Shoulder flexibility and strength in elite girl tennis players with and without history of shoulder pain

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This study aimed at comparing the glenohumeral (GH) range of motion, and shoulder and scapular muscle strength in elite girl tennis players with (group HoSP; n=15) and without (group H; n=16) history of shoulder pain. The GH joint range of motion in internal (IROM) and external rotation (EROM), as well as the maximal isometric strength of eight shoulder and scapular muscles were bilaterally assessed in 31 girl players. The results showed an increased IROM in HoSP, suggesting a laxity, which may contribute to humeral translation motions in the glenoid cavity at critical tennis positions. The HoSP group also presented a weakness in serratus anterior muscle strength, which may create improper motions of the scapula during the tennis strokes. These findings suggested that stretching and strengthening rehabilitative programs may be specifically developed for the young girl athletes involved in an intensive overhead activity practice.

KEYWORDS: overhead sport; range of motion; scapular muscles; injury; isometric strength

INTRODUCTION: Tennis players need to intensively practice since their childhood to perform at professional level (Cools et al., 2014). The repetitive, unilateral and overhead nature of tennis strokes makes them potentially injurious for the dominant shoulder (Cools et al, 2014). In response to the repeated high musculoskeletal loads, the shoulder joint presents some sport-specific adaptations such as a decrease in IROM, not fully compensated by the increase in EROM at the dominant GH joint; and an increase in the strength of the internal rotator muscles (IR) at the dominant shoulder in larger proportions than the external rotator muscles (ER). The GH internal rotation deficit and the unbalanced ER/IR strength ratio are common markers of symptomatic shoulder, and stretching and strengthening programs, developed for adult athletes, are commonly recommended for athletes of any years, to counteract these deleterious adaptations (Ellenbecker et al, 2010). The recent kinematic analysis of the scapulothoracic joint revealed different adaptations in scapular motions between asymptomatic and symptomatic shoulders during arm elevation, suggesting the need for an optimal balance activation of the scapular muscles to maintain the congruence of the humeral head in the glenoid cavity during arm motions (Cools et al, 2014). Few data are however available on shoulder flexibility and on shoulder and scapular muscle strengths for the young tennis players engaged in an intensive practice, and especially in girls.

This study aimed at comparing the GH range of motion, and shoulder muscle strength in elite girl tennis players with and without history of shoulder pain. It was hypothesized that the dominant GH IROM, the ER/IR strength ratio, and the scapular ER muscle strength would be lower for the shoulders with a history of pain than for the healthy shoulders.

MATERIEL AND METHODS: Thirty-one elite girls (Table 1) were volunteered to participate in this study (IRB 00009118). All players and parents gave their written informed consent. The players were assigned into two groups, according to their history of shoulder pain; the group H for the players with no history of shoulder pain and the group HoSP for the players having declared a history of shoulder pain at the dominant side.

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

	H	HoSP
n	16	15
Age (years)	11.9 ± 1.3	12.0 ± 1.5
Height (cm)	153.2 ± 6.8	152.7 ± 11.9
Mass (kg)	37.8 ± 5.8	41.5 ± 7.7
Tennis Practice (years)	5.6 ± 1.7	5.9 ± 1.8
Weekly Tennis Training (hours)	9.1 ± 1.4	8.7 ± 2.1
Weekly physical training (hours)	2.3 ± 1.1	2.1 ± 1.3
Ranking (AU)	10.6 ± 5.1	10.3 ± 6.0

IROM and EROM were bilaterally assessed twice according to the Ellenbecker and Cools' recommendations (2010). The mean of both IROM and both EROM values were used for subsequent analysis, and to calculate the Total Arc of Motion (TAM).

The maximal isometric strength of the shoulder and scapular muscles was bilaterally measured by the same examiner using a hand-held dynamometer (HHD; microFET2; Hoggan Health Industries Inc, West Jordan, Utah, USA). Each isometric strength test was repeated twice for the shoulder internal (IR) and external (ER) rotator muscles, and upper trapezius (UT), middle trapezius (MT), lower trapezius (LT), latissimus dorsi (LD), serratus anterior (SA) and rhomboids (RH) muscles (Cools et al., 2010). The highest value for each muscle was divided by the body weight and multiplied by 100 to calculate the relative strength allowing for the inter-individual comparisons. Strength ratios, such as ER/IR; UT/MT, UT/LT; UT/SA; LT/SA were also computed (Cools et al, 2010).

