



The effects of taping on scapular kinematics and muscle performance in baseball players with shoulder impingement syndrome

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ABSTRACT

Purpose: This study aimed to investigate the effect of elastic taping on kinematics, muscle activity and strength of the scapular region in baseball players with shoulder impingement.

Scope: Seventeen baseball players with shoulder impingement were recruited from three amateur baseball teams. All subjects received both the elastic taping (Kinesio Tex™) and the placebo taping (3 M Micropore tape) over the lower trapezius muscle. We measured the 3-dimensional scapular motion, electromyographic (EMG) activities of the upper and lower trapezius, and the serratus anterior muscles during arm elevation. Strength of the lower trapezius was tested prior to and after each taping application. The results of the analyses of variance (ANOVA) with repeated measures showed that the elastic taping significantly increased the scapular posterior tilt at 30° and 60° during arm raising and increased the lower trapezius muscle activity in the 60–30° arm lowering phase ($p < 0.05$) in comparison to the placebo taping.

Conclusions: The elastic taping resulted in positive changes in scapular motion and muscle performance. The results supported its use as a treatment aid in managing shoulder impingement problems.

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1. Introduction

Subacromial impingement syndrome is the most common shoulder complaint in orthopedic clinics (44–65%) (Michener et al., 2003) and the most frequent cause of shoulder pain in overarm athletes (Jobe et al., 2000). Many factors, such as anatomic morphology, overuse, and instability of the glenohumeral (GH) joint, have been shown to contribute to the occurrence of the subacromial impingement. In addition, the role of the scapular control in the impingement problems of the overarm athletes has aroused major interests after the Kibler's report (Kibler, 1998). The scapula, along with the humerus, clavicle, and thorax, makes up the shoulder complex. The scapula plays the key link between the upper extremity and the axial skeleton, and the musculature around it provides the proximal stability for the upper extremity activities. This function is important particularly for overarm athletes such as baseball players (Kibler, 1998; Wilk et al., 2002). These athletes must possess a stabilized scapula and the coordinated motion between the scapula and the humerus to deliver repetitive overarm

movements with great speed and power (Kibler, 1998). Studies have revealed that scapular dysfunction might lead to a vicious cycle involving microtrauma and chronic pain conditions and relate to the shoulder pain in baseball players (Kibler and McMullen, 2003).

The coordinated scapular movements are accomplished by the sophisticated neuromuscular control of the muscles attaching to it. Of all these muscles, the trapezius and serratus anterior are paired to form the important force couple which controls the movement of the scapular upward rotation and posterior tilt. These components of scapular movement are important for widening the subacromial space to prevent the impingement of the subacromial tissues (Michener et al., 2003; Solem-Bertoft et al., 1993). Altered function of these two muscles has been found to influence the scapular movement, and associate with subsequently poor shoulder function and chronic impingement problems (Kibler and McMullen, 2003). Cools et al. (2003) and Ludewig and Cook (2000) observed inhibition of the serratus anterior and lower trapezius, and over activation of the upper trapezius muscle in the subjects with shoulder impingement syndrome. Tai et al. (2005) identified the weakness of the lower trapezius in the amateur baseball players with chronic shoulder pain. The changes of scapular kinematics in the subjects with shoulder impingement including increased scapular winging during arm elevation, decreased scapular upward rotation and posterior tilt, and increased scapular

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superior translation were also documented (Lin et al., 2005; Ludewig and Cook, 2000; Michener et al., 2003).

The close relation between the scapular and shoulder function lead to the emphasis of the restoration of the scapular control in the rehabilitation programs for shoulder impingement (Kibler and McMullen, 2003; Mottram, 1997). One of the useful methods to facilitate the control of scapula is taping (Mottram, 1997). Although the underlying mechanisms of the taping effects are still unclear, many believed that taping works by offering constant proprioceptive feedback or providing alignment correction during dynamic movements (Alexander et al., 2003; Ackermann et al., 2002). Researchers have demonstrated that taping effectively improved the posture alignment, increased the shoulder range of motion, and reduced pain and discomfort of the shoulder and the patellofemoral joints (Lewis et al., 2005; Christou, 2004; Whittingham et al., 2004). However, little was mentioned in the literature about the effects of scapular taping on the scapular kinematics and muscle performance. McConnell taping for the shoulder impingement syndrome (a rigid tape across the muscle belly of the upper trapezius and along the lower trapezius) seemed to reduce pain and improve range of motion of the shoulder, but produced no significant alteration on the electromyographic activities of the two taped muscles (Cools et al., 2002; Wang et al., 2001). Ackermann et al. (2002) applied a rigid tape in the professional violinists and found negative effects on the upper trapezius activity and violin performance. They explained that the rigid tape and correctional taping techniques might have caused movement restriction and skin irritation, and thus were disadvantageous for fine movement control of the upper extremity. From our clinical experiences, the elastic taping causes minimal movement restriction while providing some degree of support and cutaneous inputs, which would be a better choice for treating the overarm athletes such as baseball players with shoulder impingement syndrome. To our knowledge, no study exists discussing the effects of elastic taping on shoulder function in this population. Therefore, the aim of this study was to investigate the effects of elastic taping on the scapular kinematics, muscle strength and electromyographic activity in the baseball players with shoulder impingement problems.

