Central European Journal of Sport Sciences and Medicine | Vol. 41, No. 1/2023: 25–33
ISSN (print): 2300-9705 | ISSN (online): 2353-2807 | DOI: 10.18276/cej.2023.1-03

GLENOHUMERAL JOINT RANGE OF MOTION IN CROSSMINTON PLAYERS

Tamara Lukáčová[A, C, D]

University of Presov, Faculty of Sports, Slovakia
ORCID: 0000-0002-7412-9523 | e-mail: tamara.lukacova@smail.unipo.sk

Rút Lenková[A, B, D]

University of Presov, Faculty of Sports, Slovakia
ORCID: 0000-0002-0713-2482

[A] Study Design; [B] Data Collection; [C] Statistical Analysis; [D] Manuscript Preparation

Abstract Crossminton is a sport that combines elements of squash, badminton and tennis, creating a new sport, which is currently being played all over the world. The aim of our study was to identify and compare the bilateral differences in the internal and external rotation of the glenohumeral joint of crossminton players. The subject of our study were 13 crossminton players from Slovak Republic (25.1 ±9.3 years; 172.8 ±9.1 cm; 71.8 ±16.1 kg). The range of motion of internal (IR-ROM) and external rotation (ER-ROM) of the glenohumeral joint was measured bilaterally using a standard two-arm goniometer. Bilateral comparison, decimal and sport age pairwise comparisons were carried using the T-test for independent samples. Results point to the occurrence of glenohumeral joint adaptation. Given the bilateral differences, the dominant shoulder has lower IR-ROM ($p < 0.05$) and higher ER-ROM ($p < 0.05$) than the non-dominant shoulder. GIRD (IR difference > 13 °) was observed in 4 players. The decimal age of the players did not have a significant impact on the rotation values of the glenohumeral joint. Only IR-ROM of the dominant upper limb was lower with the growing sport age of the players ($p < 0.05$). Given the fact that adaptations in ROM of glenohumeral joint promote an increased injury risk, the present study reveals the relevance of monitoring and finding differences between upper limbs in crossminton players.

Key words: racquet sport, shoulder joint, Internal rotation, external rotation, GIRD

Introduction

Tennis, which we consider to be the oldest racquet sport, is contributing to the constant increase in interest in racquet sports. However, non-traditional racquet sports also saw a significant increase in recreational players (Nhan et al., 2018). One of them is crossminton, which combines elements of tennis, badminton and squash. It represents a new dimension of racquet sports, in which players demonstrate specific functional changes of the glenohumeral joint that are accompanied by pain and movement restrictions.

Racquet sports are characterized by a variety of strikes that are repeated in a very short period of time. It is the constant repetition of specific one-side movements that is the determining factor of the development of muscle imbalance and damage to the musculoskeletal system, especially the upper limbs (Sánchez-Alcaraz et al., 2021; Courel-Ibáñez & Herrera-Gálvez, 2020; Kozel et al., 2019; Sanchis-Moysi et al., 2013; Abrams et al., 2012).

The glenohumeral joint is a part of the body that is not only the main area of concentration in improving the game, but also the part in which injuries often occur due to high loads and forces acting during the strike. The glenohumeral joint allows the greatest mobility and the greatest range of motion, which is an advantage for racquet sports players (Roetert & Kovacs, 2014). Due to the high demands on joint mobility, muscle strength and complex biomechanics of the shoulder girdle during the overhead movements, adaptations in the glenohumeral and scapulothoracal part of the body may already occur in adolescents (Cools et al., 2010; Silva et al., 2008; Ellenbecker & Roetert, 2003).

