Unilateral and Bilateral Muscular Dysbalances of Knee Joint in Junior Tennis Players – Boys and Girls

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Abstract

Tennis game is typical for high intensity, sudden changes of directions, rapid slow down, acceleration and running for the ball. These movements lead to intensive strain to lower extremities, which is connected with selective activation of muscle groups and their further adaptation. During the muscle adaptation, muscular dysbalances might occur, which can result in an increased incidence of injuries and can be the cause for the reduced ability to maintain a balanced body posture during the game. With regard to this fact, the aim of this study was to establish, the strength level of knee extensors and flexors and assessment of their unilateral and bilateral differences, further to examine the strength level in tennis players group - boys (TEN_M, n=10, aged 13.23 ± 0.51), girls (TEN_F, n=10, aged 13.34 ± 0.69) in comparison with groups of boys (CS_M, n=10, aged 13.04 ± 0.61) and girls (CS_F, n=10, aged 13.21 ± 0.55 let) who do not perform any sport activity. Diagnostics of knee joints strength was carried out by isokinetic dynamometry (Humac Norm CSMI, Stoughton, USA) under two angular velocities (180°/s and 300°/s). Significance of differences in mean values was assessed by using Cohen´s d. Data analysis proved that differences between TEN and CS groups concerning age, body height and weight were insignificant. Comparison of isokinetic strength level (180°/s) between TEN_M and CS_M group proved significantly higher strength level of knee extensors (d=0.75) and flexors (d=1.27) in tennis players dominant extremity. Also for non-dominant leg in TEN_M group, was found significantly higher strength level of extensors (d=0.68) and flexors (d=1.05). Assessment of bilateral differences in strength of knee extensors (d=0.11) and flexors (d=0.05) of dominant and non-dominant extremity in TEN_M group did not prove their significance. Neither in CS_M group was found significant bilateral strength differences between knee extensors (d=0.07) and flexors (d=0.15) of dominant and non-dominant extremity. Comparison of isokinetic strength level (300°/s) between TEN_M and CS_M groups proved significantly higher strength level of knee extensors (d=0.91) and flexors (d=1.48) of dominant extremity in tennis players group. Also in knee extensors (d=0.85) and flexors (d=1.05) of non-dominant extremity, was proved significantly higher strength level in tennis players group.

Assessment of bilateral differences in strength of knee extensors (d=0.11) and flexors (d=0.01) of dominant and non-dominant extremity in TEN_M group did not prove their significance. Neither in CS_M group was found significant bilateral strength differences between knee extensors (d=0.10) and flexors (d=0.21) of dominant and non-dominant extremity. Comparison of isokinetic strength level (180°/s) of dominant extremity between TEN_F and CS_F groups did not prove significant differences in the strength of extensors (d=0.46) and flexors (d=0.45). Significant lateral differences in strength level in favour of TEN_F group were however proved in knee extensors (d=0.56) and flexors (d=0.73) on non-dominant extremity.

Assessment of bilateral differences in strength of knee extensors (d=0.04) and flexors (d=0.24) of dominant and non-dominant extremity in TEN_F group did not prove their significance. Neither in CS_F group was found significant bilateral strength differences between knee extensors (d=0.12) and flexors (d=0.05) of dominant and non-dominant extremity. Comparison of isokinetic strength level (300°/s) between TEN_F and CS_F group proved significantly higher strength level of knee extensors (d=0.63) of dominant extremity in tennis players group, while the significance of difference was not proved in flexors (d=0.48). Neither in knee extensors (d=0.46) of non-dominant extremity was proved significance of the difference, while in flexors (d=0.89) there was proved significantly higher strength level in TEN_F group. Assessment of bilateral differences in extensors (d=0.01) of dominant and non-dominant extremity in TEN_F group did not prove its significance, flexors (d=0.56) of dominant and non-dominant extremity proved significant difference. In CS_F group was not proved significant bilateral difference in extensors (d=0.30) and flexors (d=0.25) of dominant and non-dominant extremity.

Keywords: Isokinetic Dynamometry, Knee Joint, Muscular Dysbalances, Tennis, Anterior Cruciate Ligament, Injury.

