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Effects of scapular taping on the activity onset of scapular muscles and the scapular kinematics in volleyball players with rotator cuff tendinopathy

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Abstract

Objectives

To examine the effect of scapular taping on the activity onset of scapular muscles and the scapular kinematics during arm elevation in volleyball players with rotator cuff (RC) tendinopathy.

Design

Randomized placebo-controlled repeated measures

Methods

Twenty-six male volleyball players with RC tendinopathy (mean age = 23.6 ± 3.3 years) participated in the study. Electromyography (EMG) activity onset of upper trapezius (UT), middle trapezius (MT), lower trapezius (LT) and serratus anterior (SA) and the three-dimensional scapular kinematics quantified by using an acromial marker cluster method were compared with three scapular taping protocols, namely, no taping, therapeutic taping, and placebo taping.

Results

The MT, LT and SA activated significantly earlier in both therapeutic taping (all $p < 0.005$) and placebo taping conditions than no taping conditions (all $p < 0.002$). There was a small increase in the scapular upward rotation when therapeutic taping and no taping conditions were compared ($p = 0.007$).

Conclusions

Scapular taping may enhance the neuromotor control of the scapular muscles. Whether it provides adequate support for normal scapular kinematics during arm movement in athletes with RC tendinopathy await for further studies.

Keywords

Activity onset; Scapular muscles; Scapular kinematics; Overhead athletes; Rotator cuff tendinopathy

1. Introduction

Chronic shoulder pain is the most common musculoskeletal complaints in volleyball players. Approximately 60% of volleyball players reported a history of shoulder problems.1 Rotator cuff (RC) tendinopathy is one of the most frequently reported overuse injury in volleyball players that is characterised by pain, weakness, and disability during arm elevation,2, 3 and result in long periods of absence from training and competition.4

Scapular muscles are important for stabilizing and controlling the scapula for proper position and normal kinematics during arm elevation. Synchronized activity onset of the scapular muscles is important for a smooth scapular motion during arm abduction.5 Delayed electromyographic (EMG) activation of the upper (UT), middle (MT), and lower trapezius (LT), as well as the serratus anterior (SA) were demonstrated in non-athletes with RC tendinopathy during arm elevation6; and delayed activation of the MT and LT was reported in athletes of upper limb sports with RC tendinopathy during a sudden drop arm test.5 Alteration in the activity onset of scapular muscles during arm elevation may affect the normal kinematics of the scapula and affect the function of the rotator cuff muscles and render the athletes to RC pathology.7, 8 Maintenance of the activity onset of the scapular muscles and normal scapular motion is essential for the prevention and rehabilitation of RC tendinopathy in athletes with overhead sports, and one of the strategies for maintaining normal scapular motion is using therapeutic taping.9, 10

Therapeutic taping is widely used for the prevention and management of shoulder injuries in professional athletes.10, 11 Scapular taping is believed to help reduce pain and discomfort of the shoulder.[9, 11] One of the proposed mechanisms of taping is that it stimulates the neuromuscular pathways via increased proprioceptive feedback from cutaneous receptors and muscle afferents.[10, 12, 13] Previous studies have investigated the effects of scapular taping on the amplitude of activation of the scapular muscles[14, 15, 16]; however, the effects of scapular taping on the activity onset of scapular muscles has not been investigated. Information on changes in the activity onset of scapular muscles with application of tape would provide a better understanding of the mechanism of taping on neuromotor control in athletes with RC tendinopathy.

Another proposed mechanism of taping is the mechanical effects in correcting the scapular position leading to an increase in subacromial space.[10, 17] Although previous studies have demonstrated a mean increase in scapular upward and external rotation and posterior tilt during arm elevation in asymptomatic individuals[18] and a mean increase in external rotation in people with RC tendinopathy after therapeutic taping,[17] both studies did not standardize the tension of the tape which may affect the mechanical effects on the scapula.[17, 18] Also, whether the observed effects are related to a placebo effect is unclear.