2. Methods

A cross-over, pretest/posttest repeated measures design was used to compare the effects of elastic and placebo taping for baseball players with shoulder impingement syndrome. All subjects received both types of taping with the order of taping randomly assigned as the elastic taping first or the placebo taping first. Two taping sessions were separated by at least three days to avoid accumulation of the taping effects. The study was approved by the Institutional Review Board of National Yang Ming University.

2.1. Subjects

Baseball players with shoulder impingement syndrome were recruited from three amateur baseball teams in Taipei. All subjects were informed of the nature of this study and signed the consent form. Subjects were included if they showed positive sign in two or more shoulder impingement screening items, and in at least one of the specific subacromial impingement tests. The shoulder impingement screening items were: (1) a history of proximal anterior or lateral shoulder pain persisted for more than 1 week during the last six months; (2) painful arc with active shoulder elevation; (3) tenderness to palpation of rotator cuff tendons; (4) pain with resisted isometric shoulder abduction; (5) positive Jobe's test (empty can test). Specific subacromial impingement tests used in

this study were the Neer sign and Hawkins sign (Pappas et al., 2006; MacDonald et al., 2000).

Subjects were excluded if any of the followings was found: (1) a history of dislocation or traumatic injuries on the tested shoulder complex; (2) a history of shoulder surgery within the last 6 months; (3) reproduction of symptoms in the cervical screening examination (active and passive range of motion, and overpressure); (4) failure to complete two testing sessions.

2.2. Instrumentations

The Liberty electromagnetic tracking system (Polhemus, Colchester, VT, USA) was used to collect the three-dimensional kinematic data at a sampling rate of 120 Hz. Three sensors were used and attached respectively onto the scapula, humerus and upper trunk with double-sided tape. The selected placements did not interfere with the application of therapeutic taping or any of the testing movements. The thoracic sensor was positioned at the 3rd thoracic spinous process after cleansing the skin by 75% alcohol. The humeral sensor was fixed to the posterior aspect of the distal humerus and reinforced by an elastic strap. The scapular sensor was attached to the flat bony surface of the posterior-lateral acromion, just proximal to the origin of the deltoid (Karduna et al., 2001; Ludewig and Cook, 2000). This method of the surface scapular sensor placement has been validated by a 2-D radiographic measurement (McQuade and Smidt, 1998), and a bone-pin sensor placement method (Karduna et al., 2001). A pen stylus was used to digitize the palpated bony landmarks for defining the anatomical coordinate systems. The transmitter was fixed on a tripod behind the subject. The magnetic disturbance in the testing environment was checked for minimal orientation and position interference.

An 8-channel FM/FM Telemetric EMG system (Telemetry 900, Noraxon USA, Inc., Scottsdale, AZ) was used to record the myoelectric data. This system had an input impedance of 10 M Ω , common mode rejection ratio of 85 dB and gain of 2000. All EMG signals were converted by an analog-to-digital (A-D) converter (NI PCM-CIA 6036 E, USA; 12-bit resolution) and recorded at a sampling rate of 1000 Hz. The EMG sensors used in this study were bipolar silver/silver chloride electrodes (Blue Sensor P-00-S, Ambu Inc., Linthicum, USA), with 2 cm interelectrode distance. For the serratus anterior, the electrodes were placed at the intersection of 6th rib and midaxillary line, parallel to the muscle fibers and anterior to the latissimus dorsi muscle fibers while the subject held his arm at 90° flexion (Ludewig and Cook, 2000; Ekstrom et al., 2004). Electrodes for the upper trapezius were positioned midway between the 7th cervical spinous process and the acromion angle along the direction of the muscle fibers (Cools et al., 2003). Electrodes for the lower trapezius were obliquely placed along the line connecting the root of the spine of the scapula and the 7th thoracic spinous process when the subject's arm was fully flexed (Cools et al., 2003). The ground electrode was attached to the opposite acromial process. A hand-held dynamometer (Power track II, JTech Medical industries, Utah, USA) was used to test the muscle strength of the lower trapezius before and after taping application.

