Bilateral Differences in Handgrip Strength in Czech Female Tennis Players Aged 11–12 Years and Injury Prevention

Tomáš Válek, Roman Kolínský, Petr Konečný, Jiří Zháněl

Faculty of Sports Studies, Masaryk University in Brno

Abstract

The term laterality refers to the preference or dominance of the lateral asymmetry of the human body. The prevalence of left-handedness is reported to be 10–13%, but in some sports (e.g. boxing, ice hockey, tennis), the proportion of left-handers is higher. The left-handedness is considered an advantage in tennis; however, the one-sided load can cause muscular dysbalances leading to injuries. The research aim was to assess bilateral differences in handgrip strength in top Czech female tennis players U12 as to injury prevention. The participants were tennis players (n = 165) aged 11.0–12.9 years taking part in the regular testing by the Czech Tennis Association using the TENDIAG1 test battery between 2000 and 2018. 87.3% of all players were right-handed (RH) and only 12.7% left-handed (LH). Bilateral differences between the right- and left-hand strength of all players were medium significant in favor of the right hand. The assessment of differences between RH and LH players showed only small differences in favor of LH players. There was a medium significant difference between RH and LH players in favor of the dominant hand (DH) over the non-dominant one (NDH). As to injury prevention, it is surprising that a difference between DH and NDH strength >15% was found in 40.91% of RH players and even in 40.06% of LH players. This predicts an increased risk of injury, so it is desirable to pay attention to both sides of the training load and to include compensatory or strengthening exercises.

Keywords: *bilateral asymmetry, dynamometer, handedness, isometric strength, laterality*