Injuries of the shoulder girdle in athletes, for whom overhead movements are typical, are mainly caused by repetitive movements (Olsen et al., 2006) or muscle fatigue (Hutchinson et al., 1995) and may be associated with scapular dyskinesis (Silva et al., 2008; Kawasaki et al., 2012), rotator cuff muscle injury or weakness (Bolach et al., 2019; Byram et al., 2010), or a deficiency in the internal rotation of the glenohumeral joint (Keller et al., 2018; Wilk et al., 2011; Shanley et al., 2011). If there is a change in the range of motion of the glenohumeral joint, the pressure on the front muscles of the shoulder increases and this can lead to the impingement syndrome (Świtoń et al., 2017; Kibler, 2014).

Lädermann et al. (2016) argue that most shoulder pain is caused by impact and instability of the shoulder joint due to repeated arm lifting and overhead movements. One of the most common rotational adaptations of the glenohumeral joint is the deficit of the internal rotation of the dominant arm, compared to the non-dominant one (GIRD). This deficit is one of the risk factors causing shoulder injuries (Kibler, 2014).

Several authors have been involved in measuring the range of motion of the glenohumeral joint of tennis players, badminton players and players of overhead sports. Therefore, the aim of our study was to identify and compare bilateral differences in the internal and external rotation of the glenohumeral joint of crossminton players.

Materials and Methods

Participants

The object of our research were 13 crossminton players representing the Slovak Republic at national and international tournaments. The participants characteristics included age (M = 25.1 ±9.3 years), height (M = 172.8 ±9.1 cm) and weight (M = 71.8 ±16.1 kg). The group consisted of 4 women (17 ±5.1 years, 163 ±7.6 cm, 52.5 ±11.7 kg) and 9 men (28.7 ±8.6 years, 177.1 ±5.7 cm, 80.3 ±8.4 kg) who are representatives of the crossminton clubs Lipany and Slávia University of Presov in categories Juniors under 14 (U14) and Juniors under 18 (U18), Women Singles and Open Singles. Average sport age of participants was 5.9 ±3.7 years. The study involved players who undergo regular trainings and their average training volume is 5.23 ±2 hours per week. All the players had a dominant right upper limb and none of the players reported any glenohumeral joint injuries during the previous 12 months.

To determine the effect of decimal age on glenohumeral joint rotations, we divided the players into 2 groups. The first consisted of players under 25 years and the second group of players over 25 years. We also performed a similar division of players into 2 groups when comparing the values of rotation with respect to the sports age of crossminton players. The first group consisted of players with a sports age of 2–4 years, the second group of players with a sports age of 6–12 years.

All players participating in the study were acquainted with its course and signed informed consent regarding the protection of personal data and the publication of measurement results for scientific purposes. The presented procedures were in accordance with the ethical standards on human experimentation and in compliance with the Declaration of Helsinki.

Measurement

Application of the chosen methodological standards was planned in one day of pre-season months. Measurements were taken during one training session in the sports hall. First of all, the players completed a questionnaire, which contained information about the decimal and sport age, training volume (hours/week), dominant upper limb and the history of glenohumeral joint injuries. Subsequently, the players performed a 15-minute warm-up, including forward/backward movements, sidestepping using a frequency ladder and mobilization exercises (i.e., arm circles, leg kicks) of individual parts of the body. Body height measurement using a fixed stadiometer and body weight measurement using the InBody 720 device were performed after the warm-up in this order. The last part was the measurement of external (ER-ROM) and internal rotation (IR-ROM) of the glenohumeral joint using a goniometer, which was performed in the presence of a physiotherapist.

The planimetric method of measuring joint mobility is mostly used to determine the range of motion in clinical practice. It is a measurement and recording of the angle between the segments, always for movement in one plane. It is often referred to as goniometric examination. To record the measurement of joint mobility SFTR method is used (Haladová & Nechvátalová, 2010; Kolář, 2009). We used a standard two-armed goniometer (KaWe) with scales marked in 1˚ increments to measure the range of motion of the glenohumeral joint of the dominant and non-dominant upper limb. The procedure for measuring individual movements was as follows: ER-ROM of the glenohumeral joint of the dominant upper limb, ER-ROM of the glenohumeral joint of the non-dominant upper limb, IR-ROM of the glenohumeral joint of the dominant upper limb, IR-ROM of the glenohumeral joint of the non-dominant upper limb. Three trials of each IR-ROM and ER-ROM tests were recorded and the mean value was used for the analysis. By summing the values of internal and external rotation, we obtained the total range of motion of the glenohumeral joint (TROM).

