The Effects of Scapular Taping on Electromyographic Muscle Activity and Proprioception Feedback in Healthy Shoulders

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ABSTRACT: We investigated the effects of scapular tape on the electromyographic (EMG) activity of the upper trapezius (UT), lower trapezius (LT), serratus anterior (SA), anterior deltoid (AD), and shoulder proprioception in 12 healthy shoulders. Participants were blindfolded and required to complete a target end/mid range position with the hand. They performed six trials under two experimental conditions; no tape and therapeutic tape. EMG activity was measured by surface electrodes, and proprioception was measured by the FASTRAK electromagnetic motion tracking system. Two-way repeated measures ANOVA showed that UT and AD activities decreased 2.65% ($p = 0.001$), and SA muscular activities increased 1.9% ($p = 0.015$) in the taping condition. The proprioceptive feedback magnitude was significantly lower in the taping condition than in the no taping condition (11.9°, $p < 0.005$). Additionally, correlation coefficients were higher than 0.5 between muscle activity and proprioceptive feedback with the taping condition; UT and magnitude in the mid range task ($R = 0.516$); LT and magnitude in the end range task ($R = -0.524$); and SA and magnitude in the mid range task ($R = -0.576$). The results suggest that scapular tape affects the muscle activity of UT, AD, and SA, and that the effects are related to proprioception feedback. These results implicate that the mechanisms by which scapular taping induces effects can be explained by neuromuscular control and proprioceptive feedback factors. J Orthop Res 29: 53–57, 2011

Keywords: shoulder proprioception; scapular taping; electromyography; upper trapezius; lower trapezius (LT); serratus anterior (SA); anterior deltoid (AD)

Shoulder pain and related glenohumeral joint movement dysfunction are common conditions.[1,2] These dysfunctions are aggravated by frequent use of the arm at or above the shoulder level. Consequently, shoulder impingement, rotator cuff disease, glenohumeral joint instability, or adhesive capsulitis may develop.[2,3] Scapular or humeral movement alterations are thought to be related to these conditions. A number of factors have been proposed to affect scapular or humeral movement, including soft tissue tightness, muscle activity, and bony alignment.[4,5] Treatments for these complaints aim to address these aspects to correct scapular or humeral movements.[4,6]

Application of tape is widely used in rehabilitation and prevention of these shoulder complaints.[7–10] The rationale for taping is that it affords protection and support for a joint during functional movement.[7] Although it is unclear if tape protects the glenohumeral joint position,[8,9] immediate symptoms improve with scapular taping and relief of symptoms is greater during functional movement than in static positions.[8,10]

Evidence to support that control of the scapula can be altered by taping is limited.[8,11] Selkowitz et al.[8] found that compared to the no taping condition, scapular taping decreased upper trapezius (UT) activity and increased lower trapezius (LT) activity in people with suspected shoulder impingement during a functional overhead-reaching task. In contrast, using a scapular taping technique on healthy individuals, Alexander et al.[11] found a decreased amplitude of the LT H-reflex, indicating an inhibitory influence of taping. On the other hand, Cools et al.[7] found no significant differences between scapular taping and no taping for the upper, middle, and LT, and the serratus anterior (SA). Tape may adjust muscle activity via proprioceptive feedback, a sensory modality allowing a person to identify the position of a limb in space and perceive limb motion.[12] Subjects with stiff shoulder have reduced proprioceptive feedback during arm elevation,[13] but others reported that scapular taping did not affect joint repositioning during active shoulder movements.[9] Just how electromyography (EMG) and proprioception are changed by taping and whether the altered EMG amplitude is associated with proprioception should be determined.

The purpose of our study was to determine if EMG activity in the scapular muscles is influenced by the application of tape over the muscle belly of the UT muscle by removing the confounding effects of pain and by including an asymptomatic group. Based on clinical assumptions and previous investigations,[7,8,14–17] we assumed that with taping, UT activity would decrease and the LT/SA would increase. Additionally, we hypothesized that taping would improve proprioception feedback. Although previous studies[8,15,16] partially supported these hypotheses in symptomatic subjects,

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taping-induced changes in EMG activity in those samples may have been related to pain reduction with taping. If the alterations were due to other factors, such as mechanical changes in scapular position or changes in proprioception, without the related effects of pain, the taping would have produced results similar to those of the asymptomatic group. We also hypothesized a correlation between muscle activity and proprioceptive feedback.