1. Introduction

Modern tennis is typical of a high intensity of movement during the ball exchanges. Thanks to the evolution of new materials and technologies the game is becoming increasingly fast, in particular in the force of strikes and velocity of the ball; as a result the game duration required for obtaining the scores is shorter (Ferrauti et al., 2014; Schönborn, 2012). An increasing intensity of the game places high demands on the players' condition. The sports performance in tennis is, among other factors, much influenced by the level of locomotion abilities among which the most important are strength, speed and coordination (Crespo & Miley, 1998; Ferrauti et al., 2014; Kovacs, 2006). The combination of the above-mentioned mechanical factors along with other factors (such as mental, somatic and tactical) influences the performance in tennis. Born (1999) states that a high level of coordination is indispensable for achieving the best performance in tennis. In the realisation of individual game elements (sprinting to the ball, stabilising the body before the strike, striking the ball and returning to the basic game position) it is necessary to engage individual segments of the body in a correct and timely manner. Sanchez & Fernandéz (2016) say that coordination is understood as the ability of the body to carry out harmonic and efficient sequences of motions. In this sense, coordination enables the necessary regulation of body motion and it helps to optimise the engagement of other fitness abilities (namely strength, speed and flexibility). Coordination, being greatly influenced by the central nervous system capacity, participates in improving the efficiency of processing information and, consequently, addressing the topical situations in the game. With regard to the high incidence of random and unpredictable situations in tennis.

Bourquin et al. (2003) emphasise that only players with the maximum level of neuromuscular (technical) and energetic (physical condition) adaptation can become the best global players. It is obvious that a high level of coordination is determined by the correct functioning of both the central nervous system and the locomotion system. With regard to the high engagement of lower extremities in the tennis game – both in basic tennis skills realization (posture at service, forehand, backhand, volley, smash) and in the player's locomotion around the court – these activities are highly dependent on the optimum neuromuscular coordination (proprioception). A number of older and newer studies (Crespo & Miley, 1998; Csanadi, 1973; Ferrauti et al., 2014; Schönborn, 2012) say that the level of neuromuscular coordination is closely connected with the dynamic stability which is an important factor in stabilising the body and thus plays an important role in the tennis game performance (Hrysomallis, McLaughlin & Goodman, 2006). In most game situations the lower extremities play an important role in maintaining the stability of the body, for example in running after the ball, abrupt changes of movement, stopping and returning to the basic position. It is possible to say that the level of strength in the knee joint and the ratio of strengths between the agonists and antagonists influence the stability. In tennis, the strength of lower extremities plays an important role in the balance of the entire body.

From biomechanical aspect, tennis put a high strain on knee joint with its surrounding ligament and tendon structures. Fernandez-Fernandez et al. (2005, 2010), Girard and Millet (2004), Ferrauti et al. (2014) claim that tennis game is typical for fast run after the ball combined with rapid deceleration, sudden changes of direction and other twist movements that are necessary to successful game performance. According to Kibler et al. (2000), one successful point in tennis match requires more than eight abrupt changes of movement, while knee joint and its surrounding structures has to transfer 1.5–2.7times of tennis player's weight. Other authors (Silva et al., 2003; Jayanthi et al., 2005) continue that 4.3–19.2 % of all injuries in junior tennis players connected with tennis originate in knee area and are predominantly of chronic character. Incidence of injury in tennis is attributed mainly to long-term overloading of stabilization structures of knee joint (ligaments and tendons).

Overloading of stabilization structures of knee joint might be connected with muscular dysbalances as the response of the body to specific movement operation during the game (sudden changes of direction, frequent acceleration, or slow down, running for the ball, etc.). Some authors (McCall et al., 2014; Jones & Bampouras, 2010; Schlumberger et al., 2006; Hickey et al., 2009) believe that unilateral muscular dysbalance can be related to injury incidence or even suboptimal achievements of the sportsperson (Young et al., 2012).

