Rigid and Elastic taping changes scapular kinematics and pain in subjects with shoulder impingement syndrome; an experimental study

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ABSTRACT

Rigid and Elastic scapular taping is used in physical rehabilitation of shoulder impingement syndrome (SIS). It is believed to reduce pain and normalise scapular movement patterns. However, there is insufficient evidence to support its use.

The aim of the study was to investigate the effect of Rigid and Elastic taping techniques on the scapular kinematics and pain in patients with SIS.

Eleven patients with SIS participated in the study. They performed elevation and lowering of the arm in the scapular and sagittal planes under three conditions: Baseline, Rigid taping and Elastic taping. The movements of the thorax, humerus and scapula were tracked. Scapular displacements and scapulothoracic joint rotations were calculated. Subjects used a visual analogue scale to rate the intensity of pain at rest and during movements in both planes.

Both taping techniques externally rotated the scapula in sagittal plane movements ($p < 0.05$) and resulted in reduced pain. In the scapular plane, Elastic taping increased the scapular retraction ($p < 0.05$) and posterior displacement ($p < 0.01$), but neither of the taping techniques had an effect on pain in this plane.

In conclusion, both taping techniques had an effect on scapular kinematics and pain in movements occurring in the sagittal plane. Elastic taping also affected scapular kinematics in scapular plane movements, but without the concomitant decrease in pain.

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1. Introduction

Shoulder impingement syndrome (SIS) accounts for the majority of reported shoulder complaints (van der Windt et al., 1996; Vecchio et al., 1995). The condition is associated with a reduced clearance of the soft tissues occupying the subacromial space as the arm is elevated (Neer, 1972). Despite its high prevalence (Lo et al., 1990; Michener et al., 2003), the underlying aetiology of the condition is still debated (Budoff et al., 1998; Fu et al., 1991; Jobe et al., 2000). Poor posture and abnormal scapular kinematics have been suggested as possible primary factors in developing SIS (Fu et al., 1991; Jobe et al., 2000) and also as secondary observed phenomena of SIS (Kamkar et al., 1993). These patterns are also believed to exacerbate the condition by further narrowing of the subacromial space (Kaya et al., 2011; Ludewig and Cook, 2000; Lukasiewicz et al., 1999).

Most of the physiotherapeutic rehabilitation programmes for SIS are designed to correct posture (Lewis et al., 2005b; Ludewig and Reynolds, 2009) and minimise the deviation of shoulder kinematics from normality (Host, 1995; Kaya et al., 2011; Ludewig and Reynolds, 2009). To this end, the application of tape is extensively used. Two types of tape of different elastic properties have been used in shoulder rehabilitation; Rigid (Ackermann et al., 2002; Alexander et al., 2003; Cools et al., 2002; Host, 1995, 2000; Kase and Kase, 2003; Lin et al., 2011; Thelen et al., 2008) and Elastic taping techniques (Bradley et al., 2009; García-Muro et al., 2010; Hsu et al., 2009; Kase and Kase, 2003; Kaya et al., 2011; Lin et al., 2011; Thelen et al., 2008).

The underlying mechanism of taping is also poorly understood. A number of hypotheses have been put forward to explain the effects