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The short-term effectiveness of scapular focused taping on scapular movement in tennis players with shoulder pain
A within-subject comparison

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Abstract

This study aimed to investigate the short-term effectiveness of scapular focused taping (SFT) on scapular position and kinematics during the tennis serve among professional players with and without shoulder pain. The cohort included 7 players who had no history of non-shoulder pain (NSP) and 6 players with shoulder pain (SP). All participants performed tennis flat serves while the Qualisys motion capture system recorded three-dimensional scapular kinematic data according to the International Society of Biomechanics recommendations. SFT was applied to the participants' torso aligned with the lower trapezius, and the same movements were repeated. In the SP group, the scapula was tilted more posteriorly after the application of SFT as compared to before at ball release and maximally externally rotated humerothoracic joint during tennis serve ($t = -5.081$, $P = .004$ and $t = -2.623$, $P = .047$, respectively). In the NSP group, the scapula was tilted more posteriorly with SFT as compared to without at first 75% timing of the cocking phase and maximally externally rotated humerothoracic joint ($t = -3.733$, $P = .010$ and $t = -2.510$, $P = .046$, respectively). And the SP group exhibited a more rotated scapula externally after the application of SFT as compared to before at Ball impact ($t = 5.283$, $P = .003$). SFT had a positive immediate effect on the scapular posterior tilting and external rotation during certain phases of the tennis serve among tennis athletes with and without shoulder pain. These findings may help clinicians and sports practitioners to prevent and rehabilitate shoulder injuries for overhead athletes.

Level of evidence: Level III; Case-Control Design; Comparative Study.

Abbreviations: NSP = non-shoulder pain, SFT = scapular focused taping, SP = shoulder pain.

Keywords: scapula, serve, shoulder injury, taping, tennis

1. Introduction

The tennis serve is a crucial stroke to gain ascendancy in a point, accounting for 45% to 60% of total strokes in one game.[1,2] Overhead throwing motions, such as the overhead stroke in tennis, are the fastest athletic movement performed in sports, during which the shoulder is exposed to extreme multidirectional forces.[3,4] These forces are often applied at the expense of the normal kinematics of the shoulder joint, which can result in a variety of pathologic changes and injuries at this joint.[5] The National Collegiate Athletic Association Injury Surveillance System reported that upper extremity injuries in 15 sports account for 18% to 21% of all injuries, and overhead athletes are at a particularly high risk of shoulder injury of up to 30%.[6,7] In the overhead sport tennis, all-level players have an injury incidence of 0.04 to 3.0 injuries per 1000 hour of tennis played, and up to 50% of all tennis-related injuries occur in the upper extremities.[1,8]

Several modifiable risk factors for shoulder injury among throwing athletes include reduced glenohumeral internal rotation, excessive glenohumeral external rotation, reduction of total glenohumeral rotation, rotator cuff strength, external rotation weakness, and low ratios of concentric and eccentric external to internal rotation strength.[9–11] Recently, scapular dyskinesis was identified as a risk factor for shoulder injuries in overhead athletes.[10,12] Shoulder injuries and pain were found to be related to an increase in upper trapezius muscle activity and reduction in lower trapezius and serratus anterior activities.[13–15] These changes impair the upward rotation, posterior tilt, and external rotation of scapula during overhead activities,[16–18]

and in addition, a deficit in the centralization of the humeral head into the glenoid cavity may occur.[14] Therefore, although no direct relationship was established between scapular position and/or movement and specific shoulder pathology, scapular movement strategies specific to changes in scapular position and movement should be included in the treatment or rehabilitation process.[19,20]