Fried and Lloyd (1992) state that quadriceps of knee joint are of the crucial role during run and jumps, further they ensure joint stability during sudden changes of direction (turnings and/or rotation) and slow down (stop). Hamstrings (muscles of back part of the thigh) are activated especially during run and they ensure knee stability in high speeds (Hagood et al., 1990), while quadriceps (muscles of front part of the thigh) are prevailingly activated in lower speed (Martini & Nath, 2009). Kellis and Katis (2007) point to the fact, that balanced ratio between quadriceps and hamstrings strength is essential for joint stability, which further decrease the risk of injury. Also others (Fousekis et al., 2010; Lawson et al., 2006; Newton et al., 2006; Stephens et al., 2005) consider functional strength ratio in lower extremities as a fundamental precondition for increased achievements of tennis players; these authors further emphasize the ratio importance in injury prevention (Jones & Bampouras, 2010; Knapik et al., 1991; Schlumberger et al., 2006; Hickey et al., 2009). Croisier et al. (2008), Kellis and Katis (2007), Ellenbecker and Roetert (1999) define balanced function of knee muscles as the ratio between maximal strength of hamstrings to quadriceps (so called H/Q_ratio), assuming that this ratio can be considered as the indicator of muscular stabilization of knee joint. Aagaard et al. (1998) state, that low strength ratio (H/Q) can stand for lowered dynamic stabilization of knee joint, which might lead to an increased risk of injury. Griffin (2000) complements this theory, saying that quadriceps are significantly stronger than hamstrings, which put an extreme strain on anterior cruciate ligament that supports hamstrings in knee stabilization function and that is exposed to risk of injury incidence. Several authors (Begalle et al., 2012; Dargel et al., 2007; Neumann, 2010; Dai et al., 2012; Hughes & Dally, 2015) agree that anterior cruciate ligament rupture occurs particularly in situations connected with sudden changes of direction, jumps, landings, or rapid acceleration. Dai et al. (2012) and Yoo et al. (2015) further state that incidence of anterior cruciate ligament injury is higher in men (it is however necessary to take a higher number of male tennis players into account), but in women the incidence is 4–8 times more frequent (Sugimoto et al., 2012; Flaxman et al., 2014; Holcomb et al., 2007). According to Barber-Westin et al. (2006) and Ahmadet et al. (2006), unilateral muscular dysbalance is one of the principal reasons leading to anterior cruciate ligament injury. In agreement with above mentioned authors, Ellenbecker et al. (2007) state that optimal ratio between agonists and antagonists muscles (quadriceps and hamstrings) is of crucial importance from injury prevention aspects. Authors further state that maintenance of optimal strength ratio between quadriceps and hamstrings has recently become a priority, especially due to more and more frequent incidence of injury connected with an anterior cruciate ligament rupture.

Numerous studies (Hewett, 2000; Rozzi et al., 1999; Barber-Westin et al., 2006) point to injury of anterior cruciate ligament that is affected by high strain on lower extremity in a wide range of sports. A potential way how to contribute to its prevention is timely and ongoing diagnostics of strength skills in young tennis players, with respect to normative values of strength level in junior age. Based on the results of lower extremities diagnostics and assessment of unilateral (H/Q) ratio as well as bilateral muscular asymmetry, it is advisable to apply convenient compensatory programmes aiming to elimination of unilateral muscular dysbalances.

2. Methodology

The study has been carried out in 4 intentionally selected groups. Two groups consist of tennis players - boys (TEN_M, n=10) and tennis players - girls (TEN_F, n=10), the other two groups consist of children who are not engaged in any sport activity: non-sportive control group- boys (CS_M, n=10) and non-sportive control group - girls (CS_F, n=10). Total number of probands was 40. The group of junior elite tennis players aged 12-14 was obtained by an intentional choice from tennis clubs in Brno (sample TEN), (sample TEN_M; TEN_F), control groups of boys and girls, aged 12-14 who are not registered in any sport club consist of elementary school pupils of Želešice, Brno (Sample CS_M, CS_F). All probands reported right lower extremity as the dominant one; they were free of acute or chronic injury in lower back or lower extremity. Legal representatives of children as well as probands have been familiarized with testing procedures, legal representatives consequently signed an informed consent with the participation in the survey, as approved by the Ethical Board of Masaryk University.