MATERIALS AND METHODS

Twelve healthy subjects (10 males) with a mean age of 23.7 ± 4.8 years, a mean height of $172.9\,V \pm 10.1$ cm, and a mean body mass of 72.4 ± 14.3 kg participated. Each subject signed an informed consent form approved by the Human Subjects Committee of University Hospital. Based on the judgment of what constitutes clinically meaningful differences and variability estimates from previous studies,[7,8,11] a sample size of 12 subjects provided 80% power to detect differences of 5° proprioception with and without the taping condition at an alpha level of 0.05 with a two-tailed test. We used an "I" shaped Kinesio tape (Kinesio Tex KT-X-050, Osaka, Japan). With a method modified from Lewis et al.,[18] subjects were asked to fully retract and depress their scapula and maintain the posture. At the same time, we applied the Kinesio tape from the inferior margin of the medial 1/3 of the clavicle to T12 with full stretching of the tape (Fig. 1).

The 3D position and orientation of each subject's thorax, scapula, and humerus were tracked (40-Hz sampling rate) using the FASTRAK electromagnetic motion capture system (Polhemus, Inc., Colchester, VT). The sensors for the system were attached to bony landmarks with adhesive tape and Velcro straps. These surface sensor placements were the sternum, the flat superior bony surface of the scapular acromial process, and the distal humerus between the lateral and medial epicondyles.[13] A fourth sensor, attached to a stylus, was used to digitize palpated anatomical coordinates (bony landmarks: sternal notch, xiphoid process, 7th cervical vertebra, eighth thoracic vertebra, acromioclavicular joint, root of the spine of the scapula, inferior angle of the scapula, and lateral and medial epicondyles; the glenohumeral joint rotation center was operationalized by the anterior humeral joint and posterior humeral joint).[19,20] The absolute axes defined by the sensors of the FASTRAK device were converted to anatomically defined axes derived from the bony landmarks. Raw kinematic data were low-pass filtered at a 6-Hz cutoff frequency and converted into anatomically defined rotations.[19,20] Humeral orientation relative to the scapula was described using a Euler angle sequence in which the first rotation represented the plane of elevation, the second the amount of elevation, and the third the amount of axial rotation.

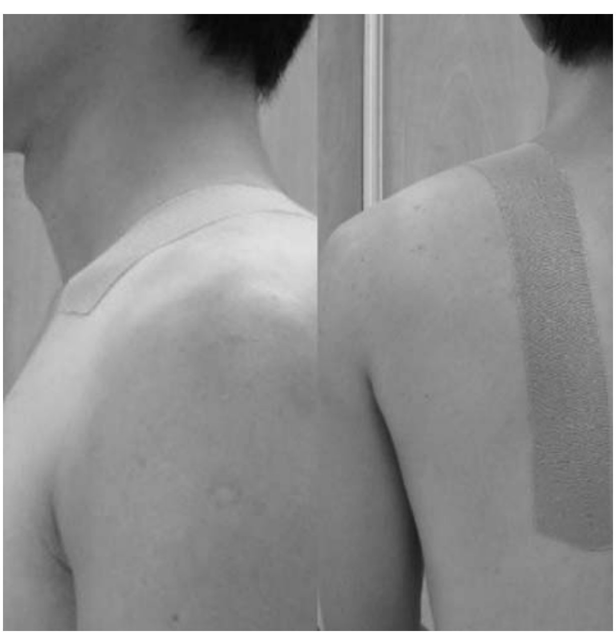

Figure 1. An "I" shaped Kinesio tape was applied from the inferior margin of the medial 1/3 clavicle to T12 with full stretching of the tape, and the subject was asked to fully retract and depress their scapula and maintain the posture.

