

STRENGTH VALUES OF SHOULDER INTERNAL AND EXTERNAL ROTATORS IN JUNIOR TENNIS PLAYERS

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Abstract:

Character of modern tennis game has become in the last decade significantly more dynamic, fast and powerful, which puts a high strain to joint and muscular system. The aim of this research was to establish strength level of external and internal shoulder rotators, and to compare the competitive tennis players group of boys (TEN, n=10, aged 12-14 years) and boys who did not perform any sport activity at a competitive level (CS, n=10, aged 12-14 years) as well as to assess lateral differences in both groups. Using isokinetic dynamometry (Humac Norm CSMI Stoughton, MA, USA), we tested strength level of external and internal shoulder rotators (at 180°/s, 300°/s). The TEN and CS group are comparable from the aspects of age, body height and body weight. Comparison of isokinetic strength values in the TEN and CS groups proved a significantly higher strength level of external and internal rotators in both (dominant and non-dominant) extremities for the TEN group. The lateral difference assessment proved the insignificant difference in external and the significant difference in internal rotators in the TEN group, and the insignificant difference in both the external and internal rotators in the CS group. A lower strength level was found in the internal rotators in comparison with the external rotators in both groups (for both the dominant and non-dominant extremity), whereas in the TEN group lower differences between the external and internal rotators of the dominant extremity were proved. Although research on adult highly skilled tennis players has indicated a higher strength level of the upper extremity internal rotators, this was not pronounced in the TEN group. An ideal external/internal rotators' ratio in adult players is considered within the interval of 66-75%. Significantly higher values obtained in the TEN group might be attributed to a younger age and also a lower performance level. It can be said that the level of isokinetic strength in the TEN group is significantly higher than in the CS group due to the influence of a long-term game and training load.

Key words: *isokinetic dynamometry, glenohumeral joint, muscular dysbalances, prediction of injury*

Introduction

Character of modern tennis game has become in the last decade significantly more dynamic faster and powerful, which is influenced by new technologies (racquets and strings), but first and foremost by enhanced fitness level of players. In modern competitive game many strokes from open positions are used, which puts a great strength demand on players and thus a high strain on joint and muscular system (Ferrauti, Maier, & Weber, 2014; Roetert & Kovacs, 2011; Zháněl, Vaverka, & Černošek, 2000; Zháněl, et al., 2015). Turner and Dent (1996) state that contemporary tennis game is characterized by an effort to maximize ball velocity; in fact, the velocity of serve today reaches more than 220 km/h. Ellenbecker, Roetert, Bailie, Davies, and

Brown (2002), Sonnery-Cottet, Edwards, Noel, and Walch (2002) explain that the playing arm, moving in internal rotation during a serve, reaches angular velocities between 1074°/s and 2500°/s. Elliott, Fleisig, Nicholls, and Escamilia (2003) consider that the serve is the most demanding stroke in tennis due to high activity of shoulder muscles. As Vodička, Pieter, Reguli, and Zvonař (2016) contend, with respect to asymmetric character of strain the human body is exposed to in number of sports, muscular dysbalances might occur, especially in the upper extremities, and might lead to injury incidences. Ellenbecker (1995) points out to the fact that up to 10-30% of junior players have experienced a shoulder injury which might be caused by asymmetry of shoulder muscles. A number of studies aiming to diagnose strength values in tennis players