2.3. Procedures

The measurements of muscle strength, EMG and scapular motion were performed in both placebo and Kinesio sessions. The sensors and electrodes were placed on the dominant arm, and the subject was positioned sitting with his arms relaxed on both sides. Ten bony landmarks were then palpated and digitized by the stylus, including jugular notch, xiphoid process, spinous process of 7th cervical vertebra, spinous process of 8th thoracic vertebra, root of the spine of scapula, inferior angle, acromial angle, acromioclavicular

vicular joint, medial epicondyle and lateral epicondyle (Wu et al., 2005). The testing movement in this study was scaption, which involved elevating and lowering the humerus in the scapular plane (30° anterior to the frontal plane), guided by a wooden pole (Fig. 1). Each cycle of scaption took 8 s to accomplish (4-s elevation and 4-s lowering), paced by a metronome rhythm. The subject practiced several scaptions before the testing. When the subject was able to match the movement rhythm, he would then perform three successive scaptions with a 2-kg weight in hand while the kinematic and EMG data were simultaneously collected.

After a 3-min rest, the reference voluntary contraction (RVC) tasks were carried out. This required the seated subject to hold a 2-kg weight in the hand and keep the arm in a 125°-scaption position for 5 s. Three RVC tasks were repeated with at least 1-min rest between each contraction. The averaged EMG amplitude of RVC tasks would be used for normalization of the EMG data of the dynamic scaption tests. Afterwards, the lower trapezius muscle strength was tested by a blinded examiner. The subject lay prone and placed the tested arm overhead in the line of the lower trapezius muscle fibers with the thumb pointing upward (Hislop and Montgomery, 1995). Three maximal voluntary isometric contractions of the lower trapezius were performed, and the peak values were averaged for further analysis.

The subjects then rested for 3-min before taping the lower trapezius muscle with either elastic or a placebo tape. The elastic tape was a 5 cm × 28 cm piece of Kinesio tape (Kinesio Tex, KT-X-050, Tokyo, Japan), cut into an Y shape, and applied to envelope the lower trapezius muscle (Fig. 2) with minimal tension according to the recommendation of Kase (Kase and Wallis, 2002). The placebo tape was a same-sized Y-shaped 3 M Micropore tape (3 M, St. Paul, USA), applied over the same position without any stretch force. After the taping application, the subject received second measurements of scapular motion, EMG activities, and isometric strength of the lower trapezius.

2.4. Data analysis

The kinematic data from the electromagnetic sensors and the stylus were recorded by the Liberty system, and used to define the anatomical coordinate systems by a customized C-based program. The definition of the segmental coordinate systems followed the recommendations of the International Shoulder Group of the



Fig. 2. Taping position for the lower trapezius.

International Society of Biomechanics (Wu et al., 2005). The inaccessible landmark, the glenohumeral joint center (GH), was estimated by the regression analysis method suggested by Meskers et al. (1998). The Euler angles of the rotational matrices of the humerus and scapula with respect to the thorax were then calculated. The humeral rotations were described firstly about the Y-axis of the thorax (the plane of elevation), the Z-axis of the humerus (elevation), and then the Y-axis of the humerus (humeral internal/external rotation). Scapular rotations were represented as rotation about the Y-axis of the scapula (scapular internal/external rotation), about the Z-axis of the scapula (upward/downward rotation), and about the X-axis of the scapula (posterior/anterior tilt) (Myers et al., 2005; Wu et al., 2005). The displacement of the scapula relative to the thorax was calculated by the distance of AA to IJ in the directions of X (+: lateral), Y (+: superior) and Z (+: posterior) of the thorax coordinate system. The position and orientation data of the scapula at 30°, 60°, 90° and 120° of humeral elevation were obtained in both the elevating and lowering phases for further comparisons.