To better understand the mechanism of tape applied on the scapula, this study examined the effect of scapular taping on the activity onset timing of scapular muscles and scapular kinematics during dynamic shoulder abduction in volleyball players with RC tendinopathy. We hypothesized that scapular taping can induce earlier activity onset of scapular muscles and can effectively increase scapular upward rotation, posterior tilt and external rotation during arm elevation in players with RC tendinopathy.

2. Method

Twenty-six male volleyball players between 18 and 35 years participated in this study. They were recruited from local sports clubs and universities. They had training experience of more than 3 years with at least three training sessions per week. Players with a history of shoulder fractures, instability or dislocation, shoulder surgery or clinical treatment for a shoulder injury, frozen shoulders (more than 50% restriction in external rotation, abduction and flexion during both active and passive movements in comparison to the uninvolved shoulder) and a positive general laxity test (>5/9 Beighton Score) were excluded.19

Demographic information such as age, gender, height, weight, body mass index (BMI), arm dominance (the side on which they throw a ball), number of years of involvement in volleyball training and training hours per week were recorded. The intensity of pain during training was recorded using a visual analogue scale (VAS) from 0 to 10, with 0 indicating no pain, and 10 indicating the worst pain during training. Clinical tests were conducted by an experienced physiotherapist to confirm the presence of RC tendinopathy. In the present study, RC tendinopathy was defined as (1) presence of shoulder pain during training for more than 3 months,19 (2) three out of five positive results for the following: painful arc, pain or weakness with resisted external rotation, Neer test, Kennedy–Hawkins test and Jobe test.20 The intensity of pain being provoked should be ≥3/10 on the VAS score,19 and (4) ultrasound image showed the presence of non-homogeneity or partial tear in the supraspinatus tendon.19 The study was approved by the Human Subjects Ethics Sub-committee of the Departmental Research Committee, The Hong Kong Polytechnic University (Reference number: HSEARS20141201002), and all participants gave their written informed consent before the study. All procedures adhered to the Declaration of Helsinki.

Three taping protocols were tested in random order: (1) no taping, (2) placebo taping (taping without tension), and (3) therapeutic taping with full tension.14, 15, 16 A piece of 3.8 cm I-shaped rigid Leukotape adhesive tape was used for conditions (2) and (3). Tape was applied with the participants seated upright on a stool with their head in the neutral position. Each participant was asked to fully extend their thoracic spine, with the scapula positioned in the full retraction and depression position.17, 18 Tape was applied starting from the inferior margin of the medial 1/3 of the clavicle, then firmly on the UT muscle with full stretching of the tape to the thoracic spine at T12 (Fig. 1).14 In order to standardize the tension, the other end of the tape was connected to a strain gauge transducer (Ronso Electronic, Hong Kong) with a digital force display unit. The examiner pulled on the strain gauge transducer until a force of 1.5–2 kg was displayed while the tape was applied to the skin.21 The placebo tape was applied in the same way but without any tension applied. The same researcher, who is experienced in the procedure, performed all the taping procedures.

A Vicon v-370 3-D motion analysis system (Vicon Motion Systems, Oxford, UK) with six cameras was used to capture the upper extremity, trunk and scapular motion during arm movement. After standard calibration procedures, the motion was filmed at 100 Hz. Reflective markers were placed over anatomical landmarks as per the recommendations of the International Society of Biomechanics: suprasternal notch, C7 vertebra, xiphoid process and T8 vertebra to determine the trunk positions.[22] A three-marker acromion cluster was adhered to the postero-lateral part of acromion to track its movement.[23] The acromial marker cluster method has been validated for measuring scapular movement with humeral elevation up to 100°.[23] The humeral four-marker cluster was also fastened to the participant's upper arm to determine the amount of shoulder abduction. The thoracic markers, acromial marker cluster, and humeral marker cluster were attached by the same investigator and remained in situ during the testing protocol.

