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Effects of trapezius kinesio taping on scapular kinematics and associated muscular activation in subjects with scapular dyskinesis

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ABSTRACT

Study Design: Crossover repeated-measure design.
Introduction: Scapular dyskinesis rehabilitation programs that focus on inhibiting upper trapezius (UT) and activating the lower trapezius (LT) may assist in restoring scapular movements. We hypothesized that taping may be able to normalize scapular movements and associated muscular recruitment.
Purpose of the Study: The purpose of this study was to investigate the immediate effects of kinesio taping over trapezius on scapular kinematics and muscular activation in different dyskinesis patterns. We expected that taping can improve scapular kinematics and muscular activation in subjects with dyskinesis.
Methods: Fifty-four participants with inferior angle prominence (pattern I), medial border prominence (pattern II), and mixed pattern (pattern I + II) were recruited. Kinesio taping was applied over 3 parts of trapezius muscles, including UT, middle trapezius (MT), and LT. The scapular kinematics and electromyographic data of trapezius and serratus anterior were collected during scapular plane elevation without taping and after each taping application.
Results: UT taping decreased UT activity (5%-7%; $P = .001$-$.003$) in 72% of participants with pattern II and pattern I + II dyskinesis, with increased posterior tipping (2.2°-2.5°; $P = .003$) in pattern II dyskinesis. MT taping increased UT activity (3%; $P = .003$) in 48% of participants with pattern II dyskinesis.
Discussion: The taping over the trapezius muscle may help to restore coordinated scapular muscle balance and increased upward rotation of the scapula, especially in pattern II dyskinesis. Although no electromyography or kinematic difference was found with LT taping in each dyskinesis pattern, methods of applying LT taping need to be further investigated.
Conclusion: Reduced UT muscle activity and scapular posterior tipping are appropriate when applying taping over UT muscle in patterns II and I + II dyskinesis. Caution should be taken when applying taping over MT and LT muscles in terms of increased UT activity, especially in pattern II dyskinesis.

Introduction

Scapular dyskinesis is characterized as change of scapular position and movement relative to the thorax at static positions or during arm movements.[1] Most patients with shoulder injuries, such as glenohumeral instability, rotator cuff injury, labral tears, and impingement syndrome, have dyskinesis.[2-5] Thus, scapular dyskinesis is believed to be associated with shoulder pathology.

Scapular dyskinesis rehabilitation programs that focus on inhibiting upper trapezius (UT) and activating the lower trapezius (LT) and serratus anterior (SA) muscles may assist in restoring scapular movements.[6] Clinically, kinesio taping (KT) has been used to restore muscle activities or kinematics. Although the underlying mechanisms of taping are still unclear, Kase et al[7] proposed that KT may provide proprioceptive feedback and correct the alignment during dynamic movement. Previous studies have demonstrated that taping effectively increases shoulder pain–free range of motion (ROM), relieves pain, and improves shoulder function immediately after application.[8-10] We hypothesized that taping may be able to normalize scapular movements and associated muscular recruitment.

Although several studies have investigated the effects of scapular taping on scapular kinematics and muscle performance, the

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results have been inconsistent.[11-14] One study showed that taping over the LT resulted in improving scapular posterior tipping and increasing LT muscle activity as compared with placebo taping, but the other did not find the differences.[11,14] In addition, taping from the inferior margin of the medial 1/3 clavicle to T12 increased SA activity and increased posterior tipping and upward rotation.[12,13] Balance of the scapular muscles activation was believed to correct kinematic impairments in participants with dyskinesis. Because specific alterations of scapular muscular activation and kinematics are found in different patterns of scapular dyskinesis,[15] there is a need to further investigate the effects of taping to specific patterns of scapular dyskinesis. The purpose of this study was to investigate the effects of trapezius KT on scapular kinematics (upward rotation, posterior tipping, and internal rotation) and associated muscular activities (UL/middle trapezius [MT]/LT and SA) in subjects with scapular dyskinesis. The primary hypothesis was that taping can alter scapular kinematics and muscular activation in subjects with scapular dyskinesis. The second hypothesis was that alterations of scapular kinematics and muscular activation due to taping would be specific to dyskinesis pattern.

Methods

Participants were recruited from an outpatient clinic in a university hospital and through local Internet media. Participants were recruited if they (1) were from 18 to 45 years old, (2) had nonspecific unilateral shoulder pain around the glenohumeral regions, (3) had full glenohumeral ROM, and (4) had scapular dyskinesis, evaluated by classification method.[16] If they had (1) shoulder dislocation, fracture, or shoulder surgery, (2) direct contact injury of neck or upper extremities within the past 1 month, (3) neurologic disorders, or (4) difficulty to complete the testing procedures, they would be excluded. All participants provided informed consent before participation. The study was approved by the Institutional Review Board of National Taiwan University Hospital.[17]