The sEMG assemblies included pairs of AgCl circular (recording diameter = 10 mm) surface electrodes (The Ludlow Co., Ch1copee, MA) with an interelectrode (center-to-center) distance of 20 mm, and a Grass AC/DC amplifier (Model 15A12, Astro-Med, Inc., West Warzick, RI) with a gain of 1,000, a common mode rejection ratio of 86 dB at 60 Hz, and a bandwidth (−3 dB) of 10–1,000 Hz. The sEMG data was collected at 2,000 Hz/channel using a 16-bit analog to digital converter (Model MP150, Biopac Systems, Inc., Goleta, CA). The impedance of each electrode was measured with respect to the reference electrode using an impedance meter (Model F-EZM5, Astro-Med, Inc.). Electrodes were controlled with impedance $<15\,k\Omega$. Full bandwidth sEMG data captured by the acquisition software (AcqKnowledge, Biopac Systems, Inc.) was reduced using a root mean square (RMS) algorithm to produce sEMG envelopes with an effective sampling rate of 20 per sec. These envelope data were the basis for subsequent processing.

The subjects removed their shirts (females wore sports bras). They were seated on a chair without back support to minimize cutaneous tactile cues. The sensors for the motion-capturing system were attached to the bony landmarks with adhesive tape. Surface EMG electrodes were placed over the four muscles.[21] The UT was identified by measuring 2/3 of the distance from the spinous process of the 7th cervical vertebra to the acromion process. The LT was identified by measuring 1/4 of the distance from the thoracic spine to the inferior angle of the scapula with the arm elevated in the sagittal plane. The lower SA was identified as being located anterior to the latissimus dorsi muscle with the arm elevated 90° in the sagittal plane. The anterior deltoid (AD) was identified by measuring three fingerbreadths below the acromion. A reference electrode was placed on the distal ulna of the other wrist. Verification of signal quality was investigated for each muscle by having the subject perform a resisted contraction in manual muscle test positions specific to each muscle of interest.[22]

Kinematics and EMG data were collected for 5 s in the resting seated posture. Subjects were blindfolded and required to self-select a target end/mid range position in space with the hand (a target position) for 5 s at a verbal cue, "Please move your hand to where you assume the end/mid range position to be for 5 seconds," and these positions were recorded. They then brought their arms to their sides, waited 5 s, and attempted to reposition their arm to the same orientation six times. As the target position was reached, a trigger was pressed to synchronize the kinematic and EMG data. Each subject performed 1 target and 6 matching mid range tasks, and 1 target and 6 matching end range tasks. Mid and end range tasks were randomly ordered.