Test protocol

The starting position examined when measuring external rotation of the glenohumeral joint was the prone position with shoulder abduction at 90˚ and elbow flexion at 90˚,s. that the forearm hangs over the edge of the table. The physiotherapist fixed the distal part of the shoulder to avoid changing the angle of attachment. Subsequently, the proband was asked to move the forearm toward the head on its own until it reached the maximum range. We placed the center of the goniometer on the olecranon of the ulna. The stationary goniometer arm was placed parallel to the table edge and the movable goniometer arm was placed parallel to the forearm centerline. When measuring the internal rotation of the glenohumeral joint, the starting position of the proband was the same as when measuring the external rotation. However, the proband was asked to move the forearm toward the pelvis until it reached the maximum range. After attaching the goniometer, we read the values for the internal rotation. Values of ER-ROM and IR-ROM were with an accuracy of 1˚.

Statistical analysis

We performed statistical data processing using the program Statistica 13.5. The mean value and standard deviation were computed for all measured data. Shapiro-Wilk test was used to determine the normality of the data distribution and then T-test for independent samples was run to analyse bilateral comparison of IR-ROM and ER-ROM of the glenohumeral joint. We determined the comparison of rotation values between players depending on their decimal and sports age using a T-test for independent samples. For all tests, the significance level was set at $p < 0.05$.

Results

From the measured values of the internal and external rotation of the glenohumeral joint of all players, we calculated the mean and the standard deviation. We found the total range of motion (TROM) of the glenohumeral joint by the sum of the values of internal and external rotation (Table 1).

Table 1. Mean and Standard Deviation of Shoulder Range of Motion

_D shoulder	NonD shoulder			
	Mean	SD	Mean	SD
IR, ˚	51.46	6.12	60.23	5.90
ER, ˚	119.69	8.40	110.38	8.46
TROM,˚	170.54	10.02	169.85	12.05

D shoulder: dominant shoulder; NonD shoulder: nondominant shoulder; IR: internal rotation; ER: external rotation; TROM: total range of motion; SD: standard deviation

Bilateral rotation comparison

For all crossminton players, we recorded a higher ER value of the glenohumeral joint of the dominant shoulder. On the contrary, the dominant upper limb showed lower IR values for almost all players. The average value of the IR difference between the upper limbs was 11.85˚ and 4 crossminton players showed the occurrence of GIRD (IR difference > 13˚). T-test for independent samples revealed statistically significant bilateral differences between the rotations of the dominant and non-dominant upper limbs. ER was greater ($p < 0.05$) and IR less ($p < 0.05$) in the dominant upper limb. We did not find statistically significant bilateral differences in the total range of motion of the glenohumeral joint (Table 2).

Table 2. Shoulder Range of Motion Test Results of D and NonD Side

_D shoulder Mean ±SD	NonD shoulder Mean ±SD	t	p	
IR, ˚	51.46 ±6.12	60.23 ±5.9	–3.71	0.001*
ER, ˚	119.69 ±8.40	110.38 ±8.46	2.81	0.010*
TROM,˚	170.54 ±10.02	169.85 ±12.05	0.16	0.876

D shoulder: dominant shoulder; NonD shoulder: nondominant shoulder; IR: internal rotation; ER: external rotation; TROM: total range of motion; SD: standard deviation; *p < 0.05; T-test for independent samples

Age Comparison

Players were divided into two groups according to their decimal age: players with age under 25 years and players with age over 25 years. We did not find statistically significant differences in IR and ER values between these two groups of players (p > 0,05) (Table 3).