Data have been obtained by calibrated isokinetic dynamometer Humac Norm CSMI (Stoughton, MA, USA). Subjects were seated and the test focused on concentric extension and concentric flexion of knee muscle group. Range of motion (ROM) in this testing was determined as 90°. In order to eliminate function of other muscle groups, fixation belts were used, according to producer's instructions. Range of motion as well as testing protocol is in accordance with Ellenbecker et al. methodology (2007). Prior to maximum strength diagnostics, the respondents warm-up their muscles on bicycle ergometre for 5mins. Six gradient submaximal repetitions with increasing strength intensity for each selected angular velocity, were carried out prior to measurement itself. The first attempt was familiarization one, followed by five attempts focusing strength with gradient force performance, so that the strength of each attempt would exceed the previous one of 20%. Which means the last (fifth) attempt reached 100% of maximal strength level. 30 seconds' rest was followed by five repetitions with maximal strength intensity. Maximal values obtained from five executed attempts both for concentric flexion and concentric extension (with the inclusion of the gravitational constant) are considered as the output data. In accordance with

Ellenbecker methodology (1991) subjects were tested at angular velocity of 180°/s and 300°/s. These levels of angular velocities correspond with further authors (Barber-Westin et al., 2006, Ellenbecker 2000), these angular velocities are also utilized in physiotherapy programmes focusing on lower extremities. Results of isokinetic diagnostics are given in Newtonmetres (Nm). Data have been processed by STATISTICA 10 and Microsoft Excel software. Substantive significance of differences in observed parameters was assessed with respect to intended choice of probands by using Cohen´s d (Cohen, 1992).

Results

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

Table 1. Basic statistic characteristics of anthropometric indicators. (male)

Group	TEN_M (n=10)	CS_M (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

Notes:

M … arithmetic mean

SD … determinative deviation

SCH … statistic characteristics

TEN_M … tennis players

CS_M … non-sportive boys

As obvious from table 1, both groups TEN_M and CS_M were almost identical as long as basic anthropometric characteristics are concerned; tiny differences have been found in age (dif=0.16 years, d=0.34) and in body height (dif=0.09 cm, d=0.01) both in favour of tennis players, and in body weight (dif=0.09 kg, d=0.01) in favour of control group of non-sportive boys. Substantive significance of differences in basic anthropometric parameters of TEN_M and CS_M group was assessed by using Cohen´s d (Cohen, 1992) proved low effect of age differences, and no effect in body height and weight. Therefore both groups can be considered as comparable from age and basic anthropometric parameters point of view.

Table 2. Basic statistic characteristics of anthropometric indicators. (female)

Group	TEN_F (n=10)	CS_F (n=10)
Variables/SCH	M ± SD	M ± SD
Age	13.34 ± 0.69	13.21 ± 0.55
Height (cm)	161.95 ± 8.30	162.95 ± 6.95
Weight (kg)	47.96 ± 8.24	48.03 ± 5.24

Notes: (see table 1)

Table 2 also shows that TEN_F and CS_F groups are almost identical at the level anthropometric parameters. Very small differences (substantively insignificant) in favour of tennis players were found in age (dif=0.13let, d=0.20), difference in favour of control group of non-sportive girls were found in body height (dif=1.00 cm, d=0.13) and weight (dif=0.08 Kg, d=0.01). Substantive significance of differences in basic anthropometric parameters was assessed by using

Cohen´s d proved low effect of age differences, and no effect in body height and weight. Also in girls, we can claim that both groups are comparable from age and basic anthropometric parameters point of view.

Table 3 presents results of statistic analysis obtained by isokinetic dynamometry (strength of knee extensors and flexors for angular velocity 180°/s and 300°/s).

Table 3. Basic statistic characteristics of results obtained by test of knee muscle groups in angular velocity of 180°/s and 300°/s (male)

Group	TEN_M (n=10)		CS_M (n=10)	
Variables	Dom M ± SD	Ndom M ± SD	Dom M ± SD	Ndom M ± SD
EXT_180	83.70 ± 23.89	81.30 ± 19.23	69.20 ± 13.03	70.20 ± 12.20
FLEX_180	45.60 ± 13.21	44.80 ± 14.27	31.50 ± 8.26	32.70 ± 7.58
EXT_300	58.00 ± 12.66	56.60 ± 11.46	45.80 ± 13.96	47.10 ± 10.62
FLEX_300	27.90 ± 4.39	28.00 ± 7.86	18.90 ± 7.35	20.40 ± 6.48
H/Q_180	54.48%	55.10%	45.52%	46.58%
H/Q_300	48.10%	49.46%	41.26%	43.31%