Surface electromyography with Ag/AgCl electrodes (SX230, Biometrics Limited, Newport, UK) was used to measure the recruitment patterns and latencies of the upper (UT), middle (MT) and lower trapezius (LT), and serratus anterior (SA). The EMG signal was sampled at 1000 Hz. The participants were asked to sit upright on a stool with arms relaxed on both sides. Skin of the tested shoulder was lightly abraded with sandpaper and cleaned with alcohol to reduce impedance. Conductive gel was applied to the electrodes and then the active electrodes were positioned longitudinally along the belly of each muscle following the recommendations of Cram et al.[24]: (1) UT: mid-way between the acromial process and C7 spinous process; (2) MT: mid-way between the medial border of the scapula and T3 spinous process; (3) LT: mid-way between the base of the scapular spine and T7 spinous process; and (4) SA: inferior to the axillary region (following the mid axillary line) at the level of the inferior angle of the scapula, just anterior to the border of the latissimus dorsi muscle and the mid axillary line. The ground electrode was attached to the opposite acromial process. Verification of signal quality was conducted for each muscle by asking the participant to contract each of the muscles against resistance from the operator.[19] An accelerometer (Analog Devices, ADXL335) was positioned on the lateral humeral epicondyle to detect the onset of arm movement. An event-timer switch was used to generate an electrical signal to both EMG and Vicon systems simultaneously.

Each participant was asked to sit upright on a stool with his head in the neutral position and forearm arm rested on their thigh at 0° of shoulder abduction. The resting EMG activity and kinematic data were recorded for 5 s. This baseline activity formed the reference value for the determination of onset time. The participant was then asked to dynamically abduct his shoulder from the neutral to maximum achievable range of abduction and then return to neutral, with elbow flexed at 90° and forearm in pronation. The speed of movement followed the pace of a metronome with 2 s to raise the arm and 2 s to lower the arm back to neutral.[25] Once the participants were able to control the speed of motion, kinematic data were captured for each cycle of shoulder abduction. A total of five measurements were recorded for each of the taping conditions and 1-min rest was allowed between each measurement.

The humeral and scapular kinematics during arm elevation were determined from the humeral cluster and acromial marker cluster with respect to the thorax using the recommended Euler angles of rotation of The International Society of Biomechanics (ISB).[22] Customized software within LabView Instrument 8.6 (National Instruments Corporate, Austin, Tx, USA) was used for data reduction. To determine the taping effects on the dynamic control of the scapula at different phase of abduction, the change in three scapular angles, namely, upward/downward rotation, anterior/posterior tilt, and internal/external rotation, were calculated with respect to shoulder abduction angles from 0° to 30°, 30° to 60° and 60° to 90° of abduction. A recent study has revealed that athletes with RC tendinopathy demonstrated more reduction in the subacromial space during early arm abduction from 0° to 30° than the healthy athletes, and the reduction in the subacromial space was associated with weakness of the scapular muscles.19 Thus, we divided the abduction range from 0° to 30°, 30° to 60°, and 60° to 90° to determine the effects of taping on the dynamic control of scapula at different phase of abduction in athletes with RC tendinopathy. The change in scapular rotation above 90° of abduction may induce measurement error and was not calculated.23 The averaged values of the five measurements were calculated for analysis. The test–retest reliability of the scapulothoracic movement was assessed in a pilot study with 13 healthy individuals, ranged between 0.71 and 0.90 which represents good to excellent reliability.26 The minimal detectable change (MDC) of the scapulothoracic movement from the pilot study for upward/downward rotation = 3.7°, anterior/posterior = 3.3° and internal/external rotation = 2.5°, respectively.

Electromyographic data processing was performed using the LabView Instrument 8.6 and was verified visually. The EMG signals were digitally full-wave rectified and low-pass filtered (Butterworth 6 Hz, 2nd order). After the signals were rectified and filtered, the muscle/arm onset was determined by the onset of muscle activity minus the arm movement onset (the start of the tilting of the accelerometer) to provide a value in seconds before (−) or after (+) the movement onset.27 The activity onset of each muscle was identified by the earliest time that the EMG activity surpassed the mean baseline activity (EMG silence 5 s) by two standard deviations and remained above this level for 50 ms.6 The test–retest reliability of the activity onset of scapular muscles was assessed in a pilot study with 13 healthy individuals, ranged between 0.89 and 0.95

which represents excellent reliability.26 The MDC of the activity onset of the scapular muscles from the pilot study for UT = 52.1 ms, MT = 30.2 ms, LT = 29.2 ms and SA = 47.8 ms, respectively.