A variety of conservative treatments, such as rest, medical treatment, steroid injections, various conventional methods of physical therapy and exercises, and kinesiology taping, have been used to relieve pain, maintain joint function, and prevent exacerbation of shoulder injuries.[21] Among these methods, application of kinesiology taping is a relatively novel option that is widely used regardless of the level of skill, gender, and age,[21] and is known to reduce edema, relieve pain, increase muscle activity of the para-scapular muscles, and improve functional activity and joint positioning.[22] Hsu et al[23] reported that elastic taping, such as kinesiology taping, resulted in increased lower trapezius activity and positive scapular movement in baseball players with impingement syndrome. Ozer et al[24] reported that taping, regardless of the material, improved scapular dyskinesis and pectoralis minor length in overhead athletes. Although there has been much debate in the literature about whether or not taping is beneficial in patients and athletes with shoulder pain,[25,26] many scholars and practitioners believe that it merely provides mechanical stabilization, rather than therapeutic efficacy.[25] Therefore, this study aimed to investigate the short-term effectiveness of scapular focused taping (SFT) on scapular position and kinematics during overhead activity among tennis athletes with shoulder pain. We hypothesized that application of SFT on the lower trapezius would increase upward rotation, posterior tilting, and external rotation, and decrease the angular velocity and joint moment of each scapular movement during the tennis serve.

2. Materials and Method

2.1. Study design

This study using a within-subject design was approved by the institutional review board of Pukyong National University. To evaluate the short-term effectiveness of SFT on scapular movement during the flat serve among tennis players with and without shoulder pain, SFT was applied to their torso aligned with the lower trapezius. The scapular position in five events, angular velocity, and moment of scapular movement in four phases during the serve were analyzed. Experiments were conducted in an indoor tennis court for three-dimensional analysis, and all participants performed a warm-up of at least 15 minutes with their own racquet to prevent injury and adapt to the experimental environment. All tests were carried out on the same day.

2.2. Participants

A total of 13 professional tennis players took part in the study, including 7 players who had no dysfunction during full arm elevation and/or history of non-shoulder pain (NSP) in the 6-month period preceding this study (age: 21.29 ± 1.38 yrs; height: 172.42 ± 9.13 cm; weight: 68.86 ± 7.34 kg; years playing tennis: 12.00 ± 2.38 yrs), and 6 players with shoulder pain (SP) with all three positive results for Hawkins–Kennedy test, Neer test, empty can test, and painful arc test (age: 21.83 ± 0.75 yrs; height: 173.33 ± 16.04 cm; weight: 68.00 ± 12.50 kg; years playing tennis: 10.83 ± 1.94 yrs). There were no significant differences in demographic data between the two groups, and all participants signed a statement of informed consent prior to participation in the study.

2.3. Data collection

Kinematic data were collected in an indoor tennis court using the Qualisys motion capture system (Qualisys AB, Sweden) consisting of 10 infrared cameras (7+, Qualisys AB) sampling at 200 Hz and a 1-color video camera (Oqus 2c, Qualisys AB). The marker set included 11 markers (diameter of 14 mm), located to the spinous processes of the 7th cervical and 8th thoracic vertebrae, suprasternal notch, xiphoid process, acromioclavicular joint, middle of scapular spine, root of the scapular spine, inferior angle of scapula, acromial angle of the scapula, glenohumeral rotation center, and elbow medial and lateral epicondyles of the participants' dominant arm according to the International Society of Biomechanics recommendations.[27] An additional acromion marker cluster was attached to the meeting point between the acromion and scapula spine, and the reflective markers were attached to the participants' own racquet and tennis ball to register the impact event. The specific static model calibration for each participant defined the scapulothoracic joint motion axes and planes.

Before the measurement of scapular movement, all participants performed the 15-minute warm-up and were educated to perform 12 flat serves to land the ball in the service box at their greatest velocity.[28] Subsequently, SFT was applied to the participants' torso aligned with the lower trapezius by a well-trained expert, and the procedures were repeated and measured in the same way.

2.4. Data analysis

The scapular data of three successful serves were collected and analyzed. The tennis serve was divided into four phases based on five key events:[28] (E1) ball release, (E2) first 75% of the cocking phase, (E3) maximal external rotation of the humerothoracic joint, (E4) ball impact, and (E5) minimal height of the tennis racquet. The cocking phase was defined as the motion from ball release to maximal external rotation of the humerothoracic joint.[28] The scapular posterior/anterior tilt, upward/downward rotation, and internal/external rotation relative to the thorax were measured at each event, and the angular velocity and joint moment were calculated for each phase.