All data are presented as mean ± standard deviation. Independent t-tests were applied to compare the demographic and tennis characteristics of both groups. ANalysis Of VAriance with one independent factor (*group*: healthy vs. history of shoulder pain) and repeated measures (*laterality*: dominant vs nondominant sides) were performed to compare the range of motion, relative strength and strength ratios in both groups. In case of significant effect, post hoc comparisons were made. For all statistical tests, the significance level was set at $p \leq 0.05$, using the Bonferroni's correction when necessary.

RESULT: No significant differences were found for the demographic and tennis characteristics (Table 1). As regard to flexibility (Table 2), ANOVA revealed a significant *group* effect for IROM (p=0.045), and a significant *laterality* effect for IROM (p=0.002) and EROM (p=0.009). No significant effect was found for TAM. The group HoSP presented higher IROM values. In both groups, the dominant shoulder displayed a reduced IROM and an increased EROM compared to the nondominant side.

Table 2:
Mean (± Standard deviation, in degrees) for the internal (IROM) and external (EROM) range of motion, and Total Arc of Motion (TAM) in the healthy group (H) and the group with a history of shoulder pain (HoSP).

	H		HoSP		
	Dominant	Nondominant	Dominant	Nondominant	
IROM	69 ± 6	74 ± 6	74 ± 5	76 ± 8	*,††
EROM	81 ± 6	78 ± 7	83 ± 8	80 ± 7	††
TAM	150 ± 6	152 ± 11	157 ± 12	156 ± 13	

* Pain effect with * for p<0.05, and ** for p <0.01 † Laterality effect with † for p<0.05, and †† for p<0.01

Concerning the muscle strength (Table 3), ANOVA reported a significant *group* effect for relative strength of the MT (p=0.04) and SA (p=0.006) muscles. Relative strength values in the group HoSP were higher for MT and lower for SA as compared to the group H. ANOVA also revealed a significant *laterality* effect for the relative strength of the IR (p=0.001), MT (p=0.001) and LD (p=0.005) muscles. For these three muscles, the dominant side presented higher values than the nondominant side. The relative strength of ER, UT, LT and RH muscles presented no significant difference either between sides or between groups.

Table3:
Mean (± Standard deviation, in percentages) for the maximal isometric relative strength of the internal rotator (IR), external rotator (ER), upper trapezius (UT), middle trapezius (MT), lower trapezius (LT), serratus anterior (SA), latissimus dorsi (LD) and rhomboid (RH) muscles in the healthy group (H) and the group with a history of shoulder pain (HoSP).

	H		HoSP		
	Dominant	Nondominant	Dominant	Nondominant	
IR	31 ± 6	28 ± 6	29 ± 5	25 ± 5	††
ER	26 ± 5	26 ± 5	26 ± 5	24 ± 4	
UT	73 ± 12	70 ± 16	66 ± 13	66 ± 16	
MT	11 ± 7	10 ± 5	17 ± 11	15 ± 10	*,††
LT	9 ± 3	8 ± 2	10 ± 4	10 ± 4	
SA	58 ± 14	60 ± 17	44 ± 18	42 ± 19	**
LD	14 ± 4	13 ± 3	15 ± 5	14 ± 6	††
RH	45 ± 9	46 ± 9	41 ± 16	42 ± 13	

* Pain effect with * for p<0.05, and ** for p <0.01; † Laterality effect with † for p<0.05, and †† for p<0.01

A significant *laterality* effect (Table 4) was found for ER/IR (p=0.002) and UT/MT (p=0.02), which were lower in the dominant side compared to the nondominant one. ANOVA revealed a significant effect of the interaction between *group* and *laterality* for UT/SA (p=0.03) and LT/SA (p=0.013). The dominant LT/SA value was higher than the nondominant one in the group H, while the dominant LT/SA value was lower than the nondominant one in the group HosP. The UT/SA was similar for both sides in the group H, while dominant UT/SA was lower than the nondominant one in the group HoSP. For both sides, the LT/SA and UT/SA values were higher in the group HoSP compared to the group H.

Table 4:
Mean (± Standard deviation) for the maximal isometric strength ratios in the healthy group (H) and the group with a history of shoulder pain (HoSP), with ER for external rotator, IR for internal rotator, UT for upper trapezius, MT for middle trapezius, LT for lower trapezius, and SA for serratus anterior muscles.

