Lateral differences in maximal grip strength in Czech male tennis players aged 11–12 in the context of injury prevention

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Abstract

The term laterality indicates the one-sided preference or functional advantage of the stronger, more accurate and coordinated limbs or organs and the brain hemisphere of a human body. In the preference process, more accurate, precise, coordinated and stronger side is chosen from the perspective of motoric functions. Among the general population is about 10–13% of left-handers and in certain sport fields this percentage may be higher (baseball, tennis, box etc.). The left-handed dominance in tennis is considered an advantage. Due to unilateral load, there may be an excessive side-effect in strength differences in tennis and overloading of specific muscle group could lead to an injury. The aim of the research was to identify the levels of somatic and strength characteristics and assess the lateral difference in maximal grip strength of Czech elite male tennis players. The sample consisted of male tennis players, ranging in age from 11 to 12.9 years (n = 186) who participated in the regular tests for Czech Tennis Association in years 2000–2018. Base anthropometrics were measured (height, weight) and maximal grip strength of both hands using the hand-held dynamometry (Grip D). Data came from normal distribution (statistically proven – chi-square test). The basic statistical characteristics were calculated (body height, M = 155.08 ± 7.98 cm; body weight, M = 43.45 ± 7.13 kg; strength of right hand: M = 24.88 ± 4.67 kp; strength of left hand: M = 21.70 ± 4.74 kp). It was found that 87.6% of the players (n = 163) were right-handed and the remaining 12.4% left-handed (n = 23). The assessment of the significance (Cohen's d) between the dominant (playing) hand for the right-handed and left-handed players showed small effect size (dominant hand right: MRHR = 25.11 ± 4.41 kp, dominant hand left: MLHL = 26.62 ± 5.65 kp; d = 0.30, small) in favor of the left-handed players. The difference between the dominant and the non-dominant hand showed large effect size for the right-handed (dominant hand right vs. hand left; MRHR = 25.11 ± 4.41 kp, MRHL = 21.01 ± 4.15 kp, d = 0.96, large) and medium effect size for the left-handed players (dominant hand left vs. hand right; MLHL = 26.62 ± 5.65 kp, MLHR = 23.24 ± 5.98 kp, d = 0.58, medium). The results showed that the value of 15 % level of strength laterality between dominant and non-dominant hand was exceeded for the right-handed (55.83 %) and left-handed (43.48%) groups ergo the exceeded value could be a cause of injuries. Because of this signals attention should be given during training process for optimizing the required load.