The surface electromyography (sEMG) assemblies contain pairs of silver chloride circular (diameter, 10 mm) surface electrodes (The Ludlow Company LP, Chocopee, MA) with interelectrode (center-to-center) distance of 20 mm and a Grass alternating current/direct current amplifier (model 15A12; Astro-Med, Inc, West Warwick, RI). Gain of 1000, a common mode rejection ratio of 86 dB at 60 Hz, and a bandwidth (−3 dB) of 10-500 Hz were selected. The sEMG data were collected by a 16-bit analog to digital converter with 1000 Hz/channel (model MP 150; Biopac Systems, Inc, Goleta, CA). An impedance meter (model F-EZM5; Astro-Med, Inc, West Warwick, RI) was used to confirm the impedance below 10 kΩ. sEMG electrodes were placed on the UT (midway between the acromion and C7), MT (midway between the root of the spine of the scapula and T3), LT (on the line between the spine of the scapula and T7), and SA (anterior to the latissimus dorsi and posterior to the pectoralis major) of the involved shoulder. The referenced electrode was placed on the ipsilateral clavicle.[18,19] The Polhemus 3Space FASTRAK system (Polhemus, Inc, Colchester, VT), an electromagnetic-based motion capture system, was used to collect 3-dimensional scapular kinematics data. The details of the methodology followed previously established methods.[20] In general, 3 sensors were placed in locations where the skin motion artifact was minimized (sternum, acromion, and distal humerus). Anatomic landmarks (sternal notch, xiphoid process, seventh cervical vertebra, eighth thoracic vertebra, acromioclavicular joint, root of the spine of the scapula, inferior angle of the scapula, lateral epicondyle, and medial epicondyle) were palpated and used for subsequent receiver mounting and landmark digitization.

Visual combined palpation was used to classify scapular position and movement patterns (single patterns or mixed patterns) in both the raising and lowering phases, modified by the method of Kibler.[1,16] Four single patterns include inferior angle prominence (pattern I), medial border prominence (pattern II), abnormal upward rotation/elevation (pattern III), and normal movement (pattern IV). The mixed patterns combine at least 2 single patterns of patterns I-III. Participants were asked to elevate their arms using the full-can position to the end range over a 3-second count with dumbbell weight and then to lower them over a 3-second count following the metronome. The dumbbells held in each side weighed 2.3 kg (5 lb) or 1.4 kg (3 lb), depending on each participant's ability to complete the experiment.

After the evaluation of dyskinesis, maximal voluntary isometric contraction (MVIC) was tested for normalizing the sEMG data of the UT/MT/LT and SA muscles. The mean amplitude of each phase was reported as a percentage of MVIC. The measurement of MVIC followed previously established methods.[15] Five seconds of a total of 3 trials of MVICs with 1 minute of rest between any 2 tests for each muscle were collected.

A crossover repeated-measure design was used to compare the effects of UT/MT/LT KT conditions to control condition with no taping. After the collection of kinematics and EMG data in the no

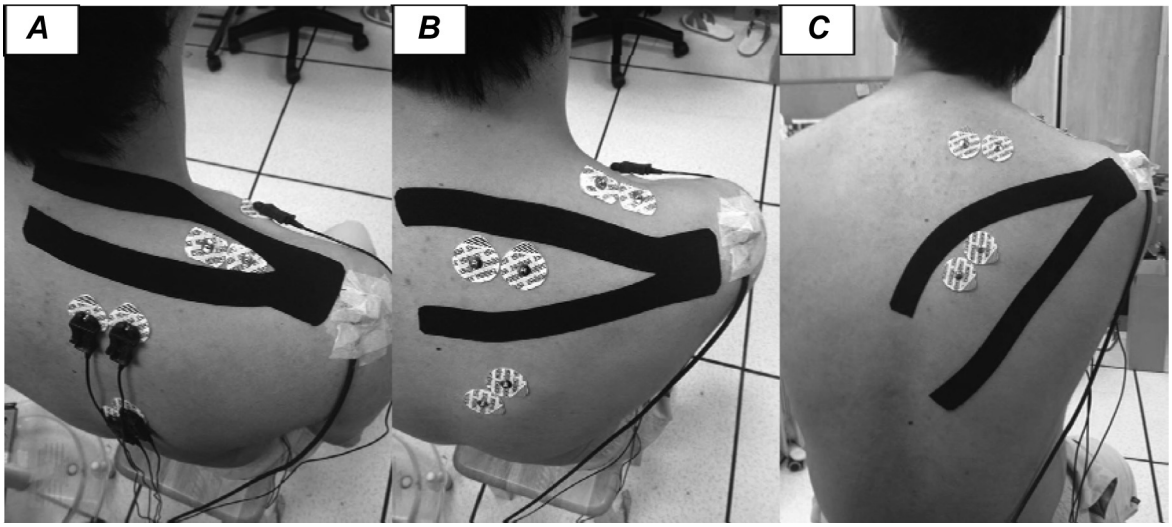

Fig. 1. Demonstration of taping method: (**A**) upper trapezius, (**B**) middle trapezius, and (**C**) lower trapezius.

taping condition, we applied a Y-shaped strip of kinesio tape (Kinesio Tex KT-X-050, Osaka, Japan) in the distal to proximal direction to envelop each of the 3 scapular muscles, as described in previous studies (Figure 1).[11,21] For the UT, participants were asked to side bend and rotate the head to the contralateral side while we applied the tape from the superior side of the acromion of the scapula near the sensor to the upper cervical spine. For the MT, participants horizontally adducted the arm on the contralateral shoulder while we applied the tape from the posterior side of the acromion of the scapula to the upper thoracic spine (T1-T5). For the LT, participants horizontally adducted the arm similarly to the position for the MT. The base of the tape was applied from the root of the spine of the scapula near the acromion to the lower thoracic spine (T6-T12). The order of the 3 taping conditions was randomized according to the Latin square method.[22] In addition, 30-minute rest after 10-minute data collection for each taping condition was allowed as washout period.