Distributions of all the outcome measures passed the Shapiro–Wilk normality test ($p > 0.05$), and the values are reported as mean ± SD. Repeated measures ANOVA were used to compare the effects of taping on the activity onset of scapular muscles during dynamic shoulder abduction (within subject factors: taping condition) and two-way repeated measures ANOVA were used to compare the effects of taping on scapular motion at different phases of shoulder abduction (within subject factors: taping condition × phase of shoulder abduction). Fisher's least significant difference (LSD) post hoc tests were used for pairwise comparisons when significant main effects were observed. The statistical analyses were performed using SPSS Version 23 for Windows (SPSS Inc, Chicago, IL.) The level of significance for all tests was set at 0.05.

3. Results

Twenty-six male volleyball players (mean age = 23.6 ± 3.3 years, weight = 70.0 ± 9.0 kg, height = 178.6 ± 6.9 cm, BMI = 21.9 ± 2.1 (kg/m2), training experience = 10.3 ± 3.3 years and training hours per week = 7.1 ± 2.9) participated in this study. They reported pain or discomfort in the shoulder during training (mean VAS = 5.7/10 ± 1.2 and duration of symptoms = 21.9 ± 17.1 months). Clinical tests and ultrasound imaging confirmed the presence of RC tendinopathy.

There were significant taping effects on the activity onset of the MT ($p = 0.001$), LT ($p < 0.001$) and SA ($p < 0.001$). No taping effect was found regarding the activity onset of the UT ($p = 0.407$). Post hoc analysis showed earlier activity onset of the MT (−61.3 ± 67.3 ms vs. −15.9 ± 56.4 ms, $p = 0.005$), LT (−101.0 ± 77.7 ms vs. −18.5 ± 43.9 ms, $p = 0.001$) and SA (−33.3 ± 41.8 ms vs. 29.2 ± 48.4 ms, $p < 0.001$) when therapeutic taping and no taping conditions were compared. There were also placebo effects on the activity onset of the MT (−84.6 ± 89.1 ms, $p = 0.002$), LT (−100.6 ± 71.5 ms, $p = 0.002$) and SA (−23.3 ± 66.1 ms, $p < 0.001$) when compared with the no taping condition. No significant difference was found between therapeutic taping and placebo taping (all $p > 0.439$) (Fig. 2).

Table 1 showed the effects of tape on scapular kinematics at different phases of abduction. Significant effects of tape ($p = 0.031$) were found on scapular upward rotation, but no significant interaction was found between arm positon × tape ($p = 0.439$). Post hoc analysis showed an increase in scapular upward rotation between therapeutic taping and no taping conditions ($p = 0.007$) and therapeutic taping and placebo taping conditions ($p = 0.032$), regardless the phase of arm abduction. There was no significant effect of tape on scapular posterior tilt ($p = 0.134$) and external rotation ($p = 0.188$), and no interaction was found ($p = 0.339$ and $p = 0.222$, respectively).

4. Discussion

Both therapeutic taping and placebo taping enhances early activation of the MT, LT and SA during arm abduction, but a relatively small increase in scapular upward rotation after therapeutic taping. Based on our findings, scapular taping may enhance the neuromotor control of the scapular muscles. However, it may only induce small change in scapular kinematics during arm movement in players with RC tendinopathy.

To our knowledge, this is the first study to investigate the effects of scapular taping on the activity onset of scapular muscles during dynamic arm abduction. Taping with or without tension hastened the activity onset of the MT, LT and SA in players with RC tendinopathy. In this connection, Cools et al.5 observed a delay in EMG activity onset of the MT and LT during a sudden drop arm test in athletes of upper limb overhead sports who have developed RC tendinopathy.5 The possible mechanism for the changed activity onset of the scapular muscles could be via cutaneous stimulation.10, 12, 13 Since the trapezius and SA muscles connect the scapula to the trunk, an earlier activity onset of these muscles is vital in providing a stable base for optimal functioning of the scapular and rotator cuff muscles during arm movements.27, 28

Nevertheless, there were placebo effects on the activity onset of the MT, LT and SA. Although the underlying mechanism for placebo taping is unknown, previous study has reported that placebo taping reassured participants and improved their perceptions of stability and confidence when performing functional tasks.29 Our findings may imply that the application of placebo tape with no tension to the scapula may also enhance proprioceptive input via cutaneous receptors and muscle afferents,12, 13 and this may result in early activation of the scapular muscles in players with RC tendinopathy.