2.5. Scapular focused taping

The SFT technique was applied to the scapula of the participants' dominant arm using two pieces of standard 2-inch tape (MSSM Kino Soft Inc., Seoul, South Korea) according to the method suggested by Lewis et al[29] First, the participants were seated on a stool while keeping their backs straight and asked to fully retract and depress their scapula. One I-shaped tape was parallel to vertebrae from the 1st to the 12th thoracic with light tension (15–25%) and the other I-shaped tape was applied diagonally from the middle of the scapular spine to the 12th thoracic vertebra with the same tension (Fig. 1). Subjects were not required to actively maintain this posture after tape application.[30]

2.6. Statistical analysis

Statistical analysis was performed with SPSS 23.0. (IBM Corporation, New York) with significance levels set at 5%. The differences between the groups for continuous data were compared using an independent t test at each event and phase. A dependent t test was used to compare the data depending on the application of SFT, and 2-way ANOVA with repeated measures was used to identify interactive effects between groups and taping condition.

Figure 1. Scapular focused taping.

3. Results

The changes in scapula position depending on SFT application onto the lower trapezius are shown in Tables 1 to 3. In the sagittal plane, there were no significant differences between groups at any event both before and after applying SFT. In the SP group, the scapula was tilted more posteriorly after the application of SFT as compared to before at E1 and E3 ($t = -5.081$, $P = .004$ and $t = -2.623$, $P = .047$, respectively). In addition, in the NSP group, the scapula was tilted more posteriorly with SFT as compared to without at E2 and E3 ($t = -3.733$, $P = .010$ and $t = -2.510$, $P = .046$, respectively). In both the frontal and transverse planes, there were no significant differences between groups at any event both before and after applying SFT. Only the SP group exhibited a more rotated scapula externally after the application of SFT as compared to before at E4 ($t = 5.283$, $P = .003$).

The differences in angular velocity and joint moment during scapular movement are shown in Tables 4 and 5. In the SP group, with SFT players had a higher angular velocity of scapular internal rotation during P3 compared to without ($t = -3.187$, $P = .024$). Next, we measured joint moment during scapula movement. Before the application of SFT, while we observed an upward rotation of the scapula in the SP group during P1, we found a downward rotation in the NSP group ($t = 2.418$, $P = .034$).

4. Discussion

In this study, we investigated the short-term effectiveness of SFT, applied to the lower trapezius, on scapular position and kinematics during the flat serve among tennis athletes with and without shoulder pain. The results suggest that whilst SFT had a positive immediate effect on the scapular posterior tilting and external rotation in all players, it did not positively affect angular velocity and joint moment of scapular movement.

The scapula plays a vital role in normal upper extremity function and in controlling the position of the glenoid.[15] Small changes in the scapulothoracic joint can affect the alignment and forces involved in movement around the glenohumeral joint, which may cause shoulder pain.[15] A previous study reported that in athletes with shoulder pain, the scapula rotated upwardly during arm elevation to compensate for shoulder impingement, in addition to inadequate posterior tilting of the scapula to narrow the subacromial space.[13] Another study demonstrated that patients with shoulder pain had a reduced upward rotation of the scapula during arm elevation compared to those without, and there were no differences in posterior tilting and internal/external rotation of the scapula.[16] In addition, Lopes et al[18] showed that the scapula of participants with shoulder pain had less external rotation during descending phases of shoulder