After familiarizing the testing movement, scapular kinematics and sEMG data were collected during 5 trials of weighted arm elevation in scapular plane with no taping and after each taping application. Raw kinematic data with 6 Hz of low-pass filtering were transformed into anatomically defined rotations. The International Society of Biomechanics guidelines for constructing a shoulder joint coordinate system were followed.[23] The anatomically defined axes were converted from the absolute axes constructed by the sensors of the FASTRAK device. The Euler angle sequence of rotation about Zs (protraction/retraction), Ys (downward/upward rotation), and Xs (posterior/anterior tipping) was defined to describe the scapular orientation relative to the thorax. The root mean square algorithm was used to produce sEMG envelopes with a sampling rate of 50 samples per second. The kinematics and sEMG data were averaged for the middle 3 trials in each phase. Raising and lowering phases were defined by a trigger marked and synchronized on sEMG data and scapular kinematic data.

The kinematic data at 30°, 60°, 90°, and 120° and EMG data for the ranges of rest-30°, 30°-60°, 60°-90°, 90°-120°, and above 120° in the raising and lowering phases of scapular plane elevation were used as dependent variables to characterize the scapular kinematics and muscular activities. Subgroup analyses for kinematic and EMG activity data were analyzed focusing on 3 subgroups: decreased UT activity with UT taping, increased MT activity with MT taping, and increased LT activity with LT taping. The choice of the 3 conditions for analysis was based on the assumed effects of taping. If UT activity decreased or MT and LT activities increased at 1 of 3 angle ranges including 60°-90°, 90°-120°, or above 120°, the participants would be selected for subgroup analyses.

The Statistical Package for the Social Sciences, version 17.0 (IBM Corporation, Armonk, NY), was used for data analysis. Descriptive statistics were used to present the demographic data and percentage of participants in 3 subgroups. The Shapiro-Wilk test was performed to confirm the normal distribution of the kinematic and EMG data. If the result showed non-normal distribution, then nonparametric analysis was used. For data with normal distribution, 3-way analysis of variance (factor: taping condition, subgroup, and angle) was used to determine the differences in the kinematic and EMG data with and without taping among 3 types of dyskinesis. In the absence of 3-way interaction, 2-way interaction or main effect of each factor was of interest. For multiple pairwise comparisons, Bonferroni corrections were used to adjust α level. The significant level was set at $\alpha = 0.05$. Values of effect size (ES) 0.8, 0.5, and 0.2 were considered as large, middle, and small.[24]

Results

Fifty-four participants (44 males: age, 26 ± 5 years; height, 172 ± 8 cm; and weight, 67 ± 10 kg) were assessed and had dyskinesis in the raising and/or lowering arm movements. In the raising phase of arm elevation in scapular plane, pattern II was found in 1 participant, pattern III in 4 participants, and the normal pattern in 49 participants. In the lowering phase, pattern I was found in 8 participants, pattern II in 18 participants, and pattern I + II in 28 participants. For our purposes, the data in the lowering phase were further analyzed. UT activity decreased with UT taping in 39 of the 54 (72%) participants (pattern I: 6/8; pattern II: 12/18; and pattern I + II: 21/28). MT activity increased with MT taping in 26 of the 54 (48%) participants (pattern I: 2/8; pattern II: 10/18; and pattern I + II: 14/28). LT activity increased with LT taping in 29 of the 54 (54%) participants (pattern I: 3/8; pattern II: 12/18; and pattern I + II: 14/28) (Table 1).

The kinematics and EMG data with UT taping in participants with decreased UT activity were shown in Table 2. The data were analyzed separately in each pattern because the data fit normal distribution in pattern I + II dyskinesis (2-way analysis of variance) but not fit normal distribution in patterns I and II (Wilcoxon signed rank test in each pattern). In EMG data, decreased UT activities were found after UT taping during 60°-90° (7%; $P = .003$) and 90°-120° (6%; $P = .002$) of arm elevation in patients with pattern II. There were no significant differences in other muscles' activation between the conditions with and without UT taping in patterns I and II. In addition, the UT activity showed a condition × angle interaction effect in pattern I + II. Decreased UT activity was found after UT taping at more than 120° (5%; $P = .001$) of arm elevation in pattern I + II. In kinematics data, increased posterior tipping was shown after taping during 60°-90° (2.5°; $P = .003$) and 90°-120° (2.2°; $P = .003$) of arm elevation in pattern II. There were no significant differences in other kinematics data between the condition with and without UT taping in patterns I and II. In addition, more scapular upward rotation with large ES was found during 30°-60° (6.3°; ES = 1.3) and 60°-90° (5.6°; ES = 1.4) of arm elevation after UT taping in pattern II compared with pattern I.

Table 1
Demographic data of participants

Characteristic	UT decreased subjects ($N = 39$)	MT increased subjects ($N = 26$)	LT increased subjects ($N = 29$)
Sex (male)	31	22	24
Age (y)	26 ± 6	26 ± 6	26 ± 5
Height (cm)	172 ± 8	171 ± 9	172 ± 8
Weight (kg)	67 ± 10	68 ± 11	67 ± 9
Duration of symptoms (mo)	24 ± 27	29 ± 35	24 ± 29
Domiant side (right)	39	26	29
Involved side (right)	33	21	24
Pattern distribution	Pattern I: 6/8 (75%)	Pattern I: 2/8 (25%)	Pattern I: 3/8 (38%)
	Pattern II: 12/18 (67%)	Pattern II: 10/18 (56%)	Pattern II: 12/18 (67%)
	Pattern I + II: 21/28 (75%)	Pattern I + II: 14/28 (50%)	Pattern I + II: 14/28 (50%)

UT = upper trapezius; MT = middle trapezius; LT = lower trapezius.
Inferior angle prominence (pattern I), medial border prominence (pattern II), and inferior angle and medial border prominence (pattern I + II).