	H		HoSP		
	Dominant	Nondominant	Dominant	Nondominant	
ER/IR	0.9 ± 0.1	1.0 ± 0.1	0.9 ± 0.2	1.0 ± 0.2	††
UT/MT	7.2 ± 2.1	8.1 ± 2.3	5.8 ± 3.4	6.4 ± 3.6	†
UT/LT	8.8 ± 2.9	9.2 ± 2.3	7.5 ± 2.9	7.7 ± 3.2	
LT/SA	0.2 ± 0.1	0.2 ± 0.1†	0.3 ± 0.2	0.4 ± 0.3†	a,b
UT/SA	1.3 ± 0.4	1.3 ± 0.5	1.7 ± 0.7	2.0 ± 1.1†	a,b

† Laterality effect with † for p<0.05, and †† for p<0.01; a difference between groups for the dominant side, with a for p<0.05; b difference between groups for the nondominant side, with b for p<0.05

DISCUSSION: The main result of this study showed that the girls with a history of shoulder pain presented higher GH joint IROM values than the healthy girls. They also had higher relative strength values of the MT muscle and lower relative strength values of the SA muscle, hence conducting to unbalanced strength ratios between LT and SA, and between UT and SA muscles, than the healthy girls.

The unilateral repetitive nature of the tennis activity involved specific adaptations at the shoulder joint in terms of flexibility and strength. Both groups presented decreased IROM, increased EROM, and maintained TAM at the dominant GH joint as compared to the nondominant one (Table 2) that could be explained by the stiffness of the soft-tissues and the humeral retroversion, respectively (Cools et al., 2014). A dramatic loss in GH joint IROM was commonly associated to the shoulder injury in overhead throwing athletes (Cools et al, 2014); in our study, the girls with a history of shoulder pain surprisingly presented higher IROM values than the healthy girls. This increased GH IROM could be due to an innate laxity or an acquired laxity resulting from the recommended stretching programs scheduled at this age (Ellenbecker et al, 2010). In both cases, such a laxity may contribute to humeral translation motions in the glenoid cavity at critical tennis positions, and thus to impingement syndromes (Charbonnier et al., 2014).

Regarding the relative muscle strength, the IR and LD muscle strength values were higher in the dominant side than in the nondominant one for both groups. This may be related to the high contribution of arm internal rotation to generate the racket velocity during the acceleration phase of the tennis serve and forehand drive. Similar adaptation of the dominant TM muscle was observed in our two groups (Table 3), which could be related to its concentric action to place the scapula in external rotation during the cocking phase of the serve (Rogowski et al, 2015) and during the backswing of the forehand drive (Rogowski et al., 2014) as well as to its eccentric action during the follow-through phase of the tennis strokes. In addition, the strength of the IR muscles increased in a larger extend than that of the ER muscles (Cools et al, 2014), leading to lower ER/IR strength ratio in the dominant side (Tables 3 & 4). The similar values for the dominant ER/IR strength ratio observed in both groups did not support our initial hypothesis, and previous findings, which associated unbalanced ER/IR ratio to shoulder injury (Cools et al, 2014). The lack of relationship between ER/IR strength ratio and history of shoulder pain in the present study as well as the higher strength for the TM muscle in the girls with history of shoulder pain may attest that the recommended rehabilitative strengthening program was included into the conditioning training. Unfortunately, such programs seem to disregard the crucial function of the SA muscle in the scapular motions, as this muscle presented lower strength in the girls with a history of shoulder pain compared to healthy girls (Table 3). The SA muscle is involved to posteriorly tilt the scapula to achieve the maximal humeral external rotation during the cocking phase of the serve, and to upwardly rotate the scapula to preserve the amount of area in the subacromial space for the maximal humeral abduction (Rogowski et al, 2015). A weakness in SA muscle may lead to a nonoptimal scapular muscle force couple, as suggesting by the unbalanced LT/SA and UT/ SA strength ratios (Table 4), and may thus create improper motions of the scapula at critical positions during the tennis strokes.

CONCLUSION: The shoulder complex is a vulnerable region as it requires dual competing functions of mobility and stability to achieve the tennis strokes. The girl tennis players with a history of shoulder pain presented a laxity in IROM and a weakness in SA muscle strength suggesting that stretching and strengthening rehabilitative programs should be specifically developed for the young girl athletes involved in an intensive overhead activity practice.

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