Keywords: *bilateral asymmetry, laterality, tennis, dynamometer, training*

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INTRODUCTION

Generally, the term laterality indicates the one-sided preference or functional advantage of the stronger, more accurate and coordinated limbs or organs (such as mainly upper and lower limbs, eyes, pelvis) and the brain hemisphere. Laterality manifests itself outwardly by giving preference to one side of the body during life, which is dependent on the movement center in the opposite brain hemisphere (eg. left hand → right brain hemisphere) controlled by cortex center. The more we used the preferred side the more economic, certain and accurate it will be (Garipuy, 2001; Loffing et al., 2014; Domino et al., 2015; Ziagkas et al., 2017). During literary review we found references to laterality in conjunction with following terms: handedness, footedness, eyedness, earedness and axis-rotation in relation to laterality manifestations. Because of the research intension we focused on the handedness issue (refers to left-hand or right-hand dominance). Handedness is divided into right-handed dominance (dextrality), left-handed dominance (sinistrality) and ambivalent sidedness (ambidexterity). The left-handedness occurs more stronger amongst men compared to women (Papadatou-Pastou et al., 2008). Preferred side may not necessarily be consistent for all tasks. In some interactive sports a higher percentage of left-handers occurs (e.g. fencing, box, baseball, cricket, ice-hockey and tennis). If we focused more on tennis, we could find a limited number of repeatedly performed motoric activities which could leads to a strength and flexibility imbalances and therefore to a possible injury. Mostly training and play load created these muscle disbalances. In tennis, injuries in the upper limbs are most often caused by the repeated excessive load of the speed-strength movement character. Alizadehkhaiyat et al. (2007) claims that muscle imbalances are defined as a failure of functional relationship between agonist and antagonist muscle group or predominance of synergist muscle group. This situation further increases joint loading and involved muscles become overloaded or weakened and may lead to an injury. Study of De Smet et al. (1997) and Pienimaki et al. (2002) say that if the injury appears (in this case tennis elbow) it can lead to a reduction in grip strength approximately about 25%. In tennis it depends on the forearm strength, especially on the grip strength which has an important role, but also on the muscular endurance because of the length of the match. So, it's important to maintain the optimal level of grip strength to prevent mainly the wrist overloading, but also elbow and shoulder joint as well (Roetert & Kovacs, 2018). Boys participated in higher physical intensity activities compared to girls after reaching the age 9 or 10 which leads to improved muscular strength (Butterfield et al., 2009). Study of Ploegmakers et al. (2013) claims that boy's grip strength grew linearly until the 12th year in both hands and after that the accelerated strength increase tendencies were observed for dominant hand. For non-dominant hand the similar tendencies were shown after reaching the 13th year. The maximal grip strength remained relatively stable during repeated measurements in this age. Because according to Häger Ross & Rösblad (2002) and Omar et al. (2015) it could be the result of an incomplete maximal strength.

During the training process players should maintain the optimal muscle balance, focus onto development of strength and endurance (both necessary for tennis) which is important for prevention and performance optimization. Because the asymmetries and strength differences could start in at early age between 11–12th year according to Ellenbecker et al. (2002) and in a long-time this process may be the cause of injuries. According to Sell et al. (2012) and Pluim et al. (2009) lower limbs (LL) injuries were 1.3 times more likely than injuries to the upper limbs (UL) in men (n = 704) during their recording period (1994–2009) at the US tennis championship. The data for the injury rate were shown per one thousand matches exposed for LL in 337 cases (which were 26.59 injury rates) vs. UL in 255 cases (which were 20.12 injury rates). Because our research was focused on the upper limbs, the list of injuries related to the upper limbs and their rate are described below. From 255 cases 93 of them were related to the shoulder/shoulder blade (7.34 injury rate), 49 of them concerned the elbow (3.87 injury rate), 74 of them were at wrist

(5.84 injury rate) and 23 of them were presence in hand, finger or thumb (1.82 injury rate). Vast majority of all injuries were associated with muscle or tendon injury (605 cases with 47.74 injury rates) and after that were joints with ligaments (29 cases with 2.29 injury rates) followed by a minor representation of skin, bone and nervous system injury types. By data from this study and others (Alizadehkhaiyet et al., 2009; Abrams et al., 2012; Rossi et al., 2014; Hayot et al., 2014) we could claim that the most observed and common injuries were concerning the shoulder, wrist and elbow and mostly included muscle or tendon type of injury. Studies of Hutchinson et al. (1995) and Silva et al. (2003) claimed that musculoskeletal injuries such as strains, sprains and cramps were the mostly reported type of injury amongst junior tennis players.

With regards to handedness, some of the tennis players (3.6% among male and female) play with an opposite hand used for tasks like writing etc. This could be as a result for sport-specific tasks (or sport-specific dominance) simply because of its advantage on the field (cross-dominance). Right-handed players have smaller tendency to ambidexterity (no social pressure). According to Grouios (2004) and Loffing et al. (2014), considering motor skills, the left-handers can benefit from weaker lateralization of the brain hemispheres for tasks using both hands (in their childhood almost everyday tasks were made for right-handed part of population). Left-handers have got a little bit of advantage in one-on-one situations in the game, due to lack of games played against them for right-handed (Loffing et al.,2012). The lateralization process has key role in technical aspects of the game, therefore it could be found connection between a player's laterality patterns and his strengths and weaknesses. Decoding these patterns could give a player advantage against his opponent and could therefore apply efficient tactical schemes (Garipuy, 2001; Domino et al., 2015; Loffing et al., 2014; Ziagkas et al., 2017).