INTRODUCTION

The prevalence of left-handedness in the general population is in the range of 10–13% (Faurie & Raymond, 2004), a higher proportion of left-handers was found mainly in some interactive sports (boxing, ice hockey, tennis). In tennis, the proportion of left-handers is higher among the world's elite tennis players (Holtzen, 2000). In an analysis of the World Ranking of tennis players (1968–1999), it was found that the percentage of left-handers among elite players was significantly higher (Grand Slam finalists: male = 22.27%, female = 18.75%; winners: male = 22.66%, female = 21.88%). However, the results of the study among players participating in four Grand Slam tournaments between 1968 and 2011 (Loffing, Hagemann, & Strauss, 2012) document a lower representation of left-handers among elite male finalists and winners (Grand Slam finalists: male = 8.70%, female = 17.17%; winners: male = 9.76%, female = 21.15%). The one-sided preference or functional advantage of limbs or organs, also known as laterality, reveals the individual's tendency to use coordinated, more accurate and stronger body parts mainly regarding to upper and lower limbs and the brain hemisphere during life. If we use them more often, the movement or work-related tasks will become more economic, confident, and precise (Domino, Świątkowski, & Matłosz, 2015; Hagemann, 2009; Loffing, Hagemann, Strauss, & MacMahon, 2016; Ziagkas, Mavvidis, Grouios, & Laios, 2017). Favoring one hand in everyday life creates a difference within the hands and then, a dominant hand develops. Laterality could be related to other parts of the body as well, but for our research intention, we focused on the handedness issue which referred to the left- (sinistrality) and right-hand (dextrality) dominance. In some sport fields, a higher percentage of left-handers occurred (e.g. tennis, box, baseball, handball, football). In tennis, a limited number of numerously performed activities could be seen during training or game matches and might be a cause of injury due to flexibility and strength imbalances. Upper limb injuries mostly happened by the repeated excessive load of the speed-strength movement character. Fu, Ellenbecker, Renstrom, Windler, and Dines (2018) found out musculoskeletal affliction due to joint loading and overusing amongst junior tennis players. Ellenbecker, Roetert, Bailie, Davies, and Brown (2002) claimed that strength differences could be visible as early as at the age of 11–12 and this could lead to an injury in the future during their carrier. According to Fu et al. (2018), acute injuries tended to be more likely in the lower body, but upper body suffered more by chronic overuse injuries (referred to 47% of junior tennis players problems in the study of Pluim, Loeffen, Clarsen, Bahr, and Verhagen (2016) and in Colberg, Aune, Choi, and Fleisig (2015) even 67%). Kovacs, Ellenbecker, Kibler, Roetert, and Lubbers (2014) examined 861 elite junior tennis players in their study, and they came with the result that injury rates were 11% in the 12 and underage group, 28% in the 14 and underage group, and 36% in the 16 and underage group. McCurdie, Smith, Bell, and Batt (2017) found a higher injury rate among female players compared to men. Pienimäki, Tarvainen, Siira, Malmivaara, and Vanharanta (2002) claimed that grip strength reduction up to 25% could be caused by previous injury (mainly tennis elbow) and because strength of the forearm (grip strength respectively) played the crucial role as well as muscular endurance due to the length characteristics of the match; it seemed to be important to maintain the ideal level of grip strength and to avoid overloading (Roetert & Kovacs, 2018). This approach could be helpful for prevention and performance optimization during the training process. Hutchinson, Laprade, Burnett, Moss, and Terpstra (1995) found the most common musculoskeletal injuries amongst the junior tennis players which included strains, sprains, and cramps. Tennis players at pubertal age could tolerate progressive training if it is interspersed by appropriate recovery time. But insufficient recovery will rise the risk factors such as fatigue, overtraining, and burnout. This could lead to increasing the injury risk, reducing the training effectiveness and performance dropping during the competitions. With years of training, changes are also visible in flexibility and strength on body parts that are subject to a repetitive movement and therefore tensile overload. Those maladaptation processes then alter proper function of joints and muscles and could be taken as injury risk factors or a cause that affects the performance. Compared to boys, girls have higher percentage of the injury mainly on the shoulders, wrists, and knees. This is due to a lower strength level in the upper body and inferior conditioning status comparing to their male rivals. With regards to handedness, a few percentages of players (3.6% among male and female) who play with the opposite hand to that used for tasks like writing could be, mainly due to sport-specific tasks (or sport-specific dominance), benefit from this advantage on the court (cross-dominance). So, while in some cases being left-handed could be disadvantageous in the competition (regulations, equipment, etc.), in some fast and quick sports such as tennis, left-handers are considered having more chance to success because of their weaker brain lateralization for specific tasks (Lawler & Lawler, 2011; Loffing et al., 2016; Vodička et al., 2018). This is also because laterality has been regarded as one of the significant factors for developing the talent (Sterkowicz, Lech, & Blecharz, 2010), considered inherited and developed through infancy (Kubota & Demura, 2011). It is believed that bilateral differences, or let's say sidedness, could cause a reduction in performance or predisposition to injury. The assessment of this (a) symmetries should be taken into consideration during the training process not only at the beginning but also as feedback to training effect (Loffing et al., 2016).

The purpose of the study was to evaluate the handgrip strength and its bilateral differences in the context of potential injury risk. The main purpose of the study was further divided into sub-goals which were identification of (1) the levels of somatic and strength characteristics, (2) the ratio of right-handed and left-handed players, (3) bilateral differences in handgrip strength between the dominant and non-dominant hand.