Table 2
Changes in scapular kinematics and muscle activation with UT taping at 120°, 90°, 60°, and 30° of arm elevation ($N = 54$)

Arm elevation	Pattern I (mean ± SD); $N = 6$					Pattern II (mean ± SD); $N = 12$					Pattern I + II (mean ± SD); $N = 21$				
	>120°	90°-*120°*	60°-*90°*	30°-*60°*	Rest-*30°*	>120°	90°-*120°*	60°-*90°*	30°-*60°*	Rest-*30°*	>120°	90°-*120°*	60°-*90°*	30°-*60°*	Rest-*30°*
UR		34.6 ± 5.6	26.1 ± 2.2	14.4 ± 2.2	4.0 ± 3.3		39.9 ± 8.8	30.5 ± 5.5	18.9 ± 5.2	5.5 ± 4.7		38.0 ± 5.4	29.1 ± 4.5	18.7 ± 4.5	5.8 ± 3.8
Taping		35.1 ± 5.3	25.7 ± 1.7[a]	13.6 ± 2.1[a]	3.3 ± 2.6		42.2 ± 8.3	31.3 ± 5.3[a]	18.9 ± 5.5[a]	6.3 ± 4.9		38.1 ± 6.5	28.5 ± 4.8	17.5 ± 1.4	5.5 ± 3.4
PT		4.0 ± 7.5	2.8 ± 5.2	0.1 ± 3.5	−1.4 ± 3.1		5.3 ± 9.4[b]	3.8 ± 6.6[b]	1.8 ± 3.9	−0.1 ± 2.0		7.4 ± 6.7	5.8 ± 6.0	4.0 ± 4.7	2.1 ± 3.5
Taping		4.2 ± 6.8	2.9 ± 5.2	0.5 ± 3.7	−1.0 ± 3.3		7.8 ± 9.4[b]	6.0 ± 6.7[b]	3.3 ± 4.6	1.0 ± 2.6		8.0 ± 6.8	7.0 ± 6.2	5.0 ± 4.7	2.8 ± 3.1
ER		15.5 ± 6.3	9.3 ± 4.5	4.4 ± 4.8	2.7 ± 4.7		9.9 ± 8.6	6.2 ± 6.5	3.0 ± 6.9	2.0 ± 6.2		10.1 ± 6.0	4.6 ± 5.6	1.1 ± 4.8	−0.5 ± 3.7
Taping		14.2 ± 6.4	8.5 ± 5.9	4.2 ± 5.2	3.0 ± 4.4		8.5 ± 8.9	5.2 ± 5.7	2.3 ± 6.0	1.2 ± 5.1		10.0 ± 7.7	4.2 ± 6.8	1.0 ± 5.3	−0.1 ± 3.7
UT	42.5 ± 25.3	28.2 ± 10.6	22.4 ± 4.5	16.9 ± 4.2	10.3 ± 6.4	48.1 ± 23.4	34.8 ± 13.4[b]	30.7 ± 12.3[b]	21.6 ± 12.2	13.2 ± 10.6	36.0 ± 14.6[b]	30.0 ± 8.5	27.2 ± 7.6	18.9 ± 7.0	8.2 ± 3.7
Taping	32.8 ± 17.1	24.3 ± 13.3	22.5 ± 11.2	13.9 ± 4.7	7.1 ± 1.9	48.1 ± 30.9	28.5 ± 10.6[b]	24.0 ± 8.1[b]	16.8 ± 5.7	9.7 ± 5.3	31.2 ± 14.3[b]	28.1 ± 10.0	24.5 ± 9.4	17.2 ± 7.3	7.9 ± 4.2
MT	26.4 ± 11.7	22.0 ± 8.2	17.9 ± 6.4	14.3 ± 6.2	8.6 ± 5.4	37.7 ± 13.8	23.3 ± 5.9	19.6 ± 7.0	14.6 ± 5.9	9.8 ± 3.6	26.8 ± 12.1	22.1 ± 7.1	18.9 ± 6.2	14.5 ± 5.4	8.9 ± 4.0
Taping	23.7 ± 12.9	20.3 ± 7.8	18.1 ± 7.3	13.4 ± 5.8	8.3 ± 3.7	33.3 ± 11.1	22.4 ± 6.0	19.0 ± 6.5	14.9 ± 5.6	9.9 ± 4.0	24.8 ± 13.4	21.5 ± 8.8	19.1 ± 7.0	14.7 ± 5.5	9.0 ± 3.9
LT	16.8 ± 3.3	14.7 ± 3.9	14.0 ± 5.8	10.4 ± 5.8	6.4 ± 3.0	23.1 ± 7.9	17.7 ± 7.0	16.9 ± 9.0	13.3 ± 8.2	8.0 ± 5.2	16.2 ± 8.3	15.9 ± 6.9	15.4 ± 6.6	11.2 ± 4.8	6.1 ± 3.1
Taping	14.7 ± 5.9	14.3 ± 5.5	13.8 ± 7.4	11.2 ± 6.2	6.3 ± 3.0	24.1 ± 8.0	17.6 ± 5.5	18.3 ± 8.5	13.6 ± 7.1	7.2 ± 4.1	15.9 ± 10.1	15.9 ± 6.7	15.8 ± 6.7	12.0 ± 5.3	6.1 ± 3.3
SA	61.4 ± 13.5	35.1 ± 13.2	22.3 ± 9.6	10.0 ± 4.4	7.3 ± 2.4	54.4 ± 20.9	33.1 ± 15.1	21.0 ± 7.5	9.4 ± 3.6	6.4 ± 2.3	46.0 ± 10.5	29.5 ± 7.5	22.8 ± 9.3	13.0 ± 5.6	7.0 ± 4.1
Taping	56.8 ± 14.6	37.4 ± 14.2	24.8 ± 11.1	9.2 ± 4.1	7.2 ± 2.4	54.4 ± 21.2	30.9 ± 12.9	21.0 ± 7.5	10.0 ± 3.9	6.6 ± 2.3	44.7 ± 13.1	30.8 ± 10.3	23.2 ± 9.5	13.1 ± 6.9	7.0 ± 4.3