The EMG signals were band-pass filtered from 15 to 500 Hz and band-stop filtered between 58–62 Hz (Butterworth), and then root-mean-squared (RMS) with a window of 50 ms. The dynamic EMG data of the upper and lower trapezius, and the serratus anterior were extracted, normalized and averaged in the windows of 30–60°, 60–90°, 90–120°, 120–90°, 90–60° and 60–30° of the scaption. The normalization values for these three muscles were obtained during the RVC task (holding a 2-kg weight in hand at 125° arm scaption). This testing position was chosen for it was close to the highest point in our dynamic testing and not too difficult for our subjects to perform. The RVC normalization method has been used in the previous dynamic study and the muscle activities recorded in our RVC task were proven in the pilot study a reliable submaximal isometric contraction to be used as the normalization values (Hsu et al., 2005; Bao et al., 1995). The kinematic and EMG data of the second and third scaption trials were averaged for each testing session. The change scores of all variables were then calculated by subtracting the pretest values from the posttest values for subsequent analyses.

The within-day reliability of the kinematic data, normalized EMG activities, and muscle strength has been established in the pilot studies ($ICC_{3,2} = .74-.99$) (Hsu et al., 2005, 2006).

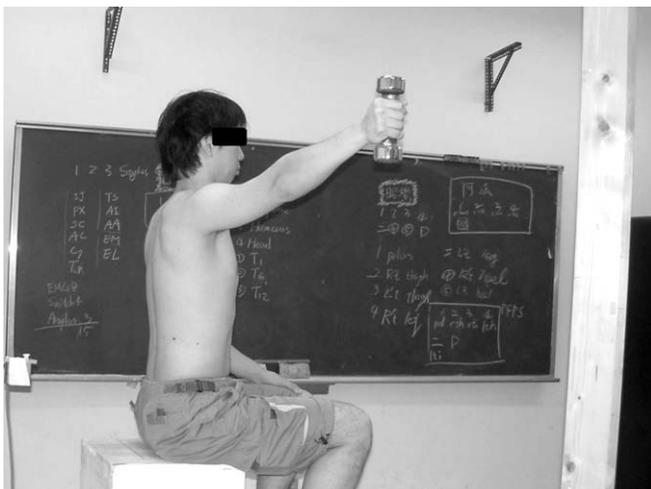


Fig. 1. The scaption test involved elevating and lowering the humerus in the scapular plane (30° anterior to the frontal plane).

2.5. Statistical method

Paired *t* tests were used to compare the pre-taping baseline values of the Kinesio and placebo sessions for all outcome variables. The change scores of all outcome variables between the two taping applications were analysed by the analyses of variance (ANOVA) with repeated measures. The α level of .05 was set for the statistical significance. All the statistical analyses were performed with the Statistical Package for Social Sciences version 12.0 (SPSS 12.0, SPSS Inc., Chicago, USA).

3. Results

3.1. Description of subjects

A total of seventeen baseball players completed the tests. The basic data of these subjects were averaged: age = 23 ± 2.8 years old; BMI = 25.5 ± 2.3 kg/m²; duration of participation in baseball = 14 ± 2.9 years. The duration of shoulder symptoms ranged from 0 to 24 months (median = 2 months); the maximal pain intensity in the last 24 h was between 0 and 8 (median = 3). Among the subjects, nine were pitchers and eight were fielders of various positions. Five pitchers were assigned in the elastic taping first and four in the placebo taping first group. Only one left-handed pitcher was recruited in the placebo taping first group. The subjective characteristics were similar between the two groups ($p > .05$).

The total testing time was about an hour for each session. All testing of our study was conducted under pain-free condition. No subject complained of fatigue during and after the test. Two subjects (one in each group) complained of discomfort when they were positioned for testing the lower trapezius muscle strength. The testing position of these two subjects was then modified by decreasing 15° of shoulder elevation.

3.2. Baseline data characteristics

During the elevation phase of 30–120° scaption, the scapula rotated upwards (−1.5° to 29.8°), tilted posteriorly (−10.5° to 2.0°), and shifted superiorly, medially and posteriorly. Relative small internal/external rotation of the scapula was observed (Fig. 3). A reversed pattern of scapular movement was found as the arm lowered down (the lowering phase). For the scapular muscles, the activities of the serratus anterior, and the lower and upper trapezius increased with arm elevation and decreased as the arm lowered down (Fig. 4).

The baseline testing showed no significant difference of all outcome variables between two taping conditions ($p > .05$), except larger scapular upward rotation in the Kinesio session at 90° and 120° of humeral elevation ($p = .03$ and $.04$). Thus these two baseline scapular upward rotation data were used as covariates in the subsequent comparisons.

3.3. Scapular kinematic changes with two types of taping

Tables 1 and 2 show the post-taping changes of the scapular kinematics. Both Kinesio and placebo taping decreased the scapular upward rotation between 30° and 60° of arm elevation, but increased it afterwards. Posterior tilt and internal rotation of the scapula tended to increase with Kinesio taping and decrease with the placebo taping in two-third of the scaption cycle. However, significant differences between the two types of taping were only found in the scapular posterior tilt at 30° and 60° of humeral elevation ($p < .05$). Change in scapular displacement was not statistically significant between two types of taping.