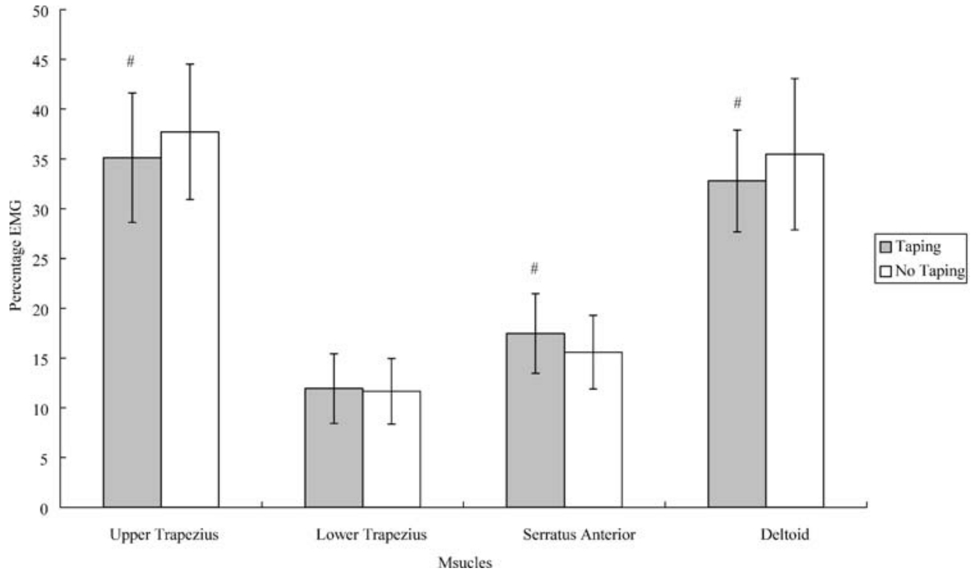

Figure 2. Mean EMG distribution from end/mid range tasks between two conditions across four muscles. No significant end/mid tasks interaction effect or end/mid range tasks main effect was found ($p > 0.05$). #A significant difference existed between taping and no taping conditions.

For the analysis, proprioceptive feedback index (PFI)[13] was calculated from the mean of the 4th, 5th, and 6th trials. The PFI comprised two values: one derived from the total absolute angle difference between targeted movement and reproduced trials of movements (the sum of 10% movement difference, square root of ((target − reproduced plane)^2 + (target − reproduced elevation)^2 + (target − reproduced axial rotation)^2 recorded for movement (proprioceptive feedback magnitude, PFM); the other is derived from the correlation between instant movement and prototype instant movement on arm elevation (similarity index, SI).[13] An instant movement was generated from every 10% of the movement based on time by averaging across each trial of each test. The instant movement of each target task was used as a prototype instant movement for each trial. Thus, the unit of the 1st numeric value is the angle. A lower angle means more accuracy in terms of proprioception. The 2nd numeric value means the relative correlation between two movements. Values were recorded from 0, with the least movement similarity, to 1, with the most movement similarity. This approach provides quantitative analysis and elementary pattern recognition of proprioception feedback during movements. Task-specific normalization of sEMG data was conducted to represent muscle contraction patterns among four muscles during the task.[23,27] Averages of activity during each analyzed event (a time range about the synchronization point) were computed from the RMS values. A vector was generated as RMS values from UT, LT, SA, and AD as the response vector (RV). Normalization of RV was conducted to represent muscle contraction patterns among four muscles during the task. These values represent the relative muscle activity of each muscle. Higher values mean more activity during the task. These values were used for the EMG analysis.

$$R_{\text{norm}} = \frac{[R_1 R_2 R_3 R_4]}{\sum_i R_i^2}$$

where $R_1 = \text{UT}$, $R_2 = \text{LT}$, $R_3 = \text{SA}$, $R_4 = \text{AD}$.

The Shapiro–Wilk test confirmed normal distribution of the data. For the EMG, three-way (taping condition × task × muscle) repeated measures ANOVA were used to compare taping condition between tasks and muscles. For the proprioception, two-way (taping condition × task) repeated measures ANOVA were used to compare taping condition between tasks. Bonferroni post hoc tests were then used to identify the source of any difference. A significant alpha level of 0.05 was used. To determine the relationship between muscle activity and PFI, Pearson product–moment coefficients of correlations (R) were used. An R between 0 and 0.25 was considered to show no relationship, 0.25 and 0.5 to show a fair relationship, 0.5 and 0.75 to show a moderate relationship, and >0.75 to show a good/excellent relationship.[24]

RESULTS

Electromyographic Data

The three-way results showed no significant interaction ($p > 0.05$) and significant taping and muscle interaction effects ($p < 0.05$). Subsequently, the effects of taping were investigated for each muscle (Fig. 2). On average, across the end/mid range tasks, UT and AD activity with taping ($2.6 \pm 3.3\%$, $p = 0.001$ and $2.7 \pm 3.4\%$, $p = 0.001$, respectively) as compared with no taping. SA activity

Table 1. Proprioceptive Feedback Index of End/Mid Range Tasks With and Without Taping Condition

Variable	No Taping	Taping
End range task		
Magnitude	$25.8 \pm 14.0^\circ$	$11.4 \pm 4.8^{\circ a}$
Similarity index	0.9994 ± 0.0004	0.9944 ± 0.0129
Mid range task		
Magnitude	$24.2 \pm 11.6^\circ$	$12.1 \pm 5.6^{\circ a}$
Similarity index	0.9972 ± 0.0066	0.9971 ± 0.0077

[a]A significant difference existed between taping and no taping conditions.