by the isokinetic dynamometry method (Chandler, Kibler, Stracener, Ziegler, & Pace 1992; Ellenbecker, 1991, 1992, 1995; Ellenbecker & Roetert, 2003) proved significant muscular dysbalances between the internal and external shoulder rotators in the dominant (playing) extremity. Authors concluded that the strain connected with specific tennis game operations led to a significant strength development of the internal shoulder rotators in the playing extremity to the detriment of their complementary muscle groups – external rotators. As Travell, Simons and Simons (1999) and Andrews and Wilk (1994) claim, the primary function of the external shoulder rotators is to ensure stabilization of the head of the humerus in the glenoid well of the shoulder. The external rotators also enhance a slow down movement of the playing arm during the final phase of tennis serve. As Matsen, Fu and Hawkins (1993) add, in comparison with large internal rotator muscles, the external rotators, which ensure fundamental stabilizing function of the shoulder, have a comparatively small muscle mass volume around the shoulder joint, which has a negative influence on their strength-endurance ability. Chandler et al. (1992) continue that the ideal strength ratio between the internal and external shoulder rotators is of crucial importance for preserving physiological and biomechanical function of the shoulder joint. Insufficient development of external rotators' strength, accompanied with an excessive development of internal rotators' strength, might lead to inability of the external rotators to cope with the burden and, consequently, lead to shoulder injuries (Cook, Gray, Savinar-Nogue, & Medeiros, 1987; Kibler, McQueen, & Uhl, 1988). An ideal strength ratio between the external and internal shoulder rotators (ER/IR ratio) in adult elite tennis players during isokinetic testing is recommended to be 66%-75%, which value ensures adequate muscular balance to prevent injury incidence (Chandler, et al., 1992; Codine, Bernard, Pocholle, Benaim, & Brun, 1997; Ellenbecker & Roeterert, 2003). Bilateral comparison of tennis players' strength indicates significantly higher strength of the internal rotators of the dominant extremity without lateral differences in external rotators' strength and thus lower ER/IR ratio in the playing limb. In elite, well-trained tennis players, a ratio of 1:2 was proved between the external and internal shoulder rotators (ER/IR), which related to the fact that the internal rotators were twice as strong as the external rotators. Such a high level of muscular dysbalance might lead to injury or sub-optimal performance (Ellenbecker & Roetert, 2002, 2003).

With respect to the muscular dysbalance found in tennis players described above, it is essential, in order to increase their performance and prevent possible injury, to put emphasis on the elimination of muscular dysbalances. Great attention should

be paid to the external shoulder rotators, which are often underdeveloped in tennis players, simply due to the lack of their stimulation and insufficient strengthening. To support muscle balance and thus probably prevent injuries, it is very important to include complementary exercises into the elite tennis players' training plan. Importance of preventive intervention programmes focusing on the rotator cuff and shoulder blade muscles is confirmed by numerous significant studies (Ellenbecker & Cools, 2010; Ellenbecker, et al., 2002; Kibler, Sciascia, Uhl, Tambay, & Cunningham, 2008).

The aim of the research was to determine strength level of the internal and external shoulder rotators and to assess lateral differences in junior elite tennis players in comparison with a control group of boys of the same age who did not perform any sport activities, using the isokinetic dynamometry method.

With respect to the objectives of the study, research questions have been formulated as follows:

1. What is a maximal strength level of the internal and external shoulder rotators of the right and left arm at given angular velocities (180°/s and 300°/s) in the group of tennis players in comparison with the control group.
2. How significant are strength differences between the internal and external shoulder rotators of the right and left arm at given angular velocities (180°/s and 300°/s) in the group of tennis players in comparison with the control group.

We hypothesized that significant differences exist in strength level of the internal and external shoulder rotators of the right and left extremity between tennis players (TEN) and the control group (CS).

Methods

The study was carried out with two groups of 10 participants, i.e., 20 persons in total. The group of 10 junior elite tennis players, aged 12-14 years, was created by an intentional selection from tennis clubs in Brno (sample TEN). The control group of boys, aged 12-14 years, who were not registered in any sport club, consisted of elementary school pupils of Želešice, Brno (control sample, CS). All participants reported their right upper extremity as the dominant one; they were free of acute or chronic symptoms of tennis elbow, tendonitis or any other upper extremity injury.