Table 3. Shoulder Range of Motion Test Results Between Different Age Groups

_Group 1 Mean±SD	Group 2 Mean ±SD	t	p	
ER D, °	121.67 ±11.06	118.00 ±5.66	0.77	0.46
ER NonD,°	108.50 ±11.90	112.00 ±4.32	–0.73	0.48
IR D, °	51.17 ±3.92	51.71 ±7.87	–0.15	0.88
IR NonD, °	58.33 ±6.53	61.86 ±5.24	–1.08	0.30

ER D: external rotation of dominant shoulder; ER NonD: external rotation of nondominant shoulder; IR D: internal rotation of dominant shoulder; IR NonD: internal rotation of nondominant shoulder; Group 1: age <25; Group 2: age >25; SD: standard deviation; *p < 0.05; T-test for independent samples

Crossminton Experience Comparison

We also performed a similar division of players into two groups according to their sports age: players with a sports age of 2–4 years and players with a sports age of 6–12 years. We did not notice a significant effect of sports age on the values of glenohumeral joint rotation in crossminton players, except for the IR of the dominant upper limb (Table 4).

Table 4. Shoulder Range of Motion Test Results Between Different Crossminton Experience Groups

_Group 1 Mean±SD	Group 2 Mean±SD	t	p	
ER D, °	116.33 ±4.97	122.57 ±9.98	–1.38	0.19
ER NonD, °	107.83 ±11.21	112.57 ±5.13	–1.01	0.34
IR D, °	55.50 ±5.86	48.00 ±4.00	2.73	0.02*
IR NonD, °	58.83 ±7.55	61.43 ±4.31	–0.78	0.45

ER D: external rotation of dominant shoulder; ER NonD: external rotation of nondominant shoulder; IR D: internal rotation of dominant shoulder; IR NonD: internal rotation of nondominant shoulder; Group 1: crossminton experience<5; Group 2: crossminton experience>5; SD: standard deviation; *p<0.05; T-test for independent samples

Discussion

In our study, we found that crossminton players also have adaptations to the glenohumeral joint due to the nature of the sport. We found that the dominant upper limb is characterized by increased values of external rotation and decreased values of internal rotation compared to non-dominant. We also noticed the occurrence of GIRD (IR bilateral difference >13˚) in some players.

A review by Anderton et al. (2018) points to a wide range of values for normal glenohumeral joint range of motion. Based on several studies, they report the average value of the external rotation of the glenohumeral joint as 83˚, while the obtained values were in the range of 40˚–117˚. 74˚ is considered as the average normal value of the internal rotation of the glenohumeral joint (30˚–110˚). The average value of the external rotation of the non-dominant shoulder found by crossminton players was 110.38˚, which is in line with the range according to the review. The average value of the internal rotation of the non-dominant shoulder of crossminton players was 60.23˚, which is also the value in the range of reported results. However, the rotation values of the dominant shoulder of crossminton players are slightly different from the average values of Anderton et al. (2018). The external rotation of the dominant shoulder of crossminton players (119.69˚) has a higher value compared to the authors' standards, while the internal rotation of the dominant shoulder (51.46˚) is much lower than their average value.

Even young racquet sports players (7–8 years old) may develop a muscle imbalance in the shoulder girdle (Cools et al., 2010). Several studies indicate that the athlete's dominant shoulder, compared to the non-dominant, is characterized by reduced internal rotation also known as glenohumeral internal rotation deficit (GIRD) (Wilk et al., 2015; Burkhart et al., 2003). Wilk et al. (2011) define GIRD as the difference ≥18˚ in the internal rotation of the dominant shoulder compare to the non-dominant one. Shanley et al. (2015) describe GIRD as the difference >13˚ between dominant and non-dominant upper limb in internal rotation in baseball players.

Chang et al. (2018) investigated internal and external rotation of the glenohumeral joint in beginner and advanced players. They found that advanced players showed a lower values of total range of motion than beginner players. Both groups showed lower internal rotation and higher external rotation of the glenohumeral joint of the dominant upper limb.

