KINEMATICS OF SHOULDER JOINTS DURING TENNIS SERVE IN YOUNG FEMALE ATHLETES: INFLUENCE OF HISTORY OF SHOULDER PAIN

Benoit Gillet[1,2], Mickael Begon[2], Christian Berger-Vachon[3,4], and Isabelle Rogowski [1]

Laboratoire Interuniversitaire de Biologie de la Motricité, University of Lyon, Villeurbanne, France[1]
Laboratoire de Simulation et de Modélisation du Mouvement, Université of Montreal, Montréal, Canada[2]
Laboratoire de Biomécanique et Mécanique des Chocs, University of Lyon, Bron, France[3]
Ligue du Lyonnais de tennis,Bron, France[4]

The purpose of this work was to study the influence of the history of shoulder pain on the kinematic of shoulder joints during a tennis serve in competitive girls with (n=4) and without a history of shoulder pain (n=6). Players mimicked two tennis serves recorded with an electromagnetic device. T-tests were applied to the humerothoracic angles and the scapulothoracic angles. Results showed that competitive girls with a history of shoulder pain presented a decrease of humeral abduction and external rotation at the end of the cocking phase with no change in scapulothoracic angles. These findings may suggest a potential strategy used by players with history of shoulder pain to avoid pain in the serve.

KEY WORDS: Shoulder, tennis, serve, kinematic.

INTRODUCTION: Highly-skilled tennis players are commonly involved in an intensive practice since their childhood (DiFiori et al., 2014). Such a practice is known to be the main risk factor of overuse injuries in this population (DiFiori et al., 2014). These injuries mainly affect the shoulder complex and jeopardize the quality of life and the professional future of these young players. Injury prevention demands a better understanding of the tennis stroke influence on the shoulder of young competitive players.

The tennis serve is a decisive stroke to dominate the opponent (Abrams et al., 2011), but the mechanics of this motion requires critical joint position (Fleisig et al., 2003). At the end of the cocking phase, the humerus is abducted, extended and maximally externally rotated. Such a position creates a physiological contact between the glenoid of scapula and the humeral head (Mihata et al, 2012). Scapular mal-positioning, such as decreased upward rotation, increased anterior tilt or increased internal rotation, may augment the pressure and area of this contact, and then increase the risk for posterior or postero-superior impingement (Mihata et al, 2012). At impact, the humeral abduction between 100 and 120° (Rogowski et al., 2015) is also a critical position for subacromial impingement (Forthomme et al., 2008). Describing more precisely the kinematic of the tennis serve; in particular in girls with history of shoulder pain may then be useful to understand scapular positioning adaptation.

This study aimed to analyze the influence of the history of shoulder pain on the kinematic of the shoulder joints during the tennis serve. It was hypothesized that players with shoulder pain presented a decreased upward rotation at the end of the cocking phase.

METHODS: Ten competitive tennis girls (Age: 11.72 ± 1.32 years. height: 151 ± 10 cm. mass: 39.05 ± 6.34 kg) were volunteered to participate in this study. The study was approved by the Ethical Committee “Sud-Est II”. The players and parents signed an informed consent form. Although players were asymptomatic at the time of the experiment, they answered the following question: “Have you had a shoulder pain during the last 12 months?” The answers were secured with parents, coaches and their health record. Girls were included in the group with a history of shoulder pain (HSP) when the answer was yes; otherwise girls were included in the group without history of shoulder pain (NHSP).

Each player mimicked two tennis serves as accurate to their gesture on the court at slow velocity. During this motion, the humeral and scapular kinematics were recorded using an electromagnetic device (100Hz; Trackstar, Ascension Technology Corporation, Chicago, Ill) including six sensors. Two sensors were located on the flat part of the acromion (right and left), one sensor on the thorax and two sensors in the distal portion of the humerus (right and left). The sixth sensor was contained in a stylus used to digitalized 14 bony landmarks (incisura jugularis, processus xiphoideus, C7, T8, scapular angulus acromialis, trigonum scapulae, angulus inferior, humeral medial and lateral epicondyle). The glenohumeral joint center was estimated with functional method during circumvolutions (Wu et al., 2005). The latter were used to transform sensor data from a global coordinate system into anatomically based local coordinate systems (Wu et al., 2005). Raw kinematic data were filtered (low-pass 4^{th}-order Butterworth filter – 10 Hz) and Euler angle decompositions were used to calculate the scapular and humeral orientations. Scapulothoracic rotations were external(-)/internal(+) rotation, upward(-)/downward(+) rotation and anterior/posterior tilt. Humerothoracic rotations were abduction(-)/adduction(+), extension(-)/flexion(+) and external(-)/internal(+) rotation. The tennis serve was divided into three phases based on four key events (Figure 1): (1) the cocking phase, from the beginning of the serve, represented by the abduction at 70°of nondominant arm, to the maximal external rotation of the dominant arm, (2) the acceleration phase, from the maximal external rotation of the dominant arm to its position at the impact represented by its maximal abduction, (3) the follow through phase, from the impact position to the end of the tennis serve, represented by the minimal abduction of the dominant arm. The dominant humerothoracic and scapulothoracic orientation angles at each key-event were extracted and used for the statistical analysis. Student t-tests for independent samples were performed to compare the dominant humerothoracic and scapulothoracic orientations between groups with and without history of shoulder pain, using SPSS version 11.0 (SPSS, Inc., Chicago, IL.). The level of significance was fixed at $p \leq 0.05$.