Data were collected by the calibrated isokinetic dynamometer Humac Norm CSMI (Stoughton, MA, USA). During the measurement, subjects were in a supine lying position and the test focused on the concentric external and concentric internal rotation of shoulder muscles. Range of motion for testing (ROM) was determined as 155°. Range of motion was 90° for the external and 65° for the

internal rotation. Range of motion as well as testing protocol was in accordance with the Ellenbecker's methodology (2003). Six gradient submaximal repetitions were carried out prior to the measurement itself. The first attempt was the familiarization one, followed by five attempts focusing strength with gradient force performance, so that strength of each attempt would exceed the previous one by 20% beginning with the level of the first attempt. It means the last (fifth) attempt reached 100% of the maximal strength level. After 30 seconds of rest, five repetitions with maximal strength intensity followed. Maximal values obtained from the five executed motions of both concentric flexion and concentric extension (with the inclusion of the gravitational constant) were considered as the output data. In accordance with the Ellenbecker's methodology (2003), the subjects were tested at angular velocities of 180°/s and 300°/s. Results of isokinetic diagnostics are given in newtonmetres (Nm). Data were processed by STATISTICA 10 and Microsoft Excel software. Substantive significance of differences in the observed parameters was assessed by Cohen's *d* (Cohen, 1988).

Results

Results of data analysis are shown in Table 1 as the basic statistical characteristics of anthropometric indicators.

As obvious from Table 1, both groups (TEN and CS) were almost identical as long as the basic anthropometric characteristics were concerned; tiny differences were found in age (difference +0.16 year in favour of tennis players, *d*=0.34) and also

Table 1. Basic statistical characteristics of anthropometric indicators

Group	TEN (n=10)	CS (n=10)
Variables/SCH	(M±SD)	(M±SD)
Age	13.23±0.51	13.04±0.61
Height (cm)	161.59±9.22	161.50±5.04
Weight (kg)	49.57±8.63	49.66±7.83

Note. M – arithmetic mean, SD – standard deviation, TEN – group of tennis players, CS – control group.

in body height (difference +0.09 cm in favour of tennis players, *d*=0.01) and body weight (difference +0.09 kg in favour of controls, *d*=0.01). Substantive significance of differences in basic anthropometric indicators between TEN and CS was assessed by Cohen's *d* and proved low age effect on differences, or rather no effect on body height and weight variables. Therefore, both groups can be considered as comparable from the aspect of basic anthropometric characteristics.

Table 2 presents results of the isokinetic dynamometry data analysis (strength of the internal and external shoulder rotators at angular velocity of 180°/s).

In the TEN group (compared with the CS group) a higher level of isokinetic strength was diagnosed (angular velocity of 180°/s) of the external shoulder rotators of the dominant extremity (dif=2.70 Nm, *d*=0.62, medium effect); strength level in the internal shoulder rotators of the dominant extremity was diagnosed as significantly higher (dif=5.90 Nm, *d*=1.73, large effect). In case of the shoulder external rotators, a medium substantive significance was proven and for the internal rotators a high substantive contribution was proven. Both findings refer to the substantive contribution of tennis specialisation to the strength level of both the external and particularly internal shoulder rotators of the dominant limb. Effect of sport specialisation is pronounced also in the non-dominant limb, where a medium substantive significance of strength difference was revealed both in the external (dif=2.00 Nm, *d*=0.57, medium effect) and internal rotators (dif=2.20 Nm, *d*=0.63, medium effect) in favour of tennis players. Ratio between the external and internal shoulder rotators (ER/IR * 100%= ratio) at angular velocity of 180°/s in the TEN group was 118.12% in the dominant and 162.10% in the non-dominant arm. This ratio was slightly higher in the control group, particularly in case of the internal rotators of the dominant arm – 159.10% and almost equal for the non-dominant one – 177.45%.

Assessed strength levels from the laterality aspect between the external and internal shoulder rotators of the dominant and non-dominant extremity in the groups is given in Table 3.

Table 2. Basic statistical characteristics of results obtained by the test of shoulder muscles at angular velocity of 180°/s

	TEN (n=10)		CS (n=10)	
	Dom (M±SD)	Ndom (M±SD)	Dom (M±SD)	Ndom (M±SD)
ER_180	20.20±5.47	20.10±3.83	17.50±2.91	18.10±3.08
IR_180	17.10±3.70	12.40±4.34	11.00±3.32	10.20±2.32
ER/IR_180	118.12%	162.10%	159.10%	177.45%

Note. ER_180 – external shoulder rotators, IR_180 – internal shoulder rotators, ER/IR_180 – ratio of external and internal shoulder rotators, Dom – dominant extremity, Ndom – non-dominant extremity.