3.4. Scapular muscle activity changes with two types of taping

Taping tended to increase the muscle activation of the serratus anterior and upper trapezius in the entire range of scaption (Table 3). As comparing the changes with two types of taping, the placebo taping significantly increased the upper trapezius muscle activity during 90–120° of shoulder elevation. For the lower trapezius, both types of taping decreased its activity in the first two-third of the scaption. Afterwards, the placebo taping continued to reduce the lower trapezius muscle activity while Kinesio taping increased it. This opposite effect of taping reached the statistical significance during 60–30° of shoulder lowering phase ($p < .05$).

3.5. Lower trapezius muscle strength changes with two types of taping

The pre-taping lower trapezius strength was 36.3 ± 8.5 lb in the Kinesio session and 37.1 ± 6.8 lb in the placebo session ($p > .05$). The lower trapezius muscle strength increased (38.3 ± 9.9 lb) with the Kinesio taping but decreased with the placebo taping (36.4 ± 7.0 lb). The strength changes between the two taping conditions (2.0 ± 3.9 lb vs. -0.7 ± 3.3 lb) almost reached the level of statistical significance ($p = .05$).

4. Discussion

4.1. Baseline data characteristics

The scapular movement pattern observed in this investigation agreed with those in the literature (Karduna et al., 2001; Myers et al., 2005). The ranges of the scapular upward rotation (31°) and posterior tilt (12°) during 30° to 120° of shoulder scaption were comparable to the previous data.

The EMG normalization method used in this study was a static test, during which the muscle activities of the upper and lower trapezius and the serratus anterior were measured simultaneously while subjects holding a 2-kg weight in hand at 125° arm scaption. Compared to the traditional maximal voluntary isometric contraction (MVIC) method which demanded the subject to carry out maximum voluntary contractions for each muscle, our RVC method required less time and effort for patients to conduct, and could effectively eliminate the effects of factors such as electrode placement or skin conduction. Some authors have used the peak EMG value detected in a dynamic task as the normalization reference (Clarys, 2000). These authors argued that a dynamic normalization procedure was a better choice for dynamic testing because the static MVICs might be smaller than the “peak” values detected in dynamic tasks. Nevertheless, the peak muscle activity values measured in the dynamic arm elevation movement was not as repeatable as those measured in the RVC test in our study. This was probably due to the pain and fatigue in our patient group. Since the stability of the normalization value was very important for a meaningful interpretation of the muscle activities, we therefore used the RVC normalization method in this study. Despite of different references used for the normalization of EMG signals, the pattern of increasing scapular muscle activation with arm elevation and vice versa were consistent with the findings in the past (Cools et al., 2002; Ludewig and Cook, 2000).

4.2. Taping effect on the scapular kinematics

Kinesio taping over the lower trapezius tended to increase scapular posterior tilt when humeral elevation was <90° in the subjects with shoulder impingement (Table 1). Endo et al. (2001) has observed that the decreased scapular posterior tilt in the subjects with shoulder impingement syndrome occurred around 45° and