When comparing the change in scapular kinematics with different taping protocols, our findings showed a relatively small increase in scapular upward rotation after therapeutic taping. Although the changes in scapular upward rotation with therapeutic taping were smaller than the MDC, the observed power was 0.709 and may indicate real changes. In the studies of Shaheen et al.,17, 18 they showed a mean increase of scapular upward rotation (by 5.9°), posterior tilt (by 4°) and external rotation (by 3.8°) in asymptomatic individuals,18 and a mean increase of external rotation (by 3.4°) in non-athletes with RC tendinopathy after therapeutic taping.17 Although both studies of Shaheen et al.17, 18 showed an increase in scapular movement patterns with respect to elevation angles, our present study calculated the change in scapular rotations to determine the effects of taping on the dynamic control of scapula during arm abduction and also showed an increase in scapular upward rotation with therapeutic taping. The increase is relatively small because we compared the difference within a narrower range of motion (30° of elevation). Another possible reason for these small changes in scapular rotations may be due to the different taping methods. In both studies of Shaheen et al., two pieces of rigid tape were applied to the subject's thoracic vertebra and scapula.17, 18 The first piece was applied from the first to the twelfth thoracic vertebra, and the second piece was applied diagonally from the scapular spine to the twelfth thoracic vertebra. Whereas, in our present study, we only applied one piece of rigid tape to the subject's scapula and this might not have provided the full mechanical support for the scapula. Although our findings showed significant increases in the scapular upward rotation, the changes were relatively small and whether such changes are clinically significant is yet to be supported by more clinical studies.

Despite both real and placebo taping having similar effects on the activity onset of scapular muscles, the change in the scapular kinematics was relatively small with therapeutic taping applied to the scapula in players with RC tendinopathy. Noted that the control of scapular motion was associated with the strength of scapular muscles,19, 30 our present findings may suggest that taping-induced enhancement of the neuromotor control of scapular muscles alone may not be adequate to change the scapular kinematics during arm abduction in players with RC tendinopathy. The changes in scapular kinematics might be too small to be detected with the current method. Findings from the present study could only suggest that scapular taping may enhance the neuromotor control of scapular muscles for players with RC tendinopathy. Whether it provides adequate support for the dynamic control of the scapula during arm movement in athletes with RC tendinopathy await for further studies.

There were a few limitations in the present study that need to be considered when interpreting the results. (1) The three-dimensional scapular orientation during the resting position was not examined. Hence, the influence of activity onset of muscle activation on pre-setting the scapula and the effects of taping on the scapular position could not be assessed. (2) Although our findings revealed taping to have a beneficial effect on the activity onset of scapular muscles, one piece of rigid tape was applied to the subjects which has been shown to reduce pain and enhance EMG activities of the scapular muscles in previous studies.9, 15, 16 Future study can assess the effects of additional tapes, as well as different tape sizes applied to the scapula on the control of scapular movement in people with RC tendinopathy. (3) The effect of taping on pain was not assessed as this study investigated the effects and mechanism of therapeutic taping on the control of scapular movement and activity onset of scapular muscles during arm abduction. Future studies can investigate whether taping can reduce pain in athletes with RC tendinopathy. (4) This study showed the immediate effects of scapular taping on the activity onset of scapular muscles; however, the long-term effects of taping as well as the effects of combining these taping techniques with exercise were not investigated and warrant future studies.

5. Conclusion

Scapular taping enhances early activation of the scapular muscles and a relatively small change in the scapular kinematics during arm abduction. Based on our findings, scapular taping may enhance the neuromotor control of the scapular muscles during arm movement in players with RC tendinopathy. The effect of therapeutic taping on scapular kinematics requires further studies to verify its effect.

Practical implications

- Scapular taping enhances early activation of the scapular muscles during arm abduction.
- The change in the scapular kinematics after therapeutic taping was small.
- Scapular taping may enhance the neuromotor control of the scapular muscles.