METHODS

The sample consisted of Czech female junior tennis players. Ages ranged between 11 and 12.9 years (n = 165, age: M ± SD = 12.00 ± 0.54, height: M ± SD = 155.08 ± 7.31 cm, weight: M ± SD = 43.86 ± 7.30 kg). Female players took part in the project testing called Complex diagnostics in tennis (1999) in the years 2000–2018. The testing battery TENDIAG1 (Zháněl et al., 2015) was used, especially research-related parts such as: base anthropometrics (height, weight) and maximal hand grip strength (HGS) using the handgrip dynamometer Takei T.K.K. 5401 GRIP-D (Takei Scientific Instruments Co. Ltd, Tokyo, Japan). The manufacturer states the results of HGS in kilograms (kg). The players' handedness for racket use in tennis was determined by asking which hand they use when playing forehand. This hand was labeled as the playing or dominant hand and the female players as right-handers (RH) or left-handers (LH). The formula BSA = Stronger limb – Weaker limb / Stronger limb x 100 (Bishop, Read, Lake, Chavda, & Turner, 2018) was used to calculate bilateral strength asymmetry (BSA). As the authors state, the values of BSA calculated in this way are about 45% higher than those calculated using the BAI-1 formula. The authors Bishop et al. (2018), Davies, Ellenbecker, and Wilk (2009) and Hepping, Ploegmakers, Geertzen, Bulstra, and Stevens (2015) consider bilateral differences >15.0% a high risk and bilateral differences >20% a very high risk in terms of potential injury.

Players always completed two attempts on each hand and the highest obtained score was considered as a result. The execution of the measurement was strictly controlled, every player had to keep her hand parallel to the body during standing without touching it with the elbow extended and the wrist in the neutral position. To assess the effect size (ES) for bilateral differences, we used the effect size index d (Cohen, 1988), which can be interpreted as a small (d = .2), medium (d = .5) or large effect (d = .8). The data was processed using the licensed software IBM SPSS Statistics (version 28.0, SPSS Inc., Chicago, IL USA).

RESULTS

Statistical analysis (Shapiro-Wilk test) showed that the data came from a normal distribution. Base statistical and anthropometric characteristics and maximal handgrip strength are presented in Table 1. Of the 87.3% (n = 144) of the cases, the sample consisted of right-handed (RH) players and the remaining 12.7% (n = 21) were left-handed (LH) players. It was obvious from Table 1 that in comparison to the mean value of the handgrip strength of the right hand (SRH = 23.11 kg) and the left hand (SLH = 20.75 kg), the result was in favor of the RH players. For verifying the significance of the differences in mean values for the strength of both hands (2.36 kg), we used Cohen's d and it showed the medium effect size (d = 0.51, medium).

Table 1. Basic statistical characteristics of the sample

Sample	Female players (*n* = 165)			
Variables	M	SD	min	max
Age (y)	12.00	0.54	11.0	12.9
Height (cm)	155.08	7.31	135.5	181.0
Weight (kg)	43.86	7.30	28.2	66.8
SRH (kg)	23.11	4.36	12.4	35.7
SLH (kg)	20.75	4.80	10.0	43.3

Note: SRH = strength of right hand, SLH = strength of left hand, M = mean, SD = standard deviation, y = years, cm = centimeter, kg = kilogram.

Table 2 shows the results of the assessment of bilateral differences between the stronger limb and the weaker limb obtained by calculating bilateral strength asymmetry (BSA). Out of 165 observed players, 71 of them (43.03%) had bilateral differences >15%. The strength difference >20% was found in 44 players (26.67%).

Table 2. The assessment of bilateral differences between the stronger and the weaker limb

Bilateral differences	*n*	%
RH vs LH	144 vs 21	87.27 vs 12.73
BSA >15%	71	43.03
BSA >20%	44	26.67

Note: BSA = bilateral strength asymmetry between stronger limb and weaker limb, RH = right-handers, LH = left-handers, >15% = bilateral strength differences >15%, >20% = bilateral strength differences >20%.

The results of the comparison of handgrip strength dominant (DH) and non-dominant hand (NDH) levels in right-handers (Table 3) and left-handers (Table 4) are supplemented by the percentage of players for whom bilateral differences between DH and NDH >15% were found. The right-handed players (Table 3) showed relatively high percentage of the strength differences (40.91%) between the dominant and non-dominant hand that exceeded the 15% strength level asymmetry.