Table 2. Correlation Coefficients Between Muscular Activity and Proprioceptive Feedback

Variable/Muscle	Upper Trapezius	Lower Trapezius	Serratus Anterior	Deltoid
Magnitude (degrees)				
Taping and mid range	0.516[a]	−0.476	−0.576[a]	−0.186
Taping and end range	0.409	−0.524[a]	−0.278	0.344
No taping and mid range	0.173	0.072	0.251	−0.307
No taping and end range	−0.200	−0.247	0.212	−0.098
Similarity index				
Taping and mid range	0.420	0.072	−0.165	−0.057
Taping and end range	−0.279	0.042	0.029	−0.198
No taping and mid range	0.307	−0.279	0.102	−0.235
No taping and end range	−0.312	0.014	0.049	0.264

[a]A moderate to good relationship existed between muscle activity and proprioceptive feedback.

increased $1.9 \pm 1.8\%$ ($p = 0.015$), on average, for the taping condition as compared to the no taping condition (Fig. 2).

Shoulder Proprioception Data

For the PFM, no significant taping condition × task interaction effect or task main effect was found ($p > 0.05$). The PFM was significantly less with taping than with no taping ($11.9 \pm 8.3°$, $p < 0.005$). The results also showed no significant taping condition × task interaction effect or task or taping condition main effect for the SI ($p > 0.05$, Table 1).

Correlation Between Muscle Activity and Proprioceptive Feedback Index

Correlation coefficients were <0.5 between muscle activity and the PFI, except for the UT and PFM in the mid range task with taping ($R = 0.52$), the LT and PFM in the end range task with taping ($R = -0.52$), and the SA and PFM in the mid range task with taping ($R = -0.58$) (Table 2).

DISCUSSION

As expected, our results showed significant changes in EMG activity in the scapular muscles with the application of tape in the asymptomatic group. Proprioceptive feedback was also enhanced with taping. Thus, the mechanisms by which scapular taping can be explained are neuromuscular control as well as proprioceptive feedback factors. Morin et al.[14] also found a significant decrease in muscle activity in the UT muscle and an increase in muscular activity in the middle trapezius muscle with taping. In our study, we did not record the muscle activity in the middle trapezius muscle. Our results showed an increase in muscular activity in the SA muscle, but no change in muscular activity in the LT, with taping. Although the muscular imbalance from scapulothoracic dysfunction is often assumed to be the result of overactivity of the UT and decreased activity of the LT, our results suggest that taping can inhibit muscle activity in the UT and enhance activity in the SA, but not in the LT. Clinical methods of increasing muscular activity in LT should be further investigated. Further, the significant relevance of the EMG magnitude difference (1.9–2.7%) with and without taping in this study should be interpreted with caution.

In contrast to our findings, Cools et al.[7] found no significant changes in EMG activity in the scapular muscles based on the application of the tape in an asymptomatic group. However, in their study, maximal voluntary contraction (MVC) was performed as a normalization reference. Although normalization of EMG signal to MVC values is common, its reliability and stability are debatable.[17,25] We used standard guidelines for EMG recording and task-specific normalization vector.[17,23] This normalization vector method is reliable and valid.[23]

Magnitude in the PFI indicates movement control accuracy by 3D kinematics during arm elevation. Task movement and time of performing a task are important in considering this magnitude difference with and without taping. Because of the same-arm elevation task and consistent time (1.9–2.1 s) for performing the tasks between two conditions, kinematic data (12.1/14.4° for mid/end range tasks) may have practical relevance. Given that small kinematics changes (1–3° of scapular tipping) are related to clinical impingement symptoms[16,26] and high accuracy is necessary in competitive sports, the kinematics feedback changes with taping found in our study may have practical significance. Notably, our finding is that changes in kinematics in the taping condition are also related to EMG muscular activity. Therefore, scapular tape may be suitable in scapular muscle training conditions. Further study is needed to specify training protocols with the taping condition.

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