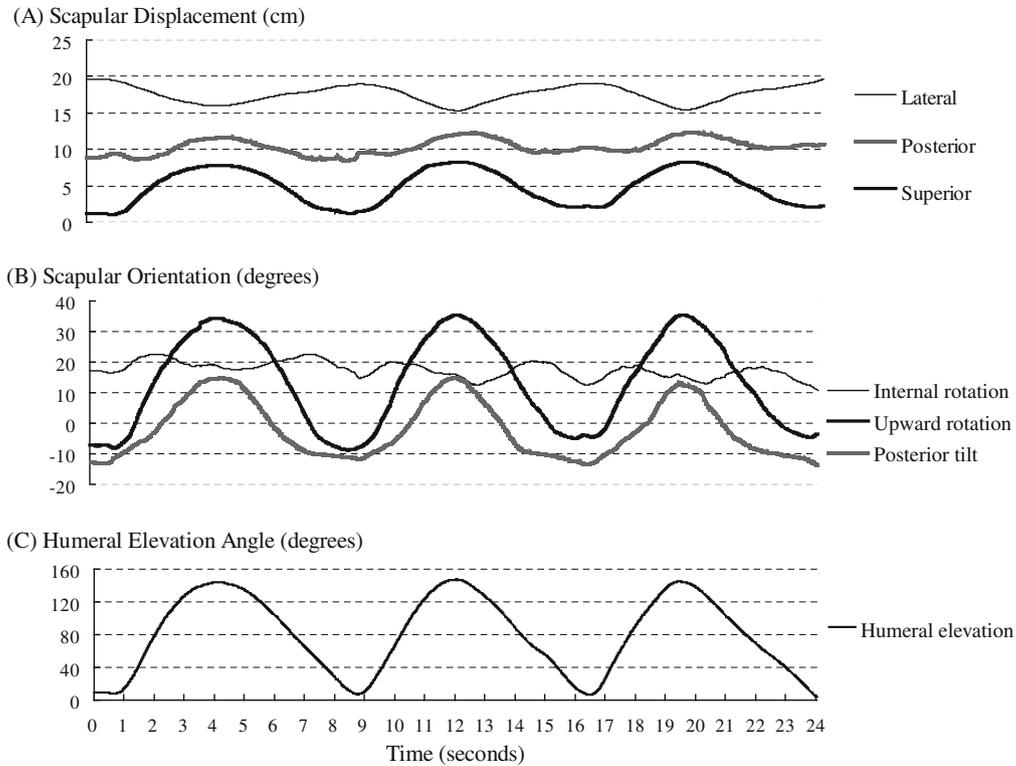


Fig. 3. Representative raw data of the scapular kinematics.

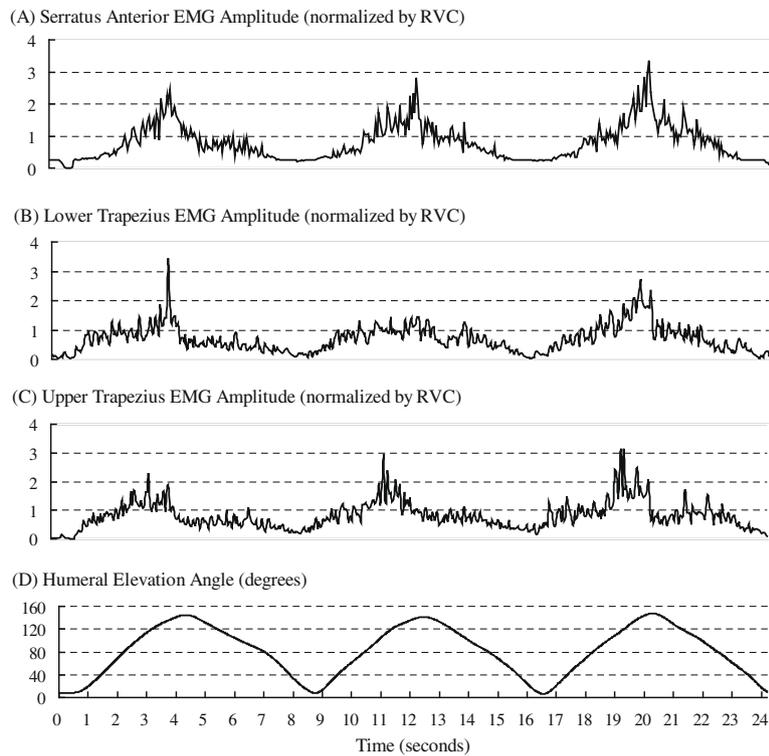


Fig. 4. Reference voluntary contraction (RVC) normalized electromyographic (EMG) data for one representative subject.

90° of humeral elevation. This suggested that Kinesio taping might assisting in correcting the affected scapular movements, and thus help these subjects to have their arm function on a more balanced

and stabilized base (the scapula). Host (1995) showed that scapular taping could decrease the excessive scapular elevation, winging and anterior tilt in the subject with anterior shoulder impingement

Table 1
Mean post-taping changes (standard deviation) in the scapular orientations (°).