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asymptomatic overhead athletes with and without scapular dyskinesis. Int J Sports Phys Ther 2015; 10(3):309–318.

Table 1 Results of the repeated ANOVA tests for scapular rotations (upward rotation, posterior tilt and external rotation) during arm elevation.

	No taping	**Therapeutic taping**	**Placebo taping**	**Taping (p-value)**	**Taping × phase (p-value)**
Upward rotation					
0°–30°	6.6 ± 2.3	7.2 ± 2.3	7.0 ± 2.3	0.031*	0.439
30°–60°	14.8 ± 3.1	15.4 ± 3.4	14.9 ± 3.4		
60°–90°	17.0 ± 4.5	18.5 ± 4.2	16.5 ± 4.3		
Posterior tilt					
0°–30°	3.2 ± 1.1	3.3 ± 0.8	3.5 ± 1.1	0.116	0.339
30°–60°	4.1 ± 2.1	3.9 ± 1.7	5.0 ± 2.8		
60°–90°	12.5 ± 5.7	11.0 ± 5.1	12.5 ± 4.2		
External rotation					
0°–30°	2.7 ± 1.0	3.7 ± 1.3	3.3 ± 1.4	0.188	0.222
30°–60°	3.9 ± 2.0	3.9 ± 1.9	4.1 ± 2.4		
60°–90°	8.7 ± 2.9	9.2 ± 3.8	8.0 ± 3.1		

Values are mean ± SD.

*$p < 0.05$.

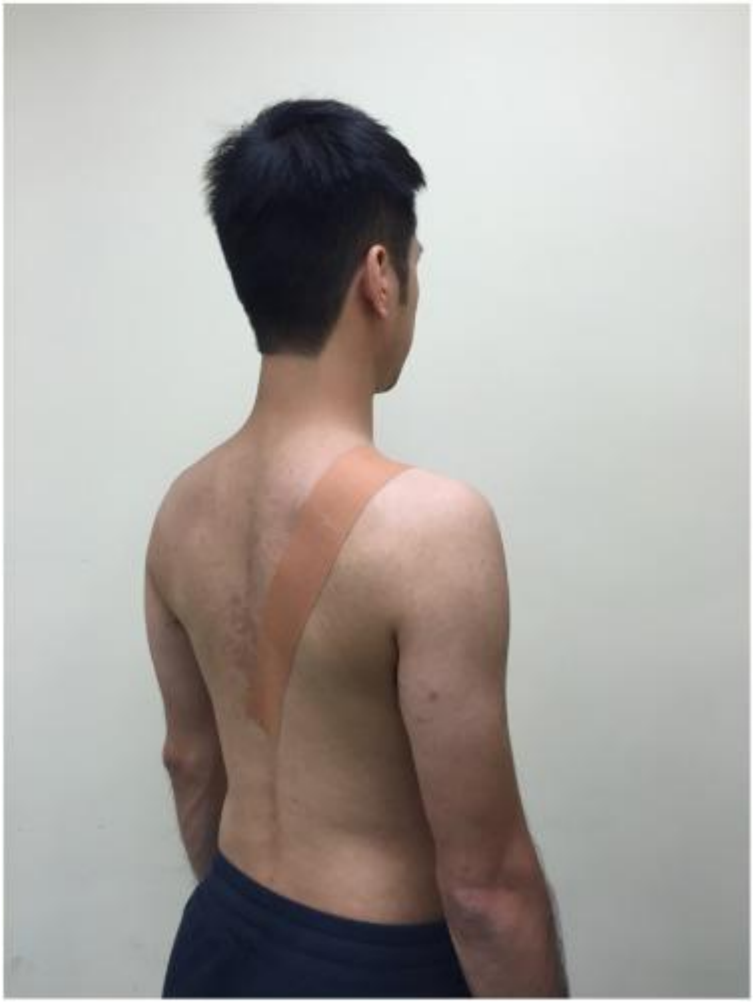

Figure 1 Scapular taping. A 3.8 cm I-shaped rigid Leukotape tape was used. Tape was applied starting from the inferior margin of the medial 1/3 of the clavicle to thoracic spine at T12.