Table 3. Bilateral differences between the dominant and non-dominant hand (RH players)

Handgrip strength	M ± SD	min	max	$D_{(R/L)}$ >15%
DRH (kg)	23.28 ± 4.28	12.40	35.70	40.91%
NDLH (kg)	20.04 ± 4.05	10.00	30.90	

Note: DRH = dominant right hand, NDLH = non-dominant left hand, M = mean, SD = standard deviation, D(R/L) = strength difference between DRH and NDLH higher than 15% percent, kg = kilogram.

The left-handed players (Table 4) showed similar tendencies and even higher percentage of the strength differences (43.06%), which was almost the half of the cases.

Table 4. Bilateral differences between the dominant and non-dominant hand (LH players)

Handgrip strength	M ± SD	min	max	$D_{(R/L)}$ >15%
DLH (kg)	25.60 ± 6.45	16.70	43.30	43.06%
NDRH (kg)	21.99 ± 4.71	15.00	32.40	

Note: DLH = dominant left hand, NDRH = non-dominant right hand, M = mean, SD = standard deviation, $D_{(R/L)}$ = strength difference between DLH and NDRH higher than 15% percent, kg = kilogram.

We also focused on comparison between dominant and non-dominant hand of the right-handers (RH, Table 3) and left-handers (LH, Table 4) which showed small differences between both dominant hands (M_{DRH} = 23.28 ± 4.28 kg, M_{DLH} = 25.60 ± 6.45 kg, *d* = 0.42, ES small) in favor of the LH players. The assessment of the dominant (DRH) and non-dominant (NDLH) bilateral differences was medium (M_{DRH} = 23.28 ± 4.28 kg, M_{NDLH} = 20.04 ± 4.05 kg, *d* = 0.78, ES medium) for RH players and also medium for LH players (M_{DLH} = 25.60 ± 6.45 kg, M_{NDRH} = 21.99 ± 4.71 kg, *d* = 0.64, ES medium).

DISCUSSION

The representation of left-handers in our study (12.73%) corresponds to the proportion of left-handed people (10–13%) in the population; data on higher representation in tennis were not shown. Also, a comparison of the proportion of left-handers among U12 female players and the results of studies by Holtzen (2000) and Loffing et al. (2012) among elite male and female players (Grand Slam finalists and winners) strongly favors elite players. The results of our study showed moderately significant bilateral differences between the right- and left-hand strength of all players (in favor of the right hand). The assessment of differences between RH and LH players showed only small differences in favor of LH players. Both RH and LH players showed moderately significant bilateral differences in favor of the dominant hand. There are only few comparable studies in the sport literature (Table 5), more authors have analyzed handgrip strength and bilateral differences in 11–12-year-old children (Butterfield & Lehnhard, 2009; Fredriksen, Mamen, Hjelle, & Lindberg, 2018; Gómez-Campos et al., 2018; Hepping et al., 2015; Kocher et al., 2017; Omar, Alghadir, Zafar, & Al Baker, 2018; Ploegmakers, Hepping, Geertzen, Bulstra, & Stevens, 2013).

Table 5. Hand grip strength and bilateral differences of different female participants (U12*)

Authors (Ch)	***n***	**SRH** (M ± SD)	**SLH** (M ± SD)	**BSA** (%)
1. Butterfield and Lenhard (2009)	69	23.1 ± 4.8	21.5 ± 4.5	3.59
2. Fredriksen et al. (2018)	284	17.4	16.1	3.88
3. Gómez-Campos et al. (2018)	313	18.8	17.5	3.58
4. Hepping et al. (2015), RH	195	22.6 ± 4.4	20.5 ± 4.1	4.87
5. Hepping et al. (2015), LH	24	21.6 ± 3.6	21.4 ± 3.8	0.47
6. Kocher et al. (2017)	398	25.9 ± 5.5	24.1 ± 5.3	3.60
Authors	***n***	**DH** (M)	**NDH** (M)	**BSA** (%)
7. ZeDI (unpub.), Tennis	166	22.8	20.3	5.80
8. Omar et al. (2018), Ch	92	17.5	16.8	2.04
9. Ploegmakers et al. (2013), Ch	219	22.3	20.6	4.21
10. Toong et al. (2018), Ice Hockey	107	21.1	20.3	1.93