SD = standard deviation; N = number; UR = upward rotation; PT = posterior tilt; ER = external rotation: kinematics value without taping (°); UT = upper trapezius; MT = middle trapezius; LT = lower trapezius; SA = serratus anterior: electromyographic value without taping (% maximal voluntary isometric contraction).
120°, *90°*, *60°*, and *30°* (in italics): kinematics value at each angle of arm elevation.
[a] Large effect size in pattern II compared with pattern I.
[b] Significant difference between taping and no taping condition.

Table 3
Changes in scapular kinematics and muscle activation with MT taping at 120°, 90°, 60°, and 30° of arm elevation ($N = 54$)

Arm elevation	Pattern I (range); $N = 2$					Pattern II (mean ± SD); $N = 10$					Pattern I + II (mean ± SD); $N = 14$				
	>120°	90°-*120°*	60°-*90°*	30°-*60°*	Rest-*30°*	>120°	90°-*120°*	60°-*90°*	30°-*60°*	Rest-*30°*	>120°	90°-*120°*	60°-*90°*	30°-*60°*	Rest-*30°*
UR		24.5-39.2	22.3 to 27.0	14.7 to 18.0	5.6 to 10.0		42.6 ± 8.9	31.4 ± 5.3	18.4 ± 4.7	4.7 ± 4.4		38.2 ± 6.4	29.6 ± 5.3	19.1 ± 5.1	6.7 ± 3.9
Taping		25.0-42.6	22.8 to 30.2	17.6 to 18.7	7.1 to 9.2		44.1 ± 6.8	31.9 ± 4.6	18.4 ± 4.0	5.5 ± 3.4		39.5 ± 6.6	30.1 ± 5.1	19.6 ± 5.0	7.4 ± 3.9
PT		1.3-15.9	−1.6 to 11.5	−3.9 to 4.6	−3.1 to 0.1		7.1 ± 10.9	4.9 ± 7.5	2.4 ± 5.1	0.4 ± 3.0		5.5 ± 4.6	4.1 ± 4.6	2.3 ± 4.1	0.4 ± 3.1
Taping		3.5-11.0	−2.0 to 10.0	−3.5 to 5.1	−3.9 to 1.1		7.2 ± 10.8	5.6 ± 7.4	3.2 ± 4.4	1.2 ± 2.5		4.8 ± 5.2	4.4 ± 4.0	2.7 ± 4.2	0.9 ± 2.8
ER		7.3-18.9	8.0 to 12.6	3.9 to 7.2	0.8 to 5.2		8.4 ± 7.7	5.6 ± 7.4	3.7 ± 7.2	2.8 ± 6.4		6.9 ± 6.5	2.1 ± 5.2	−0.5 ± 4.6	−1.3 ± 3.4
Taping		0.4-22.9	4.4 to 14.1	3.9 to 5.4	1.3 to 4.6		6.7 ± 7.9	4.9 ± 6.4	2.6 ± 6.0	1.7 ± 5.8		6.2 ± 6.3	1.5 ± 5.1	−0.4 ± 4.2	−1.3 ± 3.4
UT	26.0-30.0	22.9-27.2	18.4 to 27.3	16.8 to 25.1	9.4 to 23.0	44.5 ± 26.2	34.2 ± 13.9	30.5 ± 12.1	20.6 ± 13.4	12.4 ± 11.6	33.1 ± 13.1	28.0 ± 7.5[a]	24.6 ± 6.5	16.4 ± 6.4	7.0 ± 3.4
Taping	17.8-36.3	21.6-29.4	21.4 to 25.7	16.5 to 18.0	5.2 to 9.7	41.8 ± 21.4	35.0 ± 9.9	29.3 ± 8.4	19.2 ± 9.8	9.5 ± 6.7	34.8 ± 12.6	31.0 ± 8.7[a]	26.6 ± 6.8	16.8 ± 5.9	6.5 ± 2.6
MT	12.8-42.1	12.2-32.5	10.7 to 29.2	8.5 to 24.9	3.9 to 18.7	35.1 ± 14.9[b]	22.1 ± 4.3	18.8 ± 5.4	14.7 ± 4.4	9.8 ± 3.9	24.6 ± 10.6[b]	21.6 ± 7.8	18.5 ± 6.9	14.2 ± 6.5	8.8 ± 4.9
Taping	12.2-38.8	12.3-35.0	13.3 to 26.8	10.6 to 23.0	4.5 to 14.2	33.8 ± 13.9	24.1 ± 6.2	18.4 ± 5.0	14.3 ± 4.7	9.3 ± 3.6	25.6 ± 11.7	23.5 ± 8.9	20.8 ± 9.0	14.9 ± 6.8	8.6 ± 4.5
LT	14.1-19.3	11.4-21.4	9.8 to 22.0	6.8 to 18.3	4.7 to 10.6	33.5 ± 30.8	28.4 ± 26.9	26.0 ± 21.6	18.0 ± 12.5	10.7 ± 7.2	24.5 ± 23.4	20.2 ± 13.4	18.6 ± 10.8	13.1 ± 6.3	8.2 ± 5.4
Taping	5.3-19.4	6.9-20.7	7.1 to 22.2	4.8 to 18.2	3.2 to 9.7	30.6 ± 25.7	27.3 ± 26.5	22.5 ± 14.8	16.7 ± 10.9	9.4 ± 6.1	20.2 ± 16.3	19.7 ± 12.7	19.3 ± 12.8	14.2 ± 7.2	7.8 ± 4.7
SA	47.1-60.1	25.6-27.6	13.6 to 19.1	11.2 to 12.7	8.7 to 10.1	65.4 ± 24.3	37.8 ± 15.8	22.8 ± 11.1	11.5 ± 6.8	7.0 ± 2.8	51.5 ± 15.8	33.1 ± 10.9	22.7 ± 6.5	13.8 ± 5.6	8.1 ± 4.1
Taping	40.6-58.1	32.7	14.1 to 26.2	10.8 to 11.4	7.3 to 10.2	64.1 ± 26.5	36.3 ± 16.2	23.5 ± 11.1	13.2 ± 8.6	7.7 ± 3.8	50.7 ± 17.3	34.8 ± 12.5	23.9 ± 7.8	15.2 ± 7.0	9.0 ± 5.1