METHODS

The aim of the study was to assess the lateral difference in maximal grip strength in Czech tennis players with regard to a possible risk of injury. The subsequent goals of the research were to (1) identify the levels of somatic and strength characteristics, (2) the rate of right-handed and left-handed players, (3) lateral differences in grip strength between the dominant and non-dominant hand. The study included male tennis players. Ages ranged between 11 and 12.9 years (n = 186, mean height with standard deviation was M = 155.08 ± 7.98 cm and mean weight with standard deviation was M = 43.45 ± 7.13 kg). Because the subjects were under the 18 years old, all participants' legal representatives signed an Informed consent. Subjects participated in the project Complex diagnostics in tennis (1999) for Czech Tennis Association in years 2000–2018. Research was approved by The Research Ethics Committee of Masaryk University. The TENDIAG 1 testing battery, 3 out of 9 research-related parts was used: base anthropometrics (height, weight) and maximal hand grip strength using the hand-held dynamometry (Grip D, Takei, Japan). Hand-held dynamometry measurement results came in kiloponds (kp). The playing (dominant) hand was queried with each player. Each subject performed two attempts with each hand parallel to the body in the standing position without touching it, wrist in the neutral position and elbow extended. As a result, the highest strength score (best attempt) was considered and recorded as peak grip strength (kp). The STATISTICA 12 and Microsoft Excel software were used for data processing. According to the fact, that the research sample was not obtain as a random selection, but intentional selection, the authors (Cohen, 1988; Blahuš, 2000; Soukup, 2013) recommend using the effect size for the assessment of mean values differences. Cohen's d was used for the assessment of the significance (effect size) of differences in mean values, which could be interpreted in agreement with author (Cohen, 1988). The scale for the Cohen's d effect size was small (d = 0.2), medium (d = 0.5) and large (d = 0.8).

RESULTS

It has been statistically proven (chi-square test, variations on goodness-of-fit) that the testing data came from a normal distribution. It was found that 87.6% of the players (n = 163) were right-handed and the remaining 12.4% left-handed (n = 23). Base statistical and anthropometric characteristics and maximal hand grip strength are presented in Table 1.

Tab. 1: Basic statistical characteristics of the sample

Sample	**Male players (n = 186)**			
Variables	**M**	**SD**	**min**	**max**
Age (y)	12.05	0.55	11.0	12.9
Height (cm)	155.08	7.98	139.0	178.0
Weight (kg)	43.45	7.13	30.0	74.0
SR (kp)	24.88	4.67	12.8	40.7
SL (kp)	21.70	4.74	11.4	38.0

Legend: SR ... max. strength right hand, SL ... max. strength left hand, M ... mean, SD ... standard deviation, y ... years, cm ... centimeter, kg ... kilogram, kp ... kiloponds

Table 1 showed the difference for the mean value of maximal hand strength between the right (SR = 24.88 kp) and the left (SL = 21.70 kp) regardless of whether the individual is right-handed or left-handed. In this case the right-hand score was higher. Using the Cohen's d we verified the significance of the difference in mean values for the strength (3.18 kp) of both hands. The medium effect size was shown (d = 0.68, medium). In this sample the representation of left-handed players was 12.4%. The mean percentage difference between the maximum of left and right-hand strength was 15.72% (see Table 2). Among 186 observed players, 101 of them (54.30%) had the 15% strength difference between the dominant and non-dominant hand and amongst 63 of them (33.87%) the difference was found greater than 20%.