Note: *n* = sample size, SRH = strength of right hand, SLH = strength of left hand, DH = dominant hand, NDH = non-dominant hand, Ch = Children, ZeDI = Zentrum für Diagnostik und Intervention im Sport (Ruhr-Universitaet Bochum), unpub. = unpublished, M = mean, SD = standard deviation, * = for studies reporting HGS values separately for ages 11 and 12, the values for U12 were calculated using a weighted arithmetic mean.

While 43.03% of research participants were found to have bilateral differences >15%, 26.67% were found to have differences as high as >20%. Comparison with the results of 10 studies showed significantly lower interlimb asymmetries in sets of children of the same age. The statistical characteristics of the BSA values from all 10 studies (BSA: M ± SD = 3.40 ± 1.55, range of variation:

0.47–5.80) are well below our results, with the highest value found in German tennis players (ZeDI, unpub.), while the majority of children have low values. Both these results and the results of our study support the assumption of a higher prevalence of interlimb asymmetries in some interactive sports. Values of bilateral strength asymmetry, especially differences >15% or >20%, must be considered – in agreement with Bishop et al. (2018), Davies et al. (2009) and Hepping et al. (2015) – as a risk factor for possible injuries not only in tennis.

CONCLUSION

The aim of the study was to assess bilateral differences in grip strength in Czech U12 female tennis players in the context of injury prevention. Significant bilateral differences were found between dominant (DH) and non-dominant hand (NDH) in both right-handed (RH) and left-handed (LH) players. Detected values of bilateral strength asymmetry >15% or >20% should be considered as a predictor of possible injuries (not only) in tennis.

Lateral asymmetry could be a cause of an injury or muscle imbalances. Players and coaches should take this into consideration and a proper exercise (or compensation) should be an important part of training. An exercise for eccentric external rotators strength may help with the balancing the antagonist group strength. This crucial exercise should be incorporated into the training process in tennis mainly due to repetitively performed explosive concentric and eccentric contractions. Tennis strokes are most of the time characterized by the so-called stretch-shortening cycle so training sessions should consist of exercises of concentric and eccentric character.

Acknowledgements
This publication was written at Masaryk University as part of the project "Laterality in the context of diagnostics of selected factors of sports performance in tennis and injury prevention" number MUNI/A/1637/2020 with the support of the Specific University Research Grant, as provided by the Ministry of Education, Youth and Sports of the Czech Republic in the year 2021. The Research Ethics Committee of Masaryk University reviewed the application to conduct the research project as specified above and on June 26, 2021, the Committee approved this project to be conducted.

Disclosure statement
No potential conflict of interest was reported by the authors.

References

Butterfield, S. A., & Lehnhard, R. A. (2009). Grip Strength Performances by 5- to 19-year-olds. *Perceptual and Motor Skills*, *109*(2), 362–370. doi:10.2466/pms.109.2.362-370

Bishop, C., Read, P., Lake, J., Chavda, S., & Turner, A. (2018). Interlimb Asymmetries: Understanding How to Calculate Differences from Bilateral and Unilateral Tests. *Strength & Conditioning Journal*, *40*(4), 1–6. doi:10.1519/SSC.0000000000000371

Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Science* (2nd ed.). Hillsdale, NJ: Erlbaum.

Colberg, R. E., Aune, K. T., Choi, A. J., & Fleisig, G. S. (2015). Incidence and Prevalence of Musculoskeletal Conditions in Collegiate Tennis Athletes. *Journal of Medicine and Science in Tennis*, *20*(3), 137–144.