In the TEN group, a very small strength difference was found as long as the external rotators (ER_180_Dom x ER_180_Ndom, dif_ER=0.10 Nm, i.e., 0.49%) were concerned. On the other hand, a significantly higher strength of the upper extremity was revealed when the internal rotators were tested (IR_180_Dom x IR_180_Ndom, dif_IF=4.70 Nm, i.e., 27.48%). Cohen's d did not prove substantive significance of the lateral differences in strength of the external rotators (d=0.02, no effect), while in the internal rotators, a high substantive significance (d=1.16, large effect) was proven. Results of the CS group showed a surprisingly higher strength level in the external rotators (ER_180_Dom x ER_180_Ndom, dif_ER=0.60 Nm, i.e., 3.31%) of the left extremity, while for the internal rotators (IR_180_Dom x IR_180_Ndom, dif_IF=0.80 Nm, i.e., 7.27%) a higher strength level of the right arm was diagnosed. Both results proved a low substantive significance of the differences for both the external (d=0.20, small effect) and internal shoulder rotators (d=0.27, small effect).

When assessing the external to internal shoulder rotators' ratio in the TEN group, there was found a difference of 3.10 Nm for the dominant extremity (i.e., strength of the internal is at 84.66% of the external rotators, dif=15.34%) and in the left extremity the difference was 7.70 Nm (61.69% of the external rotators, dif=38.31%). In

the CS group, the difference in the right extremity between the external and internal shoulder rotators was 6.50 Nm (i.e., strength of the internal was 62.85% of the external rotators, dif=37.15%). In the left extremity, the difference was 7.90 Nm (i.e., strength of the internal was 56.35% of the external rotators, dif=43.65%).

In the TEN group (in comparison with the CS group) a higher level of isokinetic strength was diagnosed (angular velocity of 300°/s) of the external shoulder rotators of the dominant (right) extremity (dif=1.40 Nm, d=0.41, small effect), i.e., a low significance of sport specialisation was proven. In the internal rotators, a high substantive significance of sport-specific load (dif=5.60 Nm, d=1.84, large effect) was found. Effect of sport specialisation is pronounced in the external rotators of the non-dominant limb (dif=1.20 Nm, d=0.56, medium effect), as well as in the internal shoulder rotators (dif=3.30 Nm, d=0.82, large effect). Just as for the dominant extremity, these differences were substantively significant. The results of lateral comparison of strength levels of the upper extremities (Table 5) enabled further examination of muscle adaptation connected with the load of junior tennis players. The ratio between the external and internal shoulder rotators (ER/IR * 100%= ratio) at angular velocity of 300°/s in the TEN group was 114.17% in the dominant and 135.59% in the non-dominant arm.

Table 3. Lateral strength difference between the external and internal shoulder rotators in the TEN and CS groups for angular velocity of 180°/s

	TEN (n=10)		CS (n=10)	
	Dom x Ndom		Dom x Ndom	
ER_180	dif_DE=0.10	d=0,02 (-)	dif_DE=0.60	d=0.20 (*)
IR_180	dif_DI=4.70	d=1.16 (***)	dif_DI=0.80	d=0.27 (*)

Note. dif_DE – difference right/left extremity, external rotators, dif_DI – difference right/left extremity, internal rotators.

Table 4. Basic statistical characteristics of results obtained by the test of shoulder muscles at angular velocity of 300°/s

	TEN (n=10)		CS (n=10)	
	Dom (M±SD)	Ndom (M±SD)	Dom (M±SD)	Ndom (M±SD)
ER_300	15.30±3.20	16.00±2.14	13.90±3.53	14.80±2.14
IR_300	13.40±3.10	11.80±4.24	7.80±2.96	8.50±3.75
ER/IR_300	114.17%	135.59%	178.20%	174.11%

Note. ER_300 – external shoulder rotators, IR_300 – internal shoulder rotators, ER/IR_300 – ratio of external and internal shoulder rotators.