Tab. 2: Strength difference between the right and left hand

Difference	**n**	**%**
R vs. L	163 vs. 23	15.72
> 15–19.99%	101	54.30
> 20%	63	33.87

Legend: R vs. L ... difference between right and left hand, > 15% ... strength difference greater than 15%, > 20% ... strength difference greater than 20%

Left-handed players (Table 3 and 4) have shown a greater mean value of maximal hand strength for a dominant hand compared to right-handed (M_{LHL} = 26.62 ± 5.65 kp vs. M_{RHR} = 25.11 ± 4.41 kp). Non-dominant hand has shown the same tendencies in favor for left-handed players in comparison with right-handed (M_{LHR} = 23.24 ± 5.98 kp vs. M_{RHL} = 21.01 ± 4.15 kp).

Tab. 3: Maximal strength and differences between dominant and non-dominant hand for the right-handed players

Right-handed players					
	M	**SD**	**Min**	**Max**	**Diff > 15%**
Dominant RHR (kp)	25.11	4.41	12.80	40.70	55.83
Non-dominant RHL (kp)	21.01	4.15	11.40	33.00	
Left-handed players					
	M	**SD**	**Min**	**Max**	**Diff > 15%**
Dominant LHL (kp)	26.62	5.65	18.00	38.00	43.48
Non-dominant LHR (kp)	23.24	5.98	13.90	38.00	

Legend: RHR ... dominant hand right – right hand, RHL ... dominant hand right – left hand, LHR ... dominant hand left – right hand, LHL ... dominant hand left – left hand, M ... mean strength, SD... standard deviation, Diff > 15% ... strength difference between R and L hand higher than 15 % percent, kp ... kiloponds

Both, the right-handed (55.83%) and left-handed (43.48%) groups achieved relatively high strength differences between dominant and non-dominant hand exceeding 15% level of strength laterality.

Results focused on comparison of the strength of the right-handed (RH) and the left-handed (LH) subjects (Table 3 and 4) showed small effect size differences for their dominant hand (M_{RHR} = 25.11 ± 4.41 kp, M_{LHL} = 26.62 ± 5.65 kp; d = 0.30, small) in favor of the left-handed players. The difference between the dominant (DH) and non-dominant (NDH) hand and their strength assessment showed large effect size (M_{RHR} = 25.11 ± 4.41 kp, M_{RHL} = 21.01 ± 4.15 kp, d = 0.96, large) for right-handed players and medium effect size (M_{LHL} = 26.62 ± 5.65 kp, M_{LHR} = 23.24 ± 5.98 kp, d = 0.58, medium) for left-handed players.

DISCUSSION

Our research showed 12.4% representation of left-handed individuals in tennis which agrees with some authors who claimed, that in population is about 10–13% of left-handers (Faurie & Raymond, 2004; Raymond et al., 1996). According to Bohannon (2003) grip strength was typically greater on the dominant hand than on the non-dominant hand. But he also claimed, that it depends whether the subject was right-handed or left-handed and differences might be varying widely among sides. Hand grip strength for right-handed players was found greater in their dominant hand (comply with the 10% rule), but for the left-handed players the results were more equilibrated or even higher on their non-dominant hand (Bohannon, 2003; Hepping et al., 2015). During the study we have found the same results as authors mentioned above and others (Hepping et al., 2015; Tutkuviene & Schiefenhövel 2013; Incel et al., 2002; Bohannon, 2003), who claimed – that left-handed players were more often stronger on their non-dominant against their dominant hand in comparison with their right-handed rivals.

We compared our study results with the other studies (see Table 4) where grip strength came similar. Most of them divided our 2 years category into separate ones. But some of them did not distinguish between strength in the dominant and non-dominant hand or showed only combined results for specific year (mean for right and left hand together).