Nowadays adaptations of the glenohumeral joint occur more common in younger tennis players. Already in junior players, Cigercioglu et al. (2021) noticed decreased IR, and conversely increased ER and TROM of the dominant shoulder compared to the non-dominant. The same is confirmed by the author Fernandez-Fernandez et al. (2019), who were already found a growing trend in increasing the bilateral differences of IR in U15 category compared to the U13 category. Gillet et al. (2017) assessed changes of glenohumeral joint rotation in players aged 7–13 years. They found that the total range of motion of the glenohumeral joint gradually decreased with biological age due to a reduction of the internal rotation. The same phenomenon was reported by Cools et al. (2014), Nutt et al. (2018). In tennis players, they found a decreasing tendency of internal rotation and total range of motion of the glenohumeral joint. Kalo et al. (2020) confirmed a positive linear correlation between years of tennis experience and bilateral asymmetry of internal rotation. At the same time, they revealed a negative linear correlation between training duration and the ratio between internal and external rotation of the glenohumeral joint of the dominant upper limb. They also showed an association between reduced internal rotation of glenohumeral joint and shoulder injury.

Significant bilateral differences in the IR and TROM of the glenohumeral joint of tennis players compared to baseball and softball players were found by Oliver et al. (2020).

The occurrence of glenohumeral joint adaptation by badminton players has also been studied by several authors, but compared to tennis, there is significantly less research in this area. Dabholkar & Attili (2020), Dabholkar et al. (2018), Shimpi et al. (2015) found increase values of external and decreased values of internal glenohumeral joint rotation in both elite and novice badminton players, with a more pronounced difference in the dominant upper limb. The same results were found by Thasneem et al. (2020); Dabholkar et al. (2015).

Limitation of the Study

Some limitations in current study were observed. It is worth noting that the study was conducted on a group of crossminton players which additionally limits the sample due to the presented clubs. A group of 13 crossminton players is not able to show the details of adaptations of glenohumeral joint in crossminton players. In addition, the results of the study have possible bias in terms of gender differences or decimal and sports age. Therefore, the present study is illustrative and the first one in crossminton.

Conclusions

Based on the findings, we demonstrated the occurrence of functional changes in the glenohumeral joint of crossminton players. We found reduced values of the internal rotation of the glenohumeral joint of the dominant upper limb. Given the bilateral differences, we can state that the dominant upper limb has statistically significant lower values of internal rotation and higher values of external rotation compared to the non-dominant upper limb. We noticed the occurrence of GIRD in up to 4 players. The decimal age of the players did not have a significant influence on the glenohumeral joint rotation values. Only the value of the internal rotation of the dominant shoulder decreases with the increasing sport age of the players. Given the fact that an adaptations in range of motion of glenohumeral joint promote an increased injury risk, the present study reveals the relevance of monitoring and finding differences between upper limbs in crossminton players.

References

Abrams, G. D., Renstrom, P. A., & Safran, M. R. (2012). Epidemiology of musculoskeletal injury in the tennis player. *British Journal of Sports Medicine, 46*(7), 492–498. http://dx.doi.org/10.1136/bjsports-2012-091164

Anderton, M., Ede, M. N., & Holt, E. (2018). Normal range of motion of the shoulder: an imprecise benchmark. *Orthopaedic Proceedings*, 94.