Davies, G. J., Ellenbecker, T., & Wilk, K. E. (2009). Isokinetic Testing and Rehabilitation of the Shoulder Complex. In book: *The Athlete's Shoulder* (719–747). Edition: 2, Chapter: 54. London: Churchill Livingstone.

Domino, G., Świątkowski, P., & Matłosz, P. (2015). Characteristics and analysis of determinants for two-handed forehand in tennis. *Scientific Review of Physical Culture*, *4*(4), 253–263.

Ellenbecker, T. S., Roetert, E. P., Bailie, D. S., Davies, G. J., & Brown, S. W. (2002). Glenohumeral joint total rotation range of motion in elite tennis players and baseball pitchers. *Medicine & Science in Sports & Exercise*, *34*(12), 2052–2056. doi:10.1249/01.MSS.0000039301.69917.0C

Fredriksen, P. M., Mamen, A., Hjelle, O. P., & Lindberg, M. (2018). Handgrip strength in 6–12-year-old children: The Health Oriented Pedagogical Project (HOPP). *Scandinavian Journal of Public Health*, *46*(21_suppl), 54–60. doi:10.1177/1403494818769851

Fu, M. C., Ellenbecker, T. S., Renstrom, P. A., Windler, G. S., & Dines, D. M. (2018). Epidemiology of injuries in tennis players. *Current Reviews in Musculoskeletal Medicine*, *11*(1), 1–5. doi:10.1007/s12178-018-9452-9

Faurie, C., & Raymond, M. (2004). Handedness frequency over more than ten thousand years. *Proceedings of the Royal Society of London B: Biological Sciences*, *271*(Suppl 3), S43–S45. doi:10.1098/rsbl.2003.0092

Gómez-Campos, R., Andruske, C. L., de Arruda, M., Sulla-Torres, J., Pacheco-Carrillo, J., Urra-Albornoz, C., & Cossio-Bolaños, M. (2018). Normative data for handgrip strength in children and adolescents in the Maule Region, Chile: Evaluation based on chronological and biological age. *PLOS One*, *13*(8): e0201033. doi:10.1371/journal.pone.0201033

Hagemann, N. (2009). The advantage of being left-handed in interactive sports. *Attention, Perception & Psychophysics*, *71*(7), 1641–1648. doi:10.3758/APP.71.7.1641

Hepping, A. M., Ploegmakers, J. J., Geertzen, J. H., Bulstra, S. K., & Stevens, M. (2015). The influence of hand preference on grip strength in children and adolescents; a cross-sectional study of 2284 children and adolescents. *PLOS One*, *10*(11): e0143476. doi:10.1371/journal.pone.0143476

Holtzen, D. W. (2000). Handedness and professional tennis. *International Journal of Neuroscience*, *105*(1–4), 101–119. doi:10.3109/00207450009003270

Hutchinson, M. R., Laprade, R. F., Burnett, Q. M., Moss, R., & Terpstra, J. (1995). Injury surveillance at the USTA Boys' Tennis Championships: a 6-yr study. *Medicine & Science in Sports & Exercise*, *27*(6), 826–830.

Kocher, M. H., Romine, R. K., Stickley, C. D., Morgan, C. F., Resnick, P. B., & Hetzler, R. K. (2017). Allometric Grip Strength Norms for Children of Hawaiian Lineage. *The Journal of Strength & Conditioning Research*, *31*(10), 2794–2807. doi:10.1519/JSC.0000000000001711

Kovacs, M. S., Ellenbecker, T. S., Kibler, W. B., Roetert, E. P., & Lubbers, P. (2014). Injury trends in American competitive junior tennis players. *Journal of Medicine and Science in Tennis*, *19*(1), 19–24.