Table 1					
Differences in posterior/anterior tilting of the scapula depending on taping conditions.					
Event	Group	Before SFT	After SFT	t (p)	Taping*Group
E1	SP (n = 6)	10.27 ± 12.84	13.28 ± 11.95	−5.081 (0.004)	$F = 3.190$
	NSP (n = 7)	−1.82 ± 19.65	−0.90 ± 18.46	−0.966 (0.371)	$P = .102$
	t (p)	1.286 (0.225)	1.610 (0.136)		
E2	SP (n = 6)	−1.04 ± 12.89	1.39 ± 12.27	−1.674 (0.155)	$F = 0.020$
	NSP (n = 7)	6.21 ± 9.17	8.86 ± 9.26	−3.733 (0.010)	$P = .890$
	t (p)	−1.183 (0.262)	−1.251 (0.237)		
E3	SP (n = 6)	14.26 ± 18.55	17.34 ± 17.68	−2.623 (0.047)	$F = 2.370$
	NSP (n = 7)	17.34 ± 8.64	18.57 ± 9.27	−2.510 (0.046)	$P = .152$
	t (p)	−0.395 (0.701)	−0.161 (0.875)		
E4	SP (n = 6)	−12.19 ± 14.21	−5.60 ± 14.61	−1.815 (0.129)	$F = 1.179$
	NSP (n = 7)	−5.70 ± 2.48	−4.17 ± 9.33	−0.510 (0.628)	$P = .301$
	t (p)	−1.104 (0.318)	−0.214 (0.835)		
E5	SP (n = 6)	30.78 ± 10.08	31.03 ± 10.31	−0.072 (0.945)	$F = 0.248$
	NSP (n = 7)	35.76 ± 11.90	31.99 ± 20.81	0.553 (0.600)	$P = .628$
	t (p)	−0.806 (0.437)	−0.103 (0.920)		

Values express as mean ± standard deviation.
Positive (+) and negative (−) values mean posterior and anterior tilt, respectively.
E1 = ball release, E2 = first 75% timing of the cocking phase, E3 = maximally externally rotated humerothoracic joint, E4 = ball impact, E5 = minimal height of the tennis racket, NSP = non-shoulder pain group, SFT = scapular focused taping, SP = shoulder pain group, Unit = deg (°).

Table 2

Differences in upward/downward rotation of the scapula depending on taping conditions.

Event	Group	Before SFT	After SFT	t (p)	Taping*Group
E1	SP (n = 6)	−26.42 ± 14.17	−26.16 ± 13.79	−0.224 (0.832)	F = 1.110
	NSP (n = 7)	−42.15 ± 17.53	−40.48 ± 17.28	−2.186 (0.071)	P = .315
	t (p)	1.756 (0.107)	1.630 (0.131)		
E2	SP (n = 6)	−43.47 ± 18.14	−48.41 ± 14.85	1.890 (0.117)	F = 2.425
	NSP (n = 7)	−65.01 ± 17.59	−65.13 ± 17.13	0.067 (0.949)	P = .148
	t (p)	2.169 (0.053)	1.861 (0.090)		
E3	SP (n = 6)	−70.45 ± 22.77	−69.61 ± 25.10	−0.363 (0.731)	F = 0.330
	NSP (n = 7)	−72.91 ± 13.20	−73.50 ± 12.24	0.497 (0.637)	P = .577
	t (p)	0.242 (0.813)	0.364 (0.722)		
E4	SP (n = 6)	−99.73 ± 22.06	−102.56 ± 20.71	1.940 (0.110)	F = 3.495
	NSP (n = 7)	−94.01 ± 19.57	−92.62 ± 20.17	−0.820 (0.444)	P = .088
	t (p)	−0.496 (0.630)	−0.872 (0.402)		
E5	SP (n = 6)	−27.55 ± 11.37	−22.01 ± 8.68	−0.876 (0.421)	F = 0.147
	NSP (n = 7)	−35.30 ± 10.18	−32.36 ± 11.05	−0.905 (0.400)	P = .709
	t (p)	1.297 (0.221)	1.853 (0.091)		

Values express as mean ± standard deviation.

Positive (+) and negative (−) values mean upward and downward rotation, respectively.

E1 = ball release, E2 = first 75% timing of the cocking phase, E3 = maximally externally rotated humerothoracic joint, E4 = ball impact, E5 = minimal height of the tennis racket, NSP = non-shoulder pain group, SFT = scapular focused taping, SP = shoulder pain group, Unit = deg (°).

Table 3

Differences in internal/external rotation of the scapula depending on taping conditions.