Table 5. Lateral strength difference between the external and internal shoulder rotators in TEN and CS groups for angular velocity of 300°/s

	TEN (n=10)		CS (n=10)	
	Dom x Ndom		Dom x Ndom	
ER_300	dif_DE=0.70	d=0.25 (*)	dif_DE=0.90	d=0.30 (*)
IR_300	dif_DI=1.60	d=0.43 (*)	dif_DI=0.70	d=0.20 (*)

This ratio was slightly higher in the control group, particularly in the internal rotators of the dominant arm – 178.20%, and 174.11% in the non-dominant one.

In the TEN group a low substantive significance of lateral strength difference was proved ($d=0.25$, small effect) in the external shoulder rotators (ER_300_Dom x ER_300_Ndom, dif_ER=0.70 Nm, i.e., 4.37%) in favour of the left (non-dominant) extremity. Contrary, in the internal shoulder rotators (IR_300_Dom x IR_300_Ndom, dif_IF=1.60 Nm, i.e., 11.94%) a low substantive significance was proved of lateral strength difference ($d=0.43$, small effect) in favour of the dominant (playing) extremity.

In the CS group, a higher strength level was found in the external shoulder rotators (ER_300_Dom x ER_300_Ndom, dif_ER=0.90 Nm, i.e., 6.08%) in favour of the non-dominant extremity. In the internal shoulder rotators (IR_300_Dom x IR_300_Ndom, dif_IF=0.70 Nm, i.e., 8.23%), a higher strength level was proved in favour of the non-dominant extremity. In both cases, a low substantive significance was proved.

When assessing the ratio of the external and internal shoulder rotators in the TEN group, the difference was found of 1.90 Nm for the dominant extremity (i.e., strength of the internal was 87.58% of the external rotators, dif=12.42%), and in the left extremity, the difference was 4.20 Nm (71.95% of the external rotators, dif=28.05%). In the CS group, the difference in the right extremity between the external and internal shoulder rotators was 6.10 Nm (i.e., strength of the internal was 56.11% of the external rotators, dif=43.88%). In the left extremity, the difference of 6.30 Nm was found for the dominant extremity (i.e., strength of the internal was 57.43% of the external rotators, dif=42.57%).

Discussion and conclusions

Numerous studies focusing on the diagnostics of strength level of the internal and external shoulder rotators by means of isokinetic dynamometry, performed in junior tennis players (Ellenbecker, 1992; Ellenbecker & Roetert, 2003), university tennis players (Chandler, et al., 1992) and elite adult tennis players (Ellenbecker, 1991; Gozlan, et al., 2006; Kennedy, Altchek, & Glick, 1993), unanimously point out to a significant strength development of the internal shoulder rotators of the dominant extremity, while adequate development of the external rotators has not been observed.

From the aspect of injury incidence, arising mainly from shoulder instability, many authors (Ellenbecker & Roetert, 2003; Niederbracht, Shim, Sloniger, Paternostro-Bayles, & Short, 2008; Noffal, 2003; Scoville, Arciero, Taylor, & Stoneman, 1997; Yildiz, et al., 2006) attempted to define the ratio

between strength levels of the external and internal rotators ($ER/IR * 100\% = \text{ratio}$).

The mentioned authors recommend the strength ratio between the external and internal rotators of 66-75% for competitive elite tennis players. Warner, Micheli and Arslanian (1990) state that ER/IR ratio lower than 66% (attacking the limit of 50%), i.e., the external rotators reaching half a strength level of the internal rotators, might represent a high injury risk connected with instability of shoulder joint or impingement syndrome.