Notes: (see table 1)
EXT_180 … knee extensors, angular velocity 180°/s
FLEX_180 … knee flexors, angular velocity 180°/s
EXT_300 … knee extensors, angular velocity 300°/s
FLEX_300 … knee flexors, angular velocity 300°/s
H/Q_180 … knee flexors and extensors ratio, angular velocity 180°/s
H/Q_300 … knee flexors and extensors ratio, angular velocity 300°/s
Dom … dominant lower extremity
Ndom … non- dominant lower extremity

Comparison between TEN_M and CS_M group (in angular velocity of 180°/s) proved substantively significantly higher level of isokinetic strength in the knee of the dominant extremity both in knee extensors (dif=14.50Nm, d=0.75, medium effect), as well as in flexors (dif=14.10 Nm, d=1.27, high effect). Also for non-dominant extremity was proved significantly higher level of isokinetic strength in tennis players both in knee extensors (dif=11.10Nm, d=0.68, medium effect), as well as in flexors (dif=12.10 Nm, d=1.05, high effect), which might be assigned to sport specialization. When assessing the ratio of knee extensors to flexors strength (H/Q * 100%) in angular velocity of 180°/s in TEN_M group, it was H/Q=54,48% for dominant and H/Q=55,10% for non-dominant extremity. In CS_M group, the ratio was significantly lower, as H/Q=45.52% for dominant, and H/Q=46.58% for non-dominant extremity, which might be, again, assigned to sport specialization. Comparison of isokinetic strength between TEN_M and CS_M group in angular velocity of 300°/s proved significantly higher level of knee extensors (dif=12.20 Nm, d=0.91, high effect) and flexors of dominant extremity (dif=9.00 Nm, d=1.48, high effect) in favour of tennis players group. Similar tendency of isokinetic strength of the knee is apparent also in non-dominant extremity, higher strength level in tennis players was proved both in extensors (dif=9.50 Nm, d=0.85, high effect), as well as in flexors (dif=7.60 Nm, d=1.05, high effect). Knee flexors and extensors ratio in TEN_M group was in angular velocity of 300°/s for dominant H/Q=48.10%, and H/Q=49.46% for non-dominant extremity. In CS_M group was the ratio much lower, H/Q=41.26% for dominant and H/Q=43.31% for non-dominant extremity. Comparisons of knee extensors and flexors between dominant and non-dominant low extremity in TEN_M and CS_M group are given in table 4.

Table 4. Bilateral strength difference in extensors and flexors of the knee in TEN_M and CS_M groups for angular velocity of 180°/s and 300°/s (male)

Group	TEN_M		CS_M	
Variables	Dom x Ndom	Effect	Dom x Ndom	Effect
EXT_180	dif_EXT=2.40	d=0.11 -	dif_EXT=1.00	d=0.07 -
FLEX_180	dif_FLEX=0.80	d=0.05 -	dif_FLEX=1.20	d=0.15 -
EXT_300	dif_EXT=1.40	d=0.11 -	dif_EXT=1.30	d=0.10 -
FLEX_300	dif_FLEX=0.10	d=0.01 -	dif_FLEX=1.50	d=0.21 *

Notes: (see table 3)
Dif_DE … difference right/left lower extremity, extensors
Dif_DF … difference right/left lower extremity, flexors
- … no effect
* … small effect
** … medium effect
*** … large effect

In angular velocity of 180°/s, there was found little strength difference in knee extensors of TEN_M group (DE_180_Dom x DE_180_Ndom, dif=2.40 Nm, i.e. 2.86%) in favour of dominant extremity. Very little strength difference was also found in flexors (DF_180_Dom x DF_180_Ndom, dif=0.80 Nm, i.e. 1.75%). Assessing substantive significance did not prove significant lateral differences either in knee extensors (d=0.11, no effect) or flexors (d=0.05, no effect) of dominant and non-dominant extremity.

In angular velocity of 300°/s there was also found little strength difference in knee extensors of TEN_M (DE_300_Dom x DE_180_Ndom, dif=0.11 Nm i.e. 2.41%) in favour of dominant extremity. Very little strength difference was also found in flexors (DF_300_Dom x DF_300_Ndom, dif=0.10 Nm, i.e. 0.35%), this time in favour of non-dominant extremity. Assessing substantive significance did not prove significant lateral differences either in knee extensors (d=0.11, no effect) or flexors (d=0.01, no effect) of dominant and non-dominant extremity.