MT = middle trapezius; N = number; SD = standard deviation; UR = upward rotation; PT = posterior tilt; ER = external rotation: kinematics value without taping (°); UT = upper trapezius; LT = lower trapezius; SA = serratus anterior: electromyographic value without taping (% maximal voluntary isometric contraction).
120°, *90°*, *60°*, and *30°* (in italics): kinematics value at each angle of arm elevation.
[a] Significant difference between taping and no taping condition.
[b] Large effect size in pattern II compared with pattern I + II.

For MT taping, the kinematics and EMG data in participants with increased MT activity were demonstrated in Table 3. The data were analyzed separately in each pattern because the EMG data did not fit normal distribution. In EMG data, increased UT activity was shown after MT taping during 90°-120° (3%; $P = .003$) of arm elevation in pattern I + II. No significant differences were found in other muscles' EMG activation between the condition with and without MT taping in pattern II and pattern I + II. In addition, more MT activity with large ES was found at more than 120° (11%; ES = 0.8) of arm elevation after MT taping in pattern II compared with pattern I + II. In kinematics, no interaction or main effect was found between the condition with and without MT taping in pattern II and pattern I + II.

For LT taping, the kinematics and EMG data in participants with increased LT activity were demonstrated in Table 4. The data were analyzed separately in each pattern because the EMG data did not fit normal distribution. No significant difference was shown in kinematics and EMG data between the condition with and without LT taping in each pattern. However, more UT activity with large ES was found at more than 120° (20%; ES = 1.1) of arm elevation after LT taping in pattern II compared with pattern I + II.

Discussion

The present study aimed to assess the effects of 3 trapezius KT on scapular kinematics and associated muscular activities in subjects with scapular dyskinesis. Alterations of scapular kinematics and muscular activation due to taping were analyzed for different dyskinesis patterns. Our results showed positive effect of UT taping on decreased UT activity and increased posterior tipping during arm movements on pattern II or mixed dyskinesis. The increased UT activity from MT taping, however, had negative effect on pattern II dyskinesis. In addition, our results also supported that taping effect on altered scapular kinematics and muscular activation was specific to dyskinesis pattern. No side effects were found in all participants applied with 3 types of taping.

Several studies used KT to realign the scapular position during dynamic movement and improve scapular muscle recruitment.[11-13,21] Because excessive activation of the UT with inhibited activation of the MT/LT and SA is commonly found in patients with shoulder disorders and dyskinesis, we expected taping to inhibit the UT and facilitate the MT/LT/SA.[25,26] In our study, participants with taping over the UT muscle demonstrated decreased UT activity in 72% of participants with increased posterior tipping of the scapula during arm movements. This finding is noteworthy for participants with pattern II dyskinesis, which has been characterized as overactivation of UT during movements.[15] In addition, more scapular upward rotation with large ES was found after UT taping in pattern II compared with pattern I. This indicates that taping over the UT muscle may help to restore coordinated scapular muscle balance and increased upward rotation of the scapula, especially in pattern II dyskinesis.