Event	Group	Before SFT	After SFT	t (p)	Taping*Group
E1	SP (n = 6)	1.63 ± 23.21	−9.61 ± 19.94	0.972 (0.376)	F = 0.929
	NSP (n = 7)	−0.73 ± 22.54	−1.66 ± 22.72	0.940 (0.401)	P = .356
	t (p)	0.186 (0.856)	−0.664 (0.520)		
E2	SP (n = 6)	−50.01 ± 22.75	−49.33 ± 24.28	−0.290 (0.783)	F = 0.483
	NSP (n = 7)	−54.89 ± 19.89	−56.03 ± 18.94	0.825 (0.441)	P = .501
	t (p)	0.413 (0.688)	0.559 (0.587)		
E3	SP (n = 6)	−90.01 ± 14.52	−90.52 ± 16.09	0.650 (0.544)	F = 0.352
	NSP (n = 7)	−100.07 ± 17.38	−99.44 ± 16.93	−0.388 (0.712)	P = .565
	t (p)	1.120 (0.287)	0.968 (0.354)		
E4	SP (n = 6)	−51.63 ± 27.30	−62.95 ± 24.03	5.283 (0.003)	F = 0.610
	NSP (n = 7)	−61.36 ± 20.99	−69.02 ± 22.50	1.956 (0.098)	P = .451
	t (p)	0.727 (0.482)	0.470 (0.647)		
E5	SP (n = 6)	11.16 ± 17.55	0.48 ± 23.14	0.868 (0.425)	F = 0.144
	NSP (n = 7)	7.59 ± 12.85	1.75 ± 6.24	1.072 (0.325)	P = .711
	t (p)	0.424 (0.680)	−0.140 (0.891)		

Values express as mean ± standard deviation.

Positive (+) and negative (−) values mean internal and external rotation, respectively.

E1 = ball release, E2 = first 75% timing of the cocking phase, E3 = maximally externally rotated humerothoracic joint, E4 = ball impact, E5 = minimal height of the tennis racket, NSP = non-shoulder pain group, SFT = scapular focused taping, SP = shoulder pain group, Unit = deg (°).

flexion compared to those without. However, they also found that the difference in scapular position between the two groups during overhead activity was not observed regardless of the application of SFT. The inconsistency between these studies and ours is related to the selected shoulder movement: while the aforementioned studies were conducted during constrained planar motions, we here analyzed the scapular position during tennis-related activity. Therefore, any association between shoulder injuries and scapula position (and/or movement) in studies with constrained shoulder movement may not translate directly to sports activities.[20]

Shoulder pain and/or injury is associated with late cocking, and during deceleration of overhead throwing, extremes of motion occur at the shoulder that lead to kinematic alterations of the shoulder joint.[5] A previous study on scapular movement during the tennis serve showed that the scapula rotated internally and upwardly, and was tilted posteriorly during the late cocking phase.[28] The scapular posterior tilt and external rotation is critical to prevent the occurrence of shoulder injury, such as posterior internal impingement.[31] The present

study provides evidence that SFT applied to the lower trapezius caused posterior tilt of the scapula at some events, including the maximal external rotation of the humerothoracic joint during tennis serve, in all athletes regardless of shoulder pain. These taping-induced effects on scapular position could be explained by the alignment correction SFT provides,[30] and SFT may also allow overhead activities to be more balanced and stabilized with regard to the base of the scapula.[23] However, we did not observe significant changes in scapular internal/external rotation or upward/downward rotation in this study. This indicates that the taping method applied in this study did improve the movement components controlled by the lower trapezius, but not those that underlie other directions of scapular motion.

Joint moment calculated based on kinematics data of the human body is a very important parameter in biomechanics.[32] In addition, joint angular velocity is a measure of how fast each joint moves during activities, and the comparison of joint angular velocity between patients with and without pain may help researchers to identify how well each individual joint movement fits in with normal kinematics.[33] Moreover, the motion velocity

Table 4

Differences in angular velocity during scapular movement in each phase depending on taping conditions.