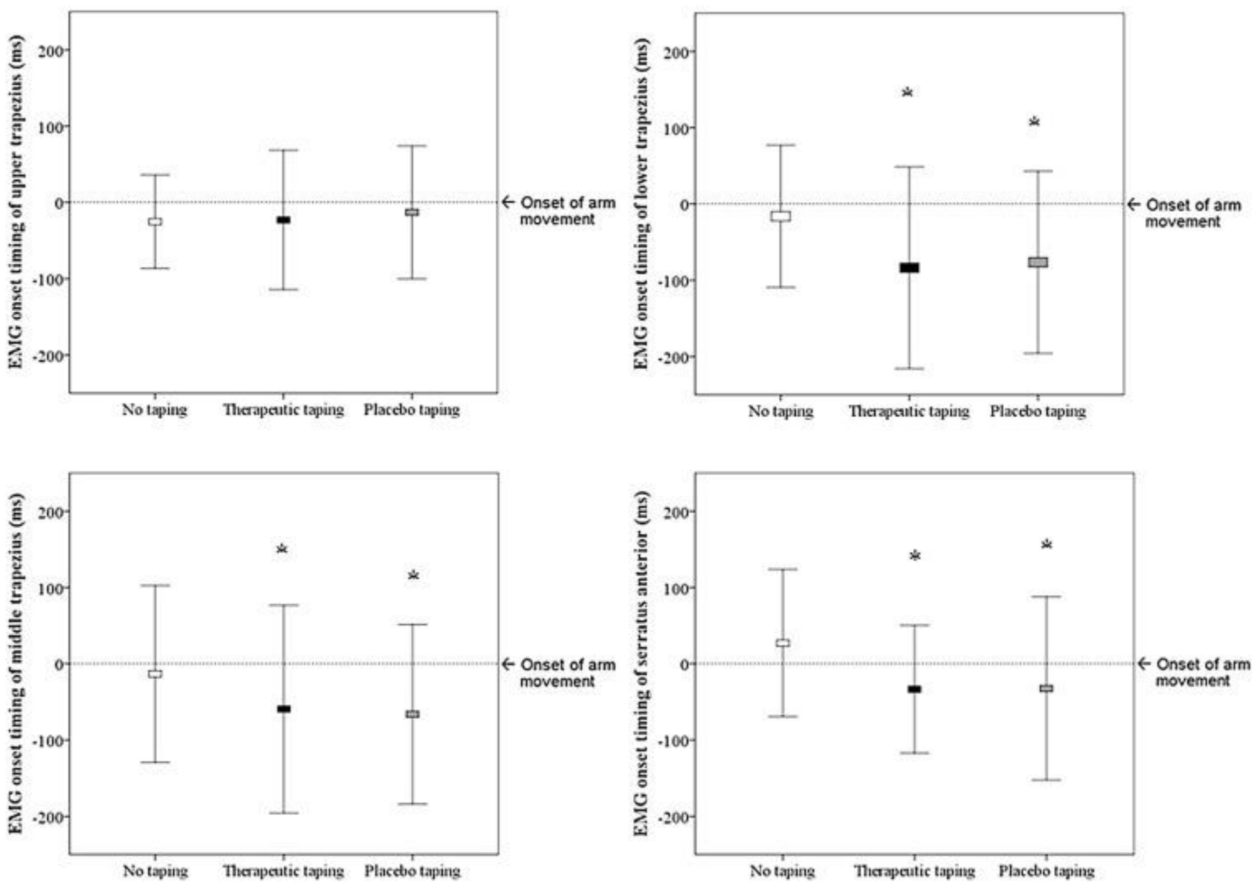

Figure 2 Mean and standard deviation for the effects of no taping (white bar), therapeutic taping (black bar), and placebo taping (grey bar) on the EMG onset timing (in ms) of (a) upper trapezius, (b) middle trapezius, (c) lower trapezius, and (d) serratus anterior before (−) or after (+) the onset of arm movement during dynamic shoulder abduction in athletes with rotator cuff tendinopathy. *Denotes a significant difference when compared with the no taping condition ($p < 0.05$).