In angular velocity of 180°/s, there was found very little strength difference in knee extensors of CS_M group (DE_180_Dom x DE_180_Ndom, dif= 1.00 Nm, i.e. 1.42%)in favour of non-dominant, left extremity. There was also found little strength difference in knee flexors (DF_180_Dom x DF_180_Ndom, dif=1.20Nm, i.e. 3.66%) in favour of non-dominant extremity. There was not proved substantive significance of differences between dominant and non-dominant extremity either in knee extensors (d=0.07, no effect) or flexors (d=0.15, no effect).

In angular velocity of 300°/s there was found little strength difference in knee extensors of CS_M group (DE_300_Dom x DE_300_Ndom, dif=1.30 Nm, i.e. 2.76%) in favour of non-dominant extremity. Bilateral comparison of flexors strength proved little strength difference (DF_300_Dom x DF_300_Ndom, dif=1.50 Nm, i.e. 7.35%), again in favour of non-dominant extremity. Assessment of substantive significance did not prove significance of lateral differences in strength between dominant and non-dominant extremity in knee extensors (d=0.10, no effect) and it proved low substantive significance of differences in flexors (d=0.21, low effect).

Table 5 shows results of statistic analysis obtained by isokinetic dynamometry in TEN_F and CS_F groups.

Table 5. Basic statistic characteristics of results obtained by test of knee muscle groups in angular velocity of 180°/s and 300°/s (female)

Group	TEN_F (n=10)		CS_F (n=10)	
Variables	Dom M ± SD	Ndom M ± SD	Dom M ± SD	Ndom M ± SD
EXT_180	74.00 ± 16.40	73.30 ± 16.43	67.00 ± 13.42	65.50 ± 10.84
FLEX_180	37.50 ± 11.70	40.60 ± 13.81	32.90 ± 8.35	32.50 ± 7.00
EXT_300	47.10 ± 11.01	47.20 ± 9.15	39.90 ± 11.55	43.00 ± 8.88
FLEX_300	20.60 ± 6.96	24.90 ± 8.26	17.60 ± 5.43	18.90 ± 4.74
H/Q_180	50.67%	55.38%	49.10%	49.61%
H/Q_300	43.73%	52.75%	44.11%	43.95%

Notes: (viz. Table 4)

In comparison with CS_F group (angular velocity 180°/s), TEN group showed a higher level of isokinetic strength (but substantively insignificant) in knee extensor of the dominant leg (dif=7.00 Nm, d=0.46, low effect). Higher level of strength (but substantively insignificant) in favour of TEN_F group, was also found in knee flexors (dif=4.60 Nm, d=0.45, low effect). Concerninng non-dominant leg, TEN_F group proved higher level of strength in both knee extensors (dif=7.80 Nm, d=0.56, medium effect) and flexors (dif=8.10 Nm, d=0.73, medium effect). Knee flexors and extensors ratio (H/Q * 100%) in TEN_F group was in angular velocity of 180°/s H/Q=50.67% for dominant and H/Q=55.38% for non-dominant extremity. Values in CS_F group were lower, both for dominant H/Q=49.10% and non-dominant extremity H/Q=49.61%. Comparison of the strength level (angular velocity 300°/s) between TEN_F and CS_F groups revealed higher strength level in TEN_F group for knee extensors of dominant leg (dif=7.20 Nm, d=0.63, medium effect), as long as flexors are concerned, the difference is insignificant (dif=3,00 Nm, d=0,48, low effect). Identical tendency of isokinetic strength of the knee is apparent also in non-dominant extremity, higher strength level (but substantively insignificant) in TEN_F group was proved in extensors (dif=4.20 Nm, d=0.46, low effect), difference for flexors was substantively significant (dif=6.00 Nm, d=0.89, high effect). Knee flexors and extensors ratio in TEN_F group was in angular velocity of 300°/s H/Q=43.73% for dominant and H/Q=52.75% for non-dominant extremity. In CS_F group was the ratio H/Q=44.11% for dominant and H/Q=43.95% for non-dominant extremity.

Results of lateral comparison of knee extensors and flexors between dominant and non-dominant low extremity in TEN_F and CS_F groups are given in table 6.