Phase	Group	Posterior(+)/Anterior(−) Tilting			Upward(+)/Downward(−) Rotation			Internal(+)/External(−) Rotation		
		Before SFT	After SFT	t (p)	Before SFT	After SFT	t (p)	Before SFT	After SFT	t (p)
P1	SP (n = 6)	146.47	125.18	1.891	122.59	112.22	0.611	69.92	30.80	0.771
		±89.06	±81.31	(0.117)	±57.70	±74.88	(0.568)	±122.58	±32.02	(0.476)
	NSP (n = 7)	122.67	116.24	0.559	132.88	134.57	−0.114	67.81	74.37	−0.213
		±69.58	±61.61	(0.596)	±74.19	±69.38	(0.890)	±71.93	±130.75	(0.838)
	t (p)	0.541	0.225		−0.275	−0.559		0.039	−0.852	
		(0.599)	(0.826)		(0.788)	(0.588)		(0.970)	(0.423)	
P2	SP (n = 6)	228.28	224.25	0.234	119.42	126.46	−0.215	71.32	16.54	1.218
		±102.54	±92.36	(0.824)	±70.36	±58.84	(0.839)	±116.22	±42.14	(0.277)
	NSP (n = 7)	193.39	183.87	0.397	199.52	179.56	1.090	68.72	78.38	−0.373
		±61.46	±44.62	(0.705)	±92.92	±110.41	(0.318)	±77.93	±90.86	(0.722)
	t (p)	0.729	1.030		−1.726	−1.052		0.048	−1.525	
		(0.487)	(0.325)		(0.112)	(0.315)		(0.963)	(0.155)	
P3	SP (n = 6)	−33.90	59.77	−1.753	−60.05	27.12	−1.731	855.53	1126.17	−3.187
		±124.84	±58.10	(0.140)	±202.81	±270.18	(0.144)	±375.97	±262.57	(0.024)
	NSP (n = 7)	−20.86	−23.42	0.050	−3.57	2.36	−0.297	996.42	1047.28	−0.522
		±185.95	±121.09	(0.962)	±147.74	±131.46	(0.777)	±577.17	±462.14	(0.620)
	t (p)	−0.145	1.532		−0.580	0.205		−0.511	0.369	
		(0.887)	(0.154)		(0.573)	(0.844)		(0.620)	(0.719)	
P4	SP (n = 6)	652.97	680.75	−0.447	1033.80	1009.14	0.242	1222.89	1245.60	−0.213
		±267.41	±195.41	(0.673)	±483.02	±372.01	(0.818)	±476.53	±312.99	(0.820)
	NSP (n = 7)	724.12	734.35	−0.275	882.36	841.46	0.314	1197.89	1173.25	0.183
		±270.79	±228.02	(0.793)	±413.75	±316.49	(0.764)	±406.99	±271.78	(0.860)
	t (p)	−0.475	−0.451		0.610	0.879		0.102	0.447	
		(0.644)	(0.661)		(0.555)	(0.389)		(0.921)	(0.664)	

Values express as mean ± standard deviation.

P1 = from ball release (E1) to first 75% timing of the cocking phase (E2), P2 = from E2 to maximally externally rotated humerothoracic joint (E3), P3 = from E3 to ball impact (E4), P4 = from E4 to minimal height of the tennis racket (E5), NSP = non-shoulder pain group, SFT = scapular focused taping, SP = shoulder pain group, Unit = deg/s.

Table 5

Differences in joint moment during scapular movement in each phase depending on taping conditions.