Bolach, B., Walowska, J., & Bolach, E. (2019). Impact of physiotherapeutic procedures on the treatment of damaged rotator cuff muscules of the shoulder girdle. *Central European Journal of Sport Sciences and Medicine, 27*(3), 17–23. https://doi.org/10.18276/cej.2019.3-02

Burkhart, S. S., Morgan, C. D., & Kibler, W. B. (2003). The disabled throwing shoulder: spectrum of pathology. Part I: pathoanatomy and biomechanics. *Arthroscopy*, *19*(4), 404–420. https://doi.org/10.1053/jars.2003.50128

Byram, I. R., Bushnell, B. D., Dugger, K., Charron, K., Harrell, F. E., & Noonan, T. J. (2010). Preseason shoulder strength measurements in professional baseball pitchers: identifying players at risk for injury. *The American Journal of Sports Medicine*, *38*(7), 1375–1382. https://doi.org/10.1177/0363546509360404

Cigercioglu, N. B., Guney, H., Ünüvar, E., Colakoglu, F., & Baltaci, G. (2021). Shoulder Range of Motion, Rotator Strength, and Upper-ExtremityFunctional Performance in Junior Tennis Players. *Journal of Sport Rehabilitation*, *30*(8), 1–9. http://dx.doi.org/10.1123/jsr.2021-0038

Cools, A. M., Declercq, G., Cagnie, B., Cambier, D., & Witvrouw, E. (2008). Internal impingement in the tennis player: rehabilitation guidelines. *British Journal of Sports Medicine, 42*(3), 165–171. https://doi.org/10.1136/bjsm.2007.036830

Cools, A. M., Johansson, F. R., Cambier, D. C., Velde, A.V., Palmans, T., & Witvrouw, E. E. (2010). Descriptive profile of scapulothoracic position, strength and flexibility variables in adolescent elite tennis players. *British Journal of Sports Medicine, 44*(9), 678–684. https://doi.org/10.1136/bjsm.2009.070128

Cools, A. M., Palmans, T., & Johansson, F. R. (2014). Age-related, sport-specific adaptions of the shoulder girdle in elite adolescent tennis players. *Journal of Athletic Training, 49*(5), 647–653. https://doi.org/10.4085/1062-6050-49.3.02

Courel-Ibáñez, J., & Herrera-Gálvez, J. J. (2020). Fitness testing in padel: Performance differences according to players' competitive level. *Science & Sports, 35*(1), 11–19. https://doi.org/10.1016/j.scispo.2019.05.009

Dabholkar, A. S., Utekar, A. S., & Dabholkar, T. A. (2015). Scapula Associated Impairments in Badminton players. *Conference: HWWE*, 411–416.

Dabholkar, A. S., & Attili, S. (2020). Does glenohumeral external rotation gain and glenohumeral internal rotation deficit predict shoulder injury in novice and elite badminton players? *Medical Science, 24*(105), 3696–3704. http://www.discoveryjournals.org/medicalscience/current_issue/v24/n105/A113.pdf

Ellenbecker, T., & Roetert, E. P. (2003). Age specific isokinetic glenohumeral internal and external rotation strength in elite junior tennis players. *Journal of Science and Medicine in Sport, 6*(1), 63–70. https://doi.org/10.1016/s1440-2440(03)80009-9

Fernandez-Fernandez, J., Nakamura, F. Y., Moreno-Perez, V., Lopez-Valenciano, A., Coso, J. D., Gallo-Salazar, C., Barbado, D., Ruiz-Perez, I., & Sanz-Rivas, D. (2019). Age and sex-related upper body performance differences in competitive young tennis players. *PLOS One, 14*(9). https://doi.org/10.1371/journal.pone.0221761

Gillet, B., Begon, M., Sevrez, V., Berger-Vachon, Ch., & Rogowski, I. (2017). Adaptive Alterations in Shoulder Range of Motion and Strength in Young Tennis Players. *Journal of Athletic Training, 52*(2), 137–144. https://doi.org/10.4085%2F1062-6050.52.1.10

Haladová, E., & Nechvátalová, L. (2010) *Vyšetřovací metody hybného systému* (3th ed.). Brno: Národní centrum ošetřovatelství a nelékařských zdravotnických oborů.