Humeral elevation (°)	Upward rotation		Posterior tilt		Internal rotation	
	Kinesio session	Control session	Kinesio session	Control session	Kinesio session	Control session
30	-.62 (1.61)	-.91 (3.20)	.39 (.95)*	-.71 (1.41)	.04 (3.30)	-.91 (5.26)
60	-.18 (1.61)	-.69 (2.70)	.44 (1.29)*	-.75 (1.75)	.63 (3.34)	-1.10 (5.72)
90	.98 (1.90)	.82 (2.53)	.36 (1.74)	-.07 (2.10)	.65 (3.15)	-1.14 (5.42)
120	1.71 (1.47)	1.40 (2.70)	-.13 (1.43)	-.05 (2.46)	.79 (3.04)	-.89 (5.77)
120	1.59 (1.81)	1.10 (2.71)	-.08 (.94)	-.69 (2.60)	.25 (2.97)	-.52 (5.57)
90	.94 (1.44)	.80 (2.33)	.27 (1.30)	-.59 (1.91)	-.27 (3.34)	-1.63 (6.05)
60	.79 (2.43)	.72 (2.15)	.76 (1.71)	-.42 (1.78)	-.44 (3.49)	-1.98 (6.02)
30	.55 (2.36)	.23 (3.03)	1.02 (1.29)	-.03 (2.20)	-.34 (3.03)	-1.83 (5.26)

* Significant difference ($p < .05$) between two taping conditions.**Table 2**
Mean post-taping changes (standard deviation) in the scapular displacements (mm).

Humeral elevation (°)	Lateral displacement		Superior displacement		Posterior displacement	
	Kinesio session	Control session	Kinesio session	Control session	Kinesio session	Control session
30	.3 (2.7)	.5 (5.2)	.9 (4.4)	.3 (6.1)	1.5 (9.4)	5.0 (16.4)
60	.3 (3.1)	1.4 (5.3)	-.6 (3.9)	.6 (4.9)	.6 (8.1)	4.9 (16.3)
90	-.2 (3.2)	.9 (5.2)	1.4 (4.0)	2.6 (5.4)	.4 (7.0)	4.6 (13.7)
120	.2 (2.5)	.4 (5.6)	2.4 (4.2)	2.9 (6.4)	.2 (6.2)	3.8 (12.9)
120	.4 (2.5)	-1.1 (4.9)	2.3 (4.5)	2.3 (6.4)	.7 (7.5)	3.7 (12.8)
90	.8 (2.7)	.1 (5.0)	1.0 (4.5)	1.9 (5.8)	1.8 (8.7)	5.8 (15.9)
60	.6 (3.3)	.9 (4.7)	.7 (5.8)	2.3 (6.4)	1.7 (9.6)	7.0 (17.4)
30	.2 (2.9)	1.1 (4.4)	.5 (5.0)	2.1 (7.6)	1.6 (8.2)	8.0 (16.8)

Table 3
Mean post-taping changes (standard deviation) in the scapular muscle electromyographic activity normalized by reference voluntary contraction (% RVC).

Humeral elevation (°)	Upper trapezius		Lower trapezius		Serratus anterior	
	Kinesio session	Control session	Kinesio session	Control session	Kinesio session	Control session
30–60	8.0 (27.7)	8.9 (20.2)	-1.2 (17.5)	-5.6 (16.7)	2.1 (7.9)	.8 (9.3)
60–90	11.1 (29.5)	16.4 (20.6)	-9.1 (21.3)	-9.9 (20.5)	4.5 (18.8)	8.5 (15.1)
90–120	1.4 (29.6)*	24.4 (24.5)	-20.3 (51.9)	-3.2 (39.2)	4.7 (31.9)	11.9 (13.9)
120–90	3.3 (20.9)	8.9 (14.2)	-6.3 (31.4)	.8 (17.6)	11.5 (17.9)	6.3 (8.9)
90–60	3.6 (28.1)	4.7 (15.1)	10.2 (27.2)	-3.5 (13.5)	13.0 (29.1)	-7 (7.6)
60–30	5.1 (25.3)	1.5 (10.9)	7.9 (28.9)*	-6.3 (8.9)	11.7 (38.3)	.8 (5.9)

* Significant difference ($p < .05$) between two taping conditions.

in a case report, and suggested that taping was beneficial for the improvement of the symptoms and could facilitate the return of the participation in the competitive sports.

Both the Kinesio and the placebo 3 M taping seemed to decrease scapular upward rotation in the initial elevation. This effect was then reversed in the later elevation and in the lowering phases. According to Mottram (1997), a well-controlled scapular movement required little rotation in the initial arm elevation, followed by a markedly increase in the higher range of shoulder elevation. Therefore our data suggested that both taping might assist in normalizing the pattern of the scapular upward rotation during shoulder scaption. We did not observe the significant taping effect on the changes of scapular internal rotation and displacements. This reflected that the design of our taping method worked well on improving the movement components controlled by the lower trapezius, but not other directions of scapular motion.