RESULTS: Both groups presented similar demographic and tennis characteristics (Table 1). At the ball release, the humerus was abducted to 52°, extended to 8° and externally rotated to 20° while the scapula was internally rotated to 18°, anteriorly tilted to 11° and upwardly rotated to 16° (Figure 1). At the maximal external rotation, the humerus was abducted to 103°, flexed to 34° and externally rotated to 76° while the scapula was internally rotated to 26° and upwardly rotated to 33° (Figure 1). At the impact, the humerus was abducted to 112°, flexed to 37° and externally rotated to 67° while the scapula was internally rotated to 39°, anteriorly tilted to 9° and upwardly rotated to 33° (Figure 1). Finally, at the end of the serve, the humerus was flexed to 28° and internally rotated to 59° while the scapula was internally rotated to 50°, anteriorly tilted to 13° and upwardly rotated to 16° (Figure 1). Players with history of shoulder pain presented lower humeral abduction and external rotation at the maximal external rotation and higher humeral internal rotation at the end of the movement than players with no history of shoulder pain ($p=0.048$; $p=0.035$; $p=0.009$, respectively), while no significant differences were reported for the scapular orientation (Figure 1). Their scapula was also more upwardly rotated at the ball release ($p=0.04$) (Figure 1).

Table 1:
Mean (± standard deviation) of the demographic and tennis characteristics for the group with (HSP) and without (NHSP) history of shoulder pain

	HSP	NHSP
n	4	6
Age (years)	11.9 ± 1.8	11.6 ± 1.0
Height (cm)	149.3 ± 15.5	152.1 ± 6.0
Mass (kg)	38.5 ± 8.9	39.4 ± 4.9
Tennis Practice (years)	6.5 ± 2.5	6.7 ± 1.8
Weekly Tennis Training (hours)	8.8 ± 0.6	9.2 ± 2.1
Weekly physical training (hours)	2.7 ± 1.7	3.5 ± 4.2
Ranking (AU)	8.0 ± 8.0	7.2 ± 7.9

