (r=0.62-0.89; p<0.05) were also monitored (collinearity problem) therefore single regression analysis was used for each group to be able to clearly predict the rate of effect on the outcome (dependent) variables. The R^2 values indicated that distance of OBT explained 68-80% of the variance of SS in each group (**Table 3. 4. 5.**). Moreover, distance of OMBT explained 45-78% of the

Table 5. Result of simple linear regression analysis of junior girl tennis players
5. táblázat. Az egyszerű lineáris regresszióselemzés eredményei (leányok) (n=115)

Model	Regression Coefficient	Standard error of measurements	Standardized regression coefficiant	*t*	p
	B	SEM	β		
	(Regressziós együttható)	(Sztenderd hiba)	(Sztenderdizált regressziós együttható)		
Intercept	53.22	5,2	0.82	10,21	<0.05
Overhand ball throw (OBT) (Egykezes felső dobás) m					
	2.93	0.18		15.79	<0.05
1. modell R^2=0.68 adj R^2=0.68 F (1-114)=249.37 p<0.05					
Intercept	82,7	5.39	0.67	15.33	<0.05
Overhead medicine ball throw (OMBT) (Kétkezes tömött labda dobás) m					
	5.49	0.56		9,8	<0.05
2. modell R^2=0.45 adj R^2=0.45 F (1-114)=96.03 p<0.05					

Legends: R2=coefficient of determination/determinációs együttható, adj. R2=adjustment coefficient of determination (módosított determinációs együttható, t=t-test (t-próba), F=F-test (F-próba)

variance of SS in each group. Finally, based on single linear regression analyses the following regression models (equations) were set up:

(boys) $SS_{(km/h)}=(b_0)\ 57.15+(b_1)\ 2.38\ {*}OBT_{(m)}$

(boys) $SS_{(km/h)}=(b_0)\ 75.07+(b_1)\ 6.71\ {*}OMBT_{(m)}$

(girls) $SS_{(km/h)}=(b_0)\ 53.22+(b_1)\ 2.93\ {*}OBT_{(m)}$

(girls) $SS_{(km/h)}=(b_0)\ 82.70+(b_1)\ 5.49\ {*}OMBT_{(m)}$

Where:

SS: serve speed=b_0: intercept + b_1: slope* OBT: overhead ball throw

SS: serve speed=b_0: intercept + b_1: slope* OMBT: overhead ball throw

Discussion and conclusions

The measured data confirmed the international literary suggestions and the previous research results in both genders (Dobos, 2011, 2018a; Dobos and Tóth, 2021; Fernandez-Fernandez et al., 2014, 2016; Ulbricht et al., 2013). But our supposition that the field test of unilateral movement origin (OBT) is more suitable to monitor reactive strength manifested during serve execution than the OMBT test, has not been verified.

The r and R^2 values well represent the findings according to which the coordination pattern of serve is built up on the stretching-shortening contraction (Reid et al., 2008, 2015; Roetert and Kovács, 2011). Furthermore, both movement is extremely complex, in which each segment of the kinetic chain has a determining role and their timing of join built on each other is critical in reaching the proper speed of movement. That is why the manifested reactive strength can be well-transformed into the movement pattern of the serve in both cases. We suppose that with the application of throwing tests and exercises without the use of trunk and leg muscles (e.g. one hand and two hand overhead throws from lying and sitting position), the differences existing between the unilateral and bilateral movement types related to SS may be better observed.

The segments (of dominant shoulder) and muscles (pectoralis major and minor, subscapularis, latissimus dorsi, serratus anterior, forearm pronators, wrist flexors of the dominant side) would much better aid those movement patterns that play role in the final speeding-up of the racquet. Beside all these, applying throwing tests and throwing exercises at a target is considerable, as we are talking about hitting the ball to a target area in tennis (Rigler, 2004).

It is important to mention the parameters of the tennis racquets (mass, stiffness), the elastic characteristics of the racket strings, the internal pressure of the ball and the actual state of its surface, as they also play role in the SS (Elliott, 2003). However, the higher speed of the ball stemming from the strings-elasticity is only 1 or 2% (Elliott, 2003) and all players used new balls uniformly and used their own tennis racquets, ensuring the highest movement execution during the testing process. That is why the gained data have proven (we have deducted from the results) that any of the motor tests of unilateral and bilateral (OBT and OMBT tests) origin applied in the study can be used to monitor the reactive strength manifested in the execution of the serve and they can be well-applied as a means of training. These unilateral and bilateral throws (OBT and OMBT) are important in developing the proper SS (Dobos and Nagykáldi 2017; Dobos and Tóth 2021; Dobos et al., 2021; Fernandez-Fernandez et al., 2013, 2016; Ulbricht et al., 2013) and special consideration given to these simple throwing forms can help in the learning and perfecting process of the serve. Therefore, combined special trainings which contain OBT and OMBT simple throws during the learning and practising process of serve are recommended. However, carrying out further research on the throwing types executed from different starting positions at target areas and their relation to the SS would be necessary.

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