Phase	Group	Posterior(+)/Anterior(−) Tilting			Upward(+)/Downward(−) Rotation			Internal(+)/External(−) Rotation		
		Before SFT	After SFT	t (p)	Before SFT	After SFT	t (p)	Before SFT	After SFT	t (p)
P1	SP	3.64	3.67	−0.161	0.51	0.56	−0.450	4.29	4.51	−0.913
	(n = 6)	±1.66	±1.87	(0.878)	±0.93	±0.84	(0.702)	±3.06	±2.81	(0.403)
	NSP (n = 7)	2.69	2.38	1.035	−0.58	−0.34	−0.741	5.11	5.18	−0.160
		±2.30	±1.66	(0.341)	±0.69	±1.02	(0.487)	±4.29	±3.73	(0.878)
	t (p)	0.837	1.325		2.418	1.722		−0.391	−0.360	
		(0.421)	(0.212)		(0.034)	(0.113)		(0.704)	(0.726)	
P2	SP	10.54	10.95	−0.686	15.33	16.06	−0.744	13.87	13.81	0.101
	(n = 6)	±4.89	±5.69	(0.523)	±5.42	±5.56	(0.491)	±7.79	±7.49	(0.924)
	NSP (n = 7)	11.04	11.50	−1.186	14.83	15.34	−0.506	15.31	15.43	−0.383
		±6.44	±6.38	(0.280)	±9.93	±9.47	(0.631)	±8.69	±9.13	(0.715)
	t (p)	−0.157	−0.163		0.109	0.163		−0.311	−0.344	
		(0.878)	(0.874)		(0.915)	(0.874)		(0.761)	(0.737)	
P3	SP	2.72	4.31	−1.768	15.57	17.48	−2.071	4.02	3.94	0.029
	(n = 6)	±3.77	±4.32	(0.137)	±6.61	±5.19	(0.093)	±4.85	±7.07	(0.978)
	NSP (n = 7)	0.87	1.63	−0.725	17.03	17.55	−0.443	1.61	0.25	1.149
		±1.79	±2.68	(0.496)	±9.61	±9.15	(0.674)	±4.19	±6.84	(0.294)
	t (p)	1.163	1.369		−0.312	−0.017		0.963	0.954	
		(0.269)	(0.198)		(0.761)	(0.987)		(0.356)	(0.360)	
P4	SP	3.40	3.63	−0.264	9.50	11.26	−2.207	4.13	3.77	0.725
	(n = 6)	±1.72	±1.74	(0.802)	±3.54	±4.61	(0.078)	±3.49	±4.10	(0.501)
	NSP (n = 7)	2.47	3.30	−1.561	10.74	11.33	−0.735	4.74	6.26	−1.822
		±1.35	±1.14	(0.169)	±6.96	±7.54	(0.490)	±3.44	±4.10	(0.118)
	t (p)	1.095	0.399		−0.392	−0.019		−0.314	−1.088	
		(0.297)	(0.698)		(0.703)	(0.985)		(0.759)	(0.300)	

Values express as mean ± standard deviation.

P1 = from ball release (E1) to first 75% timing of the cocking phase (E2), P2 = from E2 to maximally externally rotated humerothoracic joint (E3), P3 = from E3 to ball impact (E4), P4 = from E4 to minimal height of the tennis racket (E5), NSP = non-shoulder pain group, SFT = scapular focused taping, SP = shoulder pain group, Unit = Nm.

of scapular kinematics may provide insights into the underlying mechanisms of shoulder injury.[34] Assessing joint moment, we found an upward rotation of the scapula in participants with shoulder pain, whereas in those without shoulder pain the scapula rotated downwardly. This result is likely related to the compensation for shoulder pain, providing relief by increasing the subacromial space.[35] However, the application of SFT increased angular velocity of scapular internal rotation between maximal external rotation of the humerothoracic joint and ball impact among athletes with shoulder pain. Because the taping method in this study was applied to improve scapular posterior tilting, it did not have an impact on other movements of the scapula. It should also be noted that although all participants rested after non- SFT measurements prior to the application of SFT, a total of 24 flat serves were performed during a relatively short period of time, inducing fatigue of the scapular stabilizer muscles; this may have affected the performance and results.

As previously mentioned, although SFT is widely used among athletes, its efficacy has been a subject of debate.[21] And the velocity of arm movement may affect the scapulohumeral ratios, and specific movements of the scapula increase during dynamic tasks of arm elevation compared to static tasks.[34] Therefore, this study identified the differences of scapular movement among elite tennis players with and without shoulder pain and verified the effect of SFT on scapular movement during tennis serve that was known to engender a high risk of shoulder injury using 3-dimentional analysis. Further studies are needed to explore the effects of various taping methods on scapular kinematics during tennis-specific activity.

5. Conclusions

This study demonstrates that SFT applied to the lower trapezius had a positive immediate effect on the scapular posterior tilting and external rotation during the tennis serve among athletes with and without shoulder pain. However, it did not positively affect the angular velocity or joint moment of scapular movement. These findings may help clinicians and sports practitioners in the prevention and rehabilitation of shoulder injuries for overhead athletes.

Acknowledgements

We thank all the participating athletes and coaches for their contribution to the study.

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