Table 6. Lateral strength difference in extensors and flexors of the knee in TEN_F and CS_F groups for angular velocity of 180°/s and 300°/s (female)

Group	TEN_F		CS_F	
Variables	Dom x Ndom	Efekt	Dom x Ndom	Efekt
EXT_180	dif_EXT=0.70	d=0.04 -	dif_EXT=1.50	d=0.12 -
FLEX_180	dif_FLEX=3.10	d=0.24 *	dif_FLEX=0.40	d=0.05 -
EXT_300	dif_EXT=0.10	d=0.01 -	dif_EXT=3.10	d=0.30 *
FLEX_300	dif_FLEX=4.30	d=0.56 **	dif_FLEX=1.30	d=0.25 *

Notes: (see table 3)

In angular velocity of 180°/s, there was found little strength difference in knee extensors of TEN_F group (DE_180_DOM x DE_180_Ndom, dif=0.70 Nm, i.e. 0.94%) in favour of dominant extremity. Slightly higher strength difference was found in flexors (DF_180_Dom x

DF_180_Ndom, dif=3.10 Nm, i.e. 7.63%) in favour of non-dominant extremity. There was not proved substantive significance of bilateral differences in knee extensors (d=0.04, no effect) or flexors (d=0.24, low effect) of dominant and non-dominant extremity.

In angular velocity of 300°/s, there was also found little strength difference in knee extensors of TEN_F group (DE_300_Dom x DE_300_NDom, dif=0.10 Nm, i.e. 0.21%), in favour of non-dominant extremity. Higher strength difference was found in flexors (DF_300_Dom x DF_300_Ndom, dif=4.30 Nm, i.e.17.26%), again in favour of non-dominant extremity. Assessing bilateral differences in knee extensors of dominant and non-dominant extremity did not prove substantive significance (d=0.01, no effect), in case of flexors was proved medium substantive significance of difference (d=0.56, medium effect).In angular velocity of 180°/s, there was found little strength difference in knee extensors of CS_F group (DE_180_Dom x DE_180_Ndom, dif=1.50 Nm, i.e. 2.23%) in favour of dominant extremity. There was also found very little strength difference in knee flexors (DF_180_Dom x DF_180_Ndom, dif=0.40 Nm, i.e. 1.21%) in favour of dominant extremity. There were not proved substantively significant differences either in knee extensors (d=0.12, no effect) or flexors (d=0.05, no effect) of dominant and non-dominant extremity.

In angular velocity of 300°/s there was found strength difference in knee extensors of CS_F group (DE_300_Dom x DE_300_Ndom, dif=3.10 Nm, i.e. 7.20%) in favour of non-dominant extremity and there was found little strength difference in flexors (DF_300_Dom x DF_300_Ndom, dif=1.30 Nm, i.e. 6.87%), again in favour of non-dominant extremity. There were proved insignificant bilateral differences between knee extensors (d=0.30, low effect) and flexors (d=0.25, low effect) of dominant and non-dominant extremity.

3. Discussions and conclusions

Assessment of bilateral muscular dysbalances in knee joint area in TEN_M group under angular velocity of 180°/s was carried out by using Cohen´s d and it did not prove substantively significant strength differences in extensors (d=0.11) or flexors (d=0.05). Neither angular velocity of 300°/s proved substantively significant bilateral muscular dysbalance in extensors (d=0.11) or flexors (d=0.01). Substantively significant lateral differences of strength in CS_M group were not proved under angular velocity of 180°/s, or 300°/s either for extensors (d=0.07, or d=0.10) or flexors (d=0.15, or d=0.21).

In TEN_F group, under angular velocity of 180°/s, were not proved substantively significant bilateral muscular dysbalances either in extensors (d=0.04) or flexors (d=0.24). Under angular velocity of 300°/s, were not proved substantively significant lateral strength differences in extensors (d=0.01), but they were proved in flexors (d=0.56). In CS_F group were not proved substantively significant lateral strength differences in angular velocity of 180°/s neither in extensors (d=0.12), or flexors (d=0.05). Under angular velocity of 300°/s exist low substantively significant differences in extensors (d=0.30) and flexors (d=0.25).