In the observed group of tennis players, we found a ratio of the external and internal rotators as $ER/IR * 100\%=118.12\%$ for the dominant and 162.10% for the non-dominant arm at angular velocity of 180°/s. In the control group, the ratio was proved to be 159.10% for the dominant and 177.45% for the non-dominant arm. At angular velocity of 300°/s, the ratio of the external and internal rotators in tennis players was $ER/IR * 100\%=114.17\%$ for the dominant and 135.59% for the non-dominant arm. In the control group, the ratio was $ER/IR=178.20\%$ for the dominant and 174.11% for the non-dominant arm.

Ellenbecker (1991) observed the ratio ER/IR of 76.10-76.50% for the dominant and 106.40-111.00% for the non-dominant arm in a group of elite tennis players aged 18-21 years. The given ratio values refer to muscular adaptation of the internal shoulder rotators in the dominant extremity in comparison with the non-dominant extremity muscles in tennis players. Very few studies provide definition of mutual ratio values of ER/IR in tennis players with the aim to point out strength development in the dominant limb at older elementary school age. Zuša, Lanka, Čupriks, and Dravniece (2015) focused on diagnostics of shoulder extensors and flexors in junior tennis players aged 11.4±0.5. They point out the ratio $ER/IR=132.10\%$ for the dominant and $ER/IR=159.80\%$ for the non-dominant arm. These results, in concord with our study, refer to an identical trend of gradual strength development of the internal shoulder rotators in the dominant arms under the influence of game load in junior tennis players.

Results of the study prove a substantively significant higher level of isokinetic strength of the external shoulder rotators in the dominant (playing) extremity in the TEN group in comparison with the CS group results (dif=2.70 Nm, $d=0.62$); similar results have been obtained for the internal rotators (dif=5.90 Nm, $d=1.73$). Substantively significant differences in favour of the TEN group have been proved also in the non-dominant extremity, both in the external rotators (dif=2.00 Nm, $d=0.57$) and internal rotators (dif=2.20 Nm, $d=0.63$). Substantively significant differences have been proved for angular velocities of 180°/s and 300°/s. Our hypothesis cannot be rejected. This fact might be assigned

to sport specialisation and its effect on strength of the shoulder external and internal rotators of the dominant (playing) extremity.

Analysis of lateral differences in strength level of the external rotators of the dominant and non-dominant extremity (angular velocity of 180°/s) in the TEN group did not prove substantive significance (dif=0.10 Nm, d=0.02), while in the internal rotators, a high substantive significance of difference (dif=4.70, d=1.16) was found. In the CS group, a low substantive significance of lateral differences in strength between the dominant and non-dominant extremity was found in both the external (dif=0.60 Nm, d=0.20) and internal rotators (dif=0.80 Nm, d=0.27). Assessment of the strength ratio between the external and internal shoulder rotators in the TEN group proved the difference of 15.35% in the playing arm and 38.31% in the non-dominant one. In the control group, the difference of 37.15% in the dominant and 43.65% in the non-dominant extremity was found.

Analysis of lateral differences in strength level of the external rotators between the dominant and non-dominant extremity (angular velocity of 300°/s)

in the TEN group proved a low substantive significance of difference (dif=0.70 Nm, d=0.25), which applied for the internal rotators as well (dif=1.60 Nm, d=0.43). In the CS group, a low substantive significance of lateral differences was found in both the external (dif=0.90 Nm, d=0.30) and internal rotators (dif=0.70 Nm, d=0.20). Assessment of the strength ratio between the external and internal shoulder rotators in the TEN group proved the difference of 12.41% in the playing arm and 28.04% in the non-dominant one. In the control group, the difference of 43.88% in the dominant and 42.56% in the non-dominant extremity was found.

As obvious from the results obtained by dynamometry, the level of maximal isokinetic strength in junior elite tennis players is, due to the influence of game and training load, significantly higher than in a comparable group of boys (regarding age, body height and body weight) who are not involved in any sports activity. With respect to the proved muscular dysbalances found in elite junior tennis players, it is recommended to coaches and players to integrate compensatory exercises into their training plan in order to reduce injury risks.

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