Although taping over UT muscle is benefited in patterns II and I + II dyskinesis in terms of reduced UT muscle activity and scapular posterior tipping, caution should be taken when applying taping over UT muscle. Dyskinesis pattern II has been characterized as increased UT activity and increased internal rotation of the scapula during arm elevation.[15] According to our findings, UT taping effectively decreases UT activity during arm elevation. However, UT taping may not be effective for the impaired internal rotation of dyskinesis pattern II. Similarly, UT taping effect seems to be not specific for dyskinesis pattern I + II, which have been described as having decreased LT activity and increased internal rotation of the scapula during arm elevation.[15] As dyskinesis pattern I has been characterized as decreased SA activity and

Table 4
Changes in scapular kinematics and muscle activation with LT taping at 120°, 90°, 60°, and 30° of arm elevation ($N = 54$)

Arm elevation	Pattern I (range); $N = 3$				Pattern II (mean ± SD); $N = 12$				Pattern I + II (mean ± SD); $N = 14$			
	>120°	90°-120°	60°-90°	30°-60°	Rest-30°	>120°	90°-120°	60°-90°	30°-60°	Rest-30°	>120°	90°-120°	60°-90°	30°-60°	Rest -30°
UR		25.6-39.6	20.0-26.8	9.9 to 14.8	−1.9 to 3.5		38.7 ± 8.9	28.3 ± 6.3	16.5 ± 4.9	4.5 ± 4.3		37.5 ± 6.6	29.4 ± 5.5	19.0 ± 4.3	5.8 ± 3.9
Taping		25.4-40.4	18.8-27.4	8.2 to 13.0	−3.5 to 2.6		39.5 ± 8.0	28.2 ± 5.6	16.2 ± 4.0	4.4 ± 3.3		37.0 ± 7.3	28.7 ± 5.9	17.7 ± 5.1	5.1 ± 4.8
PT		3.0-8.7	2.1-5.7	1.4 to 2.7	0.5 to 2.0		5.2 ± 9.5	3.7 ± 6.6	1.4 ± 4.2	−0.2 ± 2.3		5.3 ± 4.5	4.9 ± 4.6	3.6 ± 4.3	1.5 ± 3.4
Taping		4.3-9.7	4.1-6.9	2.6 to 4.0	2.0 to 2.9		6.4 ± 8.6	4.7 ± 6.4	2.6 ± 4.1	0.5 ± 2.5		5.3 ± 4.4	5.6 ± 4.2	4.5 ± 4.0	2.1 ± 3.1
ER		9.2-11.6	4.3-5.3	0.3 to 2.5	−2.0 to 3.8		12.2 ± 8.9	7.8 ± 6.3	4.6 ± 5.8	3.0 ± 5.1		10.5 ± 6.1	5.2 ± 5.3	1.6 ± 4.9	0.4 ± 4.1
Taping		9.9-11.9	5.3-6.8	−0.2 to 3.8	−1.9 to 4.5		12.3 ± 10.5	7.4 ± 6.6	4.1 ± 5.4	2.2 ± 4.4		9.1 ± 10.2	3.8 ± 7.9	1.2 ± 5.2	0.3 ± 4.2
UT	10.7-50.8	12.3-42.3	16.4-42.7	13.2 to 27.5	7.1 to 14.2	48.4 ± 22.8	33.6 ± 12.7	28.0 ± 12.0	19.8 ± 12.2	11.2 ± 10.7	34.6 ± 14.5	27.9 ± 8.3	23.3 ± 6.3	14.9 ± 5.9	6.4 ± 2.9
Taping	9.7-45.1	10.7-44.4	13.3-44.2	12.7 to 30.2	7.2 to 17.8	51.7 ± 22.1[a]	33.8 ± 9.4	27.5 ± 7.3	17.5 ± 5.2	8.7 ± 4.8	31.5 ± 13.1[a]	27.3 ± 7.2	23.3 ± 5.6	15.0 ± 5.6	7.1 ± 3.6
MT	20.5-45.1	21.8-33.3	18.1-24.9	11.6 to 18.5	6.1 to 10.6	34.4 ± 14.2	22.1 ± 7.2	18.6 ± 7.7	14.1 ± 6.5	8.7 ± 3.6	27.4 ± 9.6	21.9 ± 7.1	18.6 ± 6.8	14.4 ± 6.1	8.0 ± 4.7
Taping	13.2-37.2	15.0-28.4	15.3-21.2	10.3 to 19.0	6.1 to 10.2	30.9 ± 12.7	21.3 ± 8.1	17.9 ± 7.5	13.2 ± 5.5	8.3 ± 3.1	25.1 ± 10.8	21.8 ± 10.1	19.1 ± 8.4	15.0 ± 8.6	8.5 ± 5.4
LT	8.3-47.6	11.5-87.0	12.6-95.7	7.5 to 54.7	4.6 to 27.4	24.0 ± 9.1	19.0 ± 9.3	18.7 ± 10.4	13.2 ± 7.3	8.2 ± 4.4	16.0 ± 9.5	15.8 ± 7.7	15.3 ± 6.5	10.5 ± 4.2	5.4 ± 3.0
Taping	8.6-48.8	11.9-84.9	11.4-97.6	6.1 to 60.5	4.4 to 29.6	26.1 ± 9.9	21.4 ± 10.3	19.9 ± 11.5	14.4 ± 7.2	7.9 ± 4.0	17.1 ± 11.4	17.3 ± 9.7	15.7 ± 7.7	10.8 ± 5.0	5.8 ± 3.5
SA	49.8-78.1	24.0-45.3	14.2-29.2	4.3 to 16.3	3.8 to 12.0	56.3 ± 20.6	32.7 ± 15.1	23.0 ± 15.8	10.7 ± 7.9	6.6 ± 2.8	51.3 ± 18.6	34.2 ± 14.2	24.7 ± 11.7	14.7 ± 9.1	9.0 ± 6.1
Taping	43.6-79.6	23.1-51.0	12.2-28.5	4.9 to 17.1	4.0 ± 11.8	56.3 ± 18.5	34.1 ± 14.4	22.8 ± 13.9	10.3 ± 4.7	6.5 ± 2.5	48.1 ± 20.6	33.8 ± 12.8	26.1 ± 13.7	15.4 ± 11.0	9.8 ± 7.7