Our conclusions are in concord with Ellenbecker and Roetert (1995) who examined diagnostics of lower extremity strength in junior tennis players aged 11–17. Their conclusions point out to bilateral symmetry of knee extensors and flexors both in male and female tennis players. In case of bilateral muscular asymmetry incidence, this cannot be attributed to selective strength development, or the effect of domineering caused by muscles adaptation connected to tennis.

Hughes and Dally (2015) and Harput et al. (2014) claim that strength ratio between quadriceps and hamstrings is of crucial importance from knee joint stability aspect, which significantly lowers especially tensile forces to the anterior crossed ligament. Dorgo et al. (2012) state that standard way to define mutual activation of knee joint muscles is the computation of their ratio arising from maximal strength (H/Q * 100%). Strength ratio (H/Q ratio) in adults has been described by numerous studies. Many studies engaged in strength of knee joint diagnostics suggest that the ratio of strength between agonists and antagonists muscle groups is recommended as H/Q=60-70%. This ratio is given as the indicator of an ideal muscle stabilization of knee joint, which is connected with elimination of risk injury of anterior crossed ligament. As mentioned in the synthesis of knowledge and further in the study (Barber-Westin, 2006; Ahmad, 2006), unilateral muscular dysbalances, i.e. lowering the ratio (under the level of 60%) might be connected with an increased risk of injury in adults.

There exist quite few studies focusing on defining unilateral strength ratio (H/Q ratio), that would describe unilateral strength ratio in tennis players of older school age. Ellenbecker and Roetert (1995) were dealing with defining of unilateral strength ratio and they managed to examine a group of junior tennis players, boys (n=62), aged 13–19, and a group of tennis players, girls (n=25), aged 13–18. Diagnostics of strength skills was carried out through identical angular velocities (180°/s and 300°/s) and the authors proved strength ratio H/Q=59% in boys for right leg and H/Q=61% for left leg (under 180°/s). Under angular velocity of 300°/s, the ratio in boys was H/Q=62% for right leg and H/Q=63% for left leg. For girls group, the authors carried out the test only for angular velocity of 300°/s. The ratio for right leg was proved as H/Q=66% and for left leg H/Q=69%. Later studies by the same author Ellenbecker et al. (2007) was carried out in more homogenous group, as long as age is concerned. Diagnostics of strength skills was realized in boy and girl groups aged 11–15, and then 16–21. Results of unilateral strength ratio tests (180°/s) in junior tennis players aged 11-15 in boys group proved H/Q=62% for dominant leg and H/Q=63% for non-dominant one.

Under angular velocity of 300°/s, the strength ratio of muscular groups was H/Q=60% for dominant leg and H/Q=66% for non-dominant one. In concord with recommendation of the authors (Ellenbecker et al., 2007), it is essential that further studies should aim the strength diagnostics at younger tennis player aged 10-12 and 12-14 in order to understand and describe strength skills development in each age category and gender groups. Zuša et al. (2015) dealt with isometric diagnostics ok knee joint in girls (n=6) aged 11.4 ± 0.5 and the strength ratio for dominant (right leg) was proved as H/Q= 38% and for left leg it was H/Q=42%. In our tested group TEN_M (aged 12-14) the strength ratio (under 180°/s) was H/Q=54.48% for dominant and H/Q=55.10% for non-dominant extremity. Under angular velocity of 300°/s, the strength ratio for extensors was H/Q=48.10% for dominant and H/Q=49.46% for non-dominant extremity. In CS_M group (angular velocity of 180°/s) the strength ratio was H/Q=45.52% for dominant and H/Q=46.58% for non-dominant extremity. Under angular velocity of 300°/s, the strength ratio for dominant extremity was H/Q=41.26% and for non-dominant extremity it was H/Q=43.31%. In TEN_F group (180°/s) the strength ratio was H/Q=50.67% for dominant and H/Q=55.38% for non-dominant extremity. Under angular velocity of 300°/s, the strength ratio for dominant leg was H/Q=43.73% and for non-dominant extremity it was H/Q=52.75%. In group of non-sportive girls (180°/s), the strength ratio was H/Q=49.10% for dominant and H/Q=49.61% for non-dominant extremity. Under angular velocity of 300°/s, the strength ratio was H/Q=44.11% for dominant and H/Q=43.95% for non-dominant extremity.

Conclusions of our study stand for a missing part of the lower extremity strength profile of older school age category.

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