Tab. 4: Hand grip strength presented in studies

Author	Age	DH	NDH
Molenaar et al. (2010)	11 yo 12 yo	19.92 kp 22.37 kp	18.33 kp 20.68 kp
Ploegmakers et al. (2013)	11 yo 12 yo	22.00 kp 24.7 kp	20.6 kp 22.9 kp
Hepping et al. (2015)	11 yo 12 yo	RH 22.5 kp; LH 19.6 kp RH 25.1 kp; LH 23.0 kp	LH 20.7 kp; RH 19.9 kp LH 23.0 kp; RH 22.7 kp
Butterfield et al. (2009)	11 yo 12 yo	22.36 kp 28.04 kp	21.27 kp 26.28 kp
Omar et al. (2017)	11 yo 12 yo	17.73 kp 21.26 kp	17.46 kp 21.05 kp
Kocher et al. (2017)	11 yo 12 yo	23.1 kp 27.6 kp	25.1 kp 29.7 kp
Kocher et al. (2018)	11 yo 12 yo	21.74 kp 24.49 kp	
Ramirez-Velez et al. (2017)	11 yo 12 yo	15.9 kp 18.1 kp	
Gomez-Campos et al. (2018)	11 yo 12 yo	18.49 kp 22.46 kp	17.25 kp 21.31 kp
Garcia-Hermoso et al. (2018)	11 yo 12 yo	17.60 kp 21.46 kp	
Fredriksen et al. (2018)	11 yo 12 yo	18.4 kp 19.9 kp	16.9 kp 19.0 kp

Legend: DH ... dominant hand, NDH ... non-dominant hand, yo ... years old, RH ... right hand, LH ... left-hand, kp ... kiloponds

These studies originated from all over the world (North America, South America, Central Europe, Eastern Europe, and Asia) and were comparable within western and eastern population. Mostly they agreed with the lowering tendency for hand grip strength amongst the children in last 2–3 decades. During our study did not appear strength drop between attempts because of incomplete maximal strength. Subjects below 12 years were able to repeat those stable attempts in comparison with older ones (13–16 years – which considered to be the strength spur). They produced more strength in a separated attempt (maximal contraction) then the next one fell. Grip strength in boys grew linearly with age in both hands until the 12th year. After that accelerated increase in strength for dominant hand occurred and for non-dominant hand we could observed the same tendencies after reaching the 13th year (Butterfield et al., 2009; Ploegmakers et al., 2013; Tutkuviene & Schiefenhövel 2013; Loffing et al., 2014; Hepping et al., 2015).

CONCLUSION

During our research it was found that out of the total of 186 players 163 were right-handed and 23 left-handed, 87.6% vs. 12.4% respectively. Observed players showed significant differences between the strength level of dominant (play) and non-dominant hand in both groups (right-handed and left-handed). Significant differences were found between the strength of the dominant right hand and the dominant left hand in favor of left-handed players. The mean difference in maximal hand strength was 15.72% (right vs. left hand). Left-handed players had a higher maximal strength in both hands (dominant and non-dominant) while right-handed only in their right hand (dominant). The value of 15% level of strength laterality between dominant and non-dominant hand was exceeded for the right-handed (55.83%) and left-handed (43.48%) groups. Strength laterality asymmetries between limbs could lead to injury or disbalances, therefore proper exercise (or compensation) should be included as an important part of the training (by coaches and players themselves). The importance of abdominal and lower back exercises (Core stability) are crucial for various types of service helps with the stabilization process (Chow et al., 2003; Elliot, 2006) and also with the appropriate strength transfer via kinetic chain from lower limbs to upper limbs. As kinetic chain continues through the trunk to the shoulder, strength imbalances can possibly cause injury in muscles related to acceleration and deceleration processes during the game. Exercise for eccentric external rotators strength may help with the balancing the antagonist group strength (Noffal, 2003). This is crucial for athletes who perform explosive concentric and eccentric contractions on a regular basis such as tennis, because most of the tennis strokes are according to Elliot (2006) characterized by so called stretch-shortening cycle (eccentric then immediately concentric contraction). It is therefore obvious that training session should include exercise of concentric and also eccentric character.

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