Hjelm, N., Werner, S., & Renstrom, P. (2010). Injury profile in junior tennis players: a prospective two year study. *Knee Surgery, Sports Traumatology, Arthroscopy, 18*(6), 845–850. https://doi.org/10.1007/s00167-010-1094-4

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. https://drrobertlaprademd.com/wp-content/uploads/2015/07/injury-surveillance-at-usta-boys-tennis-championships-1995.pdf

Chang, B. F., Liu, Ch. Ch., & Chang, H. Y. (2018). Characteristic of shoulder and hip rotation range of motion in adolescent tennis players. *The Journal of Sports Medicine and Physical Fitness, 58*(4), 450–456. https://doi.org/10.23736/s0022-4707.16.06714-1

Kalo, K., Vogt, L., Sieland, J., Banzer, W., & Niederer, D. (2020). Injury and training history are associated with glenohumeral internal rotation deficit in youth tennis athletes. *BMC Musculoskeletal Disorders, 21*(1), 1–7. https://doi.org/10.1186/s12891-020-03571-0

Kawasaki, T., Yamakawa, J., Kaketa, T., Kobayashi, H., & Kaneko, K. (2012). Does scapular dyskinesis affect top rugby players during a game season? *Journal of Shoulder and Elbow Surgery, 21*(6), 709–714. https://doi.org/10.1016/j.jse.2011.11.032

Keller, R. A., Giacomo, A. F. D., Neumann, J. A., Limpisvasti, O., & Tibone, J. E. (2018). Glenohumeral Internal Rotation Deficit and Risk of Upper Extremity Injury in Overhead Athletes: A Meta-Analysis and Systematic Review. *Sports Health: A Multidisciplinary Approach, 10*(2), 125–132. https://doi.org/10.1177/1941738118756577

Kibler, B. W. (2014). Understanding the kinetic chain in tennis performance and injury. *Aspetar Sports Medicine Journal, 3*, 492–497. https://www.aspetar.com/journal/upload/PDF/2014102612491.pdf

Kolář, P. (2009). *Rehabilitace v klinické praxi*. Praha: Galén.

Kozel, M., Nechvátal, P., Mikuľáková, W., Cinová, J., & Hudáková, Z. (2019). The influence of active sport on the athlete's posture. *European Journal of Clinical and Experimental Medicine, 23*, 51–51.

Lädermann, A., Chagué, S., Kolo, F. C., & Charbonnier, C. (2016). Kinematics of the shoulder joint in tennis players. *Journal of Science Medicine in Sport, 19*(1), 56–63. https://doi.org/10.1016/j.jsams.2014.11.009

Nhan, D. T., Klyce, W., & Lee, R. J. (2018). Epidemiological Patterns of Alternative Racquet-Sport Injuries in the United States, 1997–2016. *Orthopaedic Journal of Sports Medicine, 6*(7), 1–7. https://doi.org/10.1177/2325967118786237

Nutt, C., Mirkovic, M., Hill, R., Ranson, C., & Cooper, S. M. (2018). Reference values for glenohumeral joint rotational range of motion in elite tennis players. *International Journal of Sports Physical Therapy, 13*(3), 501–510. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6044596/pdf/ijspt-13-501.pdf

Oliver, G. D., Downs, J. L., Barbosa, G. M., & Camargo, P. R. (2020). Descriptive profile of shoulder range of motion and strength youth athletes participating in overhead sports. *International Journal of Sports Physical Therapy, 15*(6), 1090–1098. https://doi.org/10.26603/ijspt20201090

Olsen, S. J., Fleisig, G. S., Dun, S., Loftice, J., & Andrews, J. R. (2006). Risk factors for shoulder and elbow injuries in adolescent baseball pitchers. *The American Journal of Sports Medicine, 34*(6), 905–912. https://doi.org/10.1177/0363546505284188

Roetert, E. P., & Kovacs, M. S. (2014). *Tenis – anatomie*. Brno: CPress, Albatros Media a.s.