4.3. Taping effect on the scapular muscle activities

Previous opinions about the taping effect on the muscle activity were inconsistent. Studies have shown that McConnell scapular taping had no significant effect on the muscle activity (Cools et al., 2002; Wang et al., 2001). Alexander et al. (2003) found that the parallel lower trapezius taping with rigid Endura Sports tape

inhibited the trapezius H reflex in the healthy volunteers. We found a facilitating effect of the Kinesio taping on the lower trapezius muscle activity during the lowering phase of the scaption tasks. This discrepancy might be explained from several perspectives: first of all, the selected subjects (healthy population vs. shoulder impinged baseball players); secondly, the plane of the testing movement (coronal vs. scapular plane); and the third, the type of taping technique used (non-elastic tape with McConnell taping technique vs. elastic tape with Kinesio facilitating taping technique). A Moiré Topographic study revealed the significant asymmetry of the bilateral scapula during 60–30° of the arm lowering phase in the subjects with shoulder impingement (Warner et al., 1992). The authors attributed this asymmetry to the impaired eccentric control of the serratus anterior and lower trapezius. The increased lower trapezius muscle activity in the 60–30° lowering phase after Kinesio taping application implied that the subjects with shoulder impingement might be responsive to the taping treatment. The trend of decreased lower trapezius activity between 90° and 120° of shoulder scaption was unexpected. A possible explanation was that the Kinesio taping had some supporting effects which helped the lower trapezius muscle to act more efficiently. Other authors have also found that the correctional or supporting taping decreased the muscle EMG activity needed for maintaining or promoting the functional performance (Ng and

Cheng, 2002; Tsai and Chen, 2005). This was also observed in our study that an improved scapular upward rotation and posterior tilt pattern occurred with taping despite of the decreased lower trapezius muscle activity.

Compared to Kinesio taping, placebo taping increased the upper trapezius activity during 90–120° of shoulder scaption. This activation increment might be a result of the effort for counteracting the restrained scapular movement produced by the non-elastic placebo tapes. Many researchers found that the upper trapezius muscle tended to increase its activation in the patients with shoulder impingement (Ludewig and Cook, 2000; Cools et al., 2007; Lin et al., 2005). This might be a compensatory effect for the insufficient scapular control, and could result in scapular muscle imbalance and the dysfunction of the shoulder and neck region. A similar, undesirable taping effect of increased upper trapezius activation and poor performance has also been reported by Ackermann et al. (2002) in the asymptomatic violinists.

4.4. Taping effect on the strength of the lower trapezius

Compared to the placebo taping, the strength of the lower trapezius had a tendency to increase after Kinesio taping application ($p = .05$). To the authors' knowledge, no literature exists about the effect of Kinesio taping on muscle strength except one report on the public website which speculated the increased knee extension strength after Kinesio taping in two patients after anterior cruciate ligament repair (Murray, 2000). Our result of the immediate taping effect on the muscle strength, though not statistically significant, was encouraging. Improvement of muscle strength usually takes place after a period of 4–6 weeks of training. As to the reason why the application of Kinesio taping could lead to the marginal increase of the lower trapezius muscle strength immediately can be explained by the results of the facilitated muscle activity and the improved scapular alignment. This might also indicate a potential benefit of using the elastic taping to aid the scapular muscle training in the patients with shoulder impingement syndrome. The long-term effect of the Kinesio taping on the strength gain requires further research to clarify.

4.5. Limitations and further study

The cross-over design of this study aimed to prevent the over-flow effects of taping. More than three days of separation between the two taping sessions was adequate, and most of the baseline data were of no difference between the two testing sessions. However, unexpected injuries between two testing sessions and a relatively short off-season period for the data collection left us only seventeen subjects completing the study. This might result in the insufficient power for statistical analysis of some outcome variables. This study examined the immediate effects of the Kinesio taping without exercise training. Dr. Kase (Kase and Wallis, 2002), the inventor of the Kinesio taping, however suggested that Kinesio taping works better if the intervention is cooperated with adequate exercise. This would be the next step of the research. Finally, both EMG and kinematic data were recorded using skin-based methods. Taping also functions through the skin. How this skin-based treatment system affected the validity of our data should be closely monitored in the future.

5. Conclusion

This is the first study to investigate the effects of Kinesio taping on the scapular kinematics and muscle performance in the baseball players with shoulder impingement syndrome. The application of

Kinesio taping over the lower trapezius muscle improved the lower trapezius activity during 60–30° of the lowering phase of arm scaption, and increased scapular posterior tilt at 30° and 60° of arm scaption. These results suggested that Kinesio taping could be a useful therapeutic and prophylactic assistance both in the rehabilitation clinic and in the field.

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