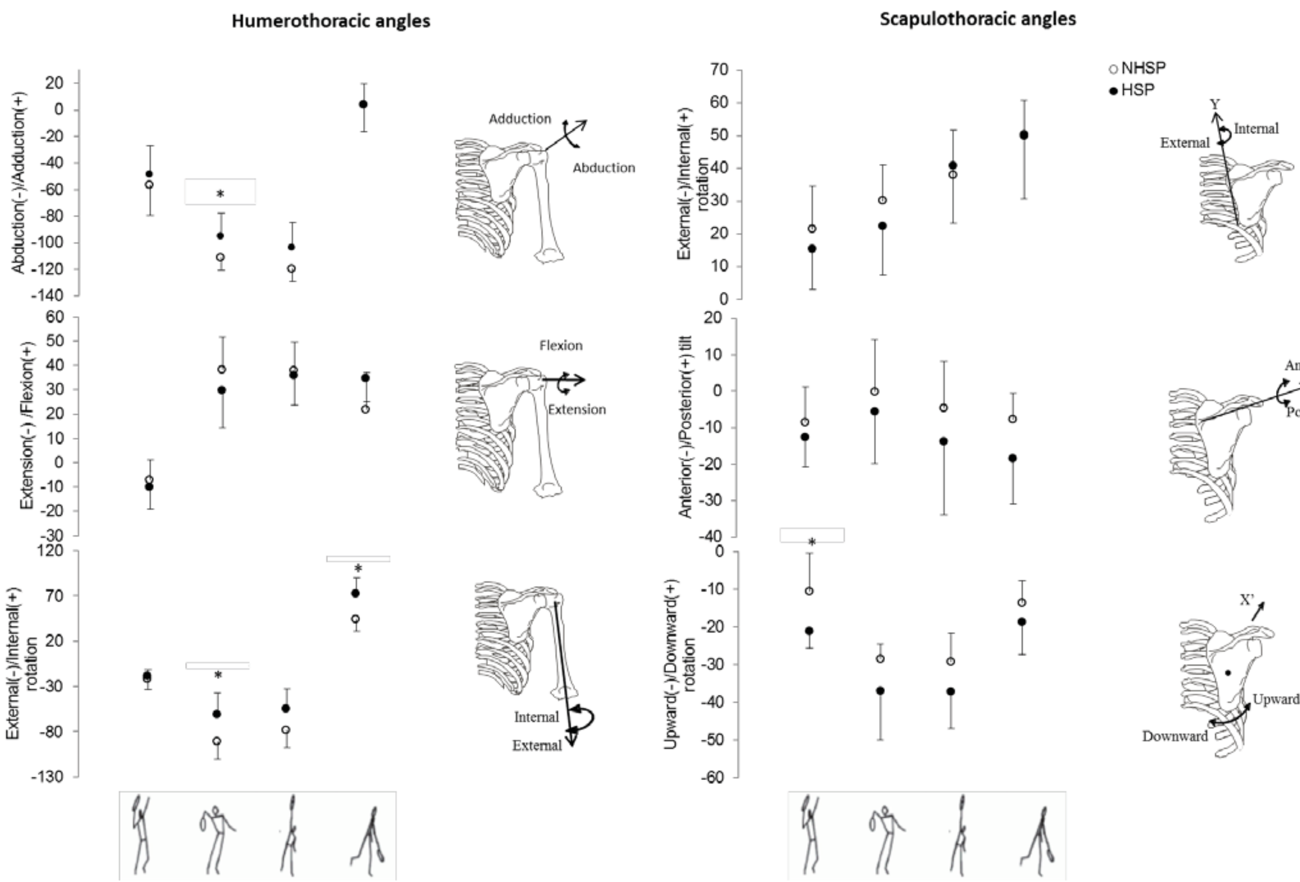

Figure 1: Mean and standard deviation of humerotoracic and scapulothoracic positionning in competitive tennis girl players with and without history of shoulder pain (NHSP and HSP) at the four key-events of the tennis serve. * for a significant difference at $p<0.05$

DISCUSSION: This study aimed to evaluate the influence of history of shoulder pain on the kinematic of shoulder joints during the tennis serve in competitive girl players. Girls with a history of shoulder pain presented lower humeral abduction and external rotation at the end of the cocking than healthy girls, whereas no difference in scapular positioning was observed between groups.

The tennis serve is characterized by four key events; the ball release, the maximal external rotation, the impact and the end of the motion (Rogowski et al, 2015). Precisely, the maximal external rotation is defined by a humerus abducted to 94°, flexed to 33° and externally rotated to 132° as well as a scapula internally rotated to 44°, anteriorly tilted to 21° and upwardly rotated to 12° (Rogowski et al, 2015). The impact presents a humerus abducted to 103°, flexed to 22° and externally rotated to 76° as well as a scapula internally rotated to 61°, upwardly rotated to 17° and anteriorly tilted to 37° (Rogowski et al, 2015). Althougth our serves were mimicked, the humerothoracic and scapulothoracic positions at the key-events were similar to those of the real tennis serve in adult tennis players, except for the external rotation at the maximal external rotation minimized by the soft tissue artefact (Rogowski et al, 2015). As the mimicked serve presented similar humerothoracic and scapulothoracic position than the real tennis serve, we could then assume that the difference between our two groups was mainly the consequence of the history of shoulder pain.

The achievement of the tennis serve requires coordinated motions of the humerus and the scapula (Rogowski et al, 2015). As previously described, alterations in scapular orientation jeopardizes shoulder integrity (Mihata et al., 2012; Abrams et al., 2011). Contrary to our hypothesis; players with a history of shoulder pain presented similar scapular positioning at the key-events of the tennis serve than those with no history of shoulder pain. However, a decrease in humeral abduction and external rotation at the end of the cocking phase were related to the history of shoulder pain. The supraspinatus is primary involved in the humeral

abduction, and the teres minor and infraspinatus muscles in the humeral external rotation. These rotator cuff muscles are very vulnerable to tendinopathies particularly in tennis players (DiFiori et al, 2014). Indeed, these rotator cuff muscles are intensely and eccentrically involved to stabilize the humeral head in the acceleration and follow-through phases (Kibler et al, 2007). Their tendons are also regularly impinged between the humeral head and the glenoid of scapula at the end of the cooking phase (Mihata et al., 2012). A decrease in humeral abduction and external rotation in this phase for player with history of shoulder pain might be an adaptive strategy to avoid pain and preserve the rotator cuff muscles while keeping the tennis serve performance.
The main limitation of this study was the number of participants, limiting the statistical power, and the check of the assumption of normality. Moreover by including young competitive girl aged to 10 to 13 years old, our results cannot be generalized to tennis players of different sex or age. Furthermore, serves were mimicked that may not represent the real kinematic of shoulder joints. Finally, this study was retrospective with the historical information about shoulder pain reported by players. The latter could be lacking in precision. Futures studies need to confirm our results with a larger population in real tennis condition, particularly in the joint ranges of motion. However, this study was the first to evaluate the influence of the history of shoulder pain on the kinematics of shoulder joints in young competitive girl during tennis serve. It rings useful information to understand how players with history of shoulder pain may adapt their motion to avoid pain and preserve their performance.

CONCLUSION: Competitive girls with a history of shoulder pain presented a decrease in humeral abduction and external rotation in comparison with those without history of shoulder pain, with no alteration in the scapular positioning at the end of the cocking phase. Such adaptations may avoid pain caused by the physiological contact between the humeral head and the glenoid and preserve the performance.

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