Kubota, H., & Demura, S. (2011). Gender differences and laterality in maximal handgrip strength and controlled force exertion in young adults. *Health*, *3*(11), 684–688. doi:10.4236/health.2011.311115

Lawler, T. P., & Lawler, F. H. (2011). Left-handedness in professional basketball: prevalence, performance, and survival. *Perceptual and Motor Skills*, *113*(3), 815–824. doi:10.2466/05.19.25.PMS.113.6.815-824

Loffing, F., Hagemann, N., & Strauss, B. (2012). Left-handedness in professional and Amateur tennis. *PLOS One*, *7*(11): e49325. doi:10.1371/journal.pone.0049325

Loffing, F., Hagemann, N., Strauss, B., & MacMahon, C. (Eds.). (2016). *Laterality in Sports: Theories and Applications*. Cambridge: Academic Press.

McCurdie, I., Smith, S., Bell, P. H., & Batt, M. E. (2017). Tennis injury data from The Championships, Wimbledon, from 2003 to 2012. *British Journal of Sports Medicine*, *51*(7), 607–611. doi:10.1136/bjsports-2015-095552

Omar, M. T., Alghadir, A. H., Zafar, H., & Al Baker, S. (2018). Hand grip strength and dexterity function in children aged 6–12 years: A cross-sectional study. *Journal of Hand Therapy*, *31*(1), 93–101. doi:10.1016/j.jht.2017.02.004

Pienimäki, T., Tarvainen, T., Siira, P., Malmivaara, A., & Vanharanta, H. (2002). Associations between pain, grip strength, and manual tests in the treatment evaluation of chronic tennis elbow. *The Clinical Journal of Pain*, *18*(3), 164–170. doi:10.1097/00002508-200205000-00005

Ploegmakers, J. J., Hepping, A. M., Geertzen, J. H., Bulstra, S. K., & Stevens, M. (2013). Grip strength is strongly associated with height, weight and gender in childhood: a cross sectional study of 2241 children and adolescents providing reference values. *Journal of Physiotherapy*, *59*(4), 255–261. doi:10.1016/S1836-9553(13)70202-9

Pluim, B. M., Loeffen, F. G. J., Clarsen, B., Bahr, R., & Verhagen, E. A. L. M. (2016). A one-season prospective study of injuries and illness in elite junior tennis. *Scandinavian Journal of Medicine & Science in Sports*, *26*(5), 564–571. doi:10.1111/sms.12471

Roetert, E. P., & Kovacs, M. (2018). *Tennis anatomy*. Champaign, IL USA: Human Kinetics.

Sterkowicz, S., Lech, G., & Blecharz, J. (2010). Effects of laterality on the technical/tactical behavior in view of the results of judo fights. *Archives of Budo*, *6*(4), 173–177.

Toong, T., Wilson, K. E., Urban, K., Paniccia, M., Hunt, A. W., Keightley, M., & Reed, N. (2018). Grip Strength in Youth Ice Hockey Players: Normative Values and Predictors of Performance. *The Journal of Strength & Conditioning Research*, *32*(12), 3494–3502. doi:10.1519/JSC.0000000000002815

Vodička, T., Zvonař, M., Pačes, J., Knjaz, D., Ružbarský, P., & Zháněl, J. (2018). Strength Values of Shoulder Internal and External Rotators in Junior Tennis Players. *Kinesiology*, *50*(2), 181–187. doi:10.26582/k.50.2.9

Zháněl, J., Černošek, M., Zvonař, M., Nykodým, J., Vespalec, T., & López Sánchez, G. F. (2015). Comparison of the level of top tennis players' performance preconditions (case study). *Apunts. Educació Física i Esports*, *122*(4), 52–60. doi:10.5672/apunts.2014-0983.es.(2015/4).122.06

Ziagkas, E., Mavvidis, A., Grouios, G., & Laios, A. (2017). Investigating the role of ipsilateral and contralateral eye-hand dominance in tennis serve accuracy of amateur tennis players. *Journal of Physical Education and Sport*, *17*(2), 867–870. doi:10.7752/jpes.2017.02132