LT = lower trapezius; N = number; SD = standard deviation; UR = upward rotation; PT = posterior tilt; ER = external rotation: kinematics value without taping (°); UT = upper trapezius; MT = middle trapezius; SA = serratus anterior: electromyographic value without taping (% maximal voluntary isometric contraction).
120°, 90°, 60°, and *30°* (in italics): kinematics value at each angle of arm elevation.
[a] Large effect size in pattern II compared with pattern I + II.

decreased posterior tipping of the scapula during arm elevation,[15] our findings showed that effect of trapezius taping is minimal for pattern I dyskinesis.

The effect of taping condition in arm elevations should be considered in relating to small size of subacromial space. Previous studies have demonstrated that the rotator cuff tendons are positioned between the undersurface of the acromion and the humeral head between 34° and 72° of scapular plane arm elevation.[27] In the present study, the 2.2°-2.5° difference between taping conditions in posterior tipping occurred in this range of impingement risk. The magnitude of the difference, however, was small, and the effects on the mechanisms of impingement have yet to be proven. Although clinical taping effect cannot be assumed with respect to these findings, the findings do support a potential taping on movement-related mechanism for symptoms related to subacromial impingement. Specifically, given that different dyskinesis type may be at risk of impingement in terms of scapular kinematics, subtle magnitude effect of taping could contribute to initiation of inhibiting symptom progression.

The appropriateness of applying taping on MT in patients with scapular dyskinesis is uncertain. The MT muscle acts as retracting the scapula during arm elevation.[28] We assumed that the MT taping may alter scapular internal rotation and increase MT muscle activity. However, our findings showed increased UT activity after MT taping in patients with pattern II dyskinesis. Overactivation of UT activity was assumed to be related to scapular muscle imbalance and altered scapular kinematics, like inadequate upward rotation and posterior tipping of the scapula during arm movements, which increase the risk of shoulder impingement.[26,29] In our knowledge, it was the first study to apply taping on MT muscle for patients with dyskinesis. Further study to validate this finding is necessary.

Although no EMG or kinematic difference was found with LT taping in each dyskinesis pattern, methods of applying LT taping need to be further investigated. Investigating KT effects on LT muscle after muscle fatigue, Zanca et al[14] found no significant kinematic differences with LT taping. In agreement with their findings, we did not identify effect of LT taping. On the other hand, Hsu et al[11] found significant increase in scapular posterior tipping and LT activity during arm elevation in scapular plane with LT taping method. Different participants' characteristics and LT taping methods may explain the inconsistent findings. We recruited patients with different scapular dyskinesis pattern performing several overhead sports, whereas Hsu et al recruited specific baseball players having shoulder impingement without recording scapular dyskinesis. Direction of taping may also influence the effect of taping as application from origin to insertion in the study by Zanca et al[14] and from insertion to origin in our study as well as the study by Hsu et al.[11] Taping methods on LT muscles need to be further investigated.

The limitations of this study should be noted. First, there was no sham taping control group in this experiment to rule out the placebo effect. However, we thought the sham group might not be necessary because Hsu et al[11] found significant differences in scapular kinematics and muscle activation as compared with a placebo group with similar taping methods. Second, we only examined the immediate effect after taping. Future studies should include long-term follow-up to evaluate the therapeutic effects. Third, the effects of UT taping may have been underestimated. We did not fully extend the taping to distal attachment of the UT muscle due to the sensor position, which was on the flat surface of the acromion for kinematic data collection. Fourth, the uneven or small sample sizes for each dyskinesis pattern should be noted. The effects of taping may have been underestimated.

Conclusions

An essential part of a shoulder rehabilitation program is appropriate muscle recruitment and kinematics of the scapula. Reduced UT muscle activity and scapular posterior tipping are appropriate when applying taping over UT muscle in patterns II and I + II dyskinesis. Caution should be taken when applying taping over MT and LT muscles in terms of increased UT activity, especially in pattern II dyskinesis. Long-term effect of adjusted taping methods or combining taping methods on shoulder symptom and function in patients with specific pattern of scapular dyskinesis need further investigation.

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1. In this article scapular dyskinesis is characterized by
   a. rotator cuff impingement
   b. insufficient activation of the lower trapezius and over activation of the upper trapezius
   c. traction of the brachial plexus
   d. cervical spine compression
2. The taping was placed over the
   a. middle trapezius
   b. upper trapezius
   c. lower trapezius
   d. all three segments of the trapezius
3. Muscle activity was monitored by
   a. videography
   b. three CHTs
   c. surface EMG
   d. needle EMG
4. Results showed
   a. decreased LT activity with MT taping
   b. increased UT activity with MT taping
   c. decreased UT activity with MT taping
   d. no change in UT activity with MT taping
5. The authors conclude that kinesio taping may reduce scapular posterior tipping
   a. true
   b. false

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