Sánchez-Alcaraz, B. J., Martínez-Gallego, R., Llana, S., Vučković, G., Muñoz, D., Courel-Ibáñez, J., Sánchez-Pay, A., & Ramón-Llin, J. (2021). Ball Impact Position in Recreational Male Padel Players: Implications for Training and Injury Management. *International Journal of Environmental Research and Public Health, 18*(2), 435. https://doi.org/10.3390/ijerph18020435

Sanchis-Moysi, J., Idoate, F., Izquierdo, M., Calbet, J. A., & Dorado, C. (2013). The hypertrophy of the lateral abdominal wall and quadratus lumborum is sport-specific: An MRI segmental study in professional tennis and soccer players. *Sports Biomechanics, 12*(1), 54–67. https://doi.org/10.1080/14763141.2012.725087

Shanley, E., Rauh, M. J., Michener, L. A., Ellenbecker, T. S., Garrison, J. C., & Thigpen, Ch. A. (2011). Shoulder range of motion measures as risk factors for shoulder and elbow injuries in high school softball and baseball players. *The American Journal of Sports Medicine, 39*(9), 1997–2006. https://doi.org/10.1177/0363546511408876

Shanley, E., Kissenberth, M. J., Thigpen, Ch. A., Bailey, L. B., Hawkins, R. J., Michener, L. A., Tokish, J. M., & Rauh, M. J. (2015). Preseason shoulder range of motion screening as a predictor of injury among youthand adolescent baseball pitchers. *Journal of Shoulder and Elbow Surgery, 24*(7), 1005–1013. https://doi.org/10.1016/j.jse.2015.03.012

Shimpi, A. P., Bhakti, S., Roshni, K., Rairikar, S. A., Shyam, A., & Sancheti, P. K. (2015). Scapular Resting Position and Gleno-Humeral Movement Dysfunction in Asymptomatic Racquet Players: A Case-Control Study. *Asian Journal of Sports Medicine, 6*(4), 1–6. https://doi.org/10.5812%2Fasjsm.24053

Silva, R. T., Hartmann, L. G., Laurino, C. F., & Biló, J. P. (2008). Clinical and ultrasonographic correlation between scapular dyskinesia and subacromial space measurement among junior elite tennis players. *British Journal of Sports Medicine, 44*(6), 407–410. https://doi.org/10.1136/bjsm.2008.046284

Świtoń, A., Wnuk, A., Szumlański, J., & Wogórka, N. (2017). Assessment of the Progress of Treatment Rehabilitation of Patients with Shoulder Joint Diseases. *Central European Journal of Sport Sciences and Medicine, 20*(4). https://doi.org/10.18276/cej.2017.4-06

Thasneem, H., Afeef, T. V., & Heera, S. (2020). Glenohumeral Internal Rotation Deficit in Collegiate Asymptomatic Cricket Bowlers and Badminton Players. *Multidisciplinary Journal of Science and Technology, 2*(1). http://dx.doi.org/10.5958/0973-5674.2017.00072.7

Wilk, K. E., Macrina, L. C., Fleisig, G. S., Porterfield, R., Simpson, Ch. D., Harker, P., Paparesta, N., & Andrews, J. R. (2011). Correlation of glenohumeral internal rotation deficit and total rotational motion to shoulder injuries in professional baseball pitchers. *The American Journal of Sports Medicine, 39*(2), 329–335. https://doi.org/10.1177/0363546510384223

Wilk, K. E., Macrina, L. C., Fleisig, G. S., Aune, K. T., Porterfield, R. A., Harker, P., Evans, T. J., & Andrews, J. R. (2015). Deficits in glenohumeral passive range of motion increase risk of shoulder injury in professional baseball pitchers: a prospective study. *The American Journal of Sports Medicine*, *43*(10), 2379–2385. https://doi.org/10.1177/0363546515594380

Cite this article as: Lukáčová, T., Lenková R. (2023). Glenohumeral Joint Range of Motion in Crossminton Players. *Central European Journal of Sport Sciences and Medicine*, *1*(41), 25–33. https://doi.org/10.18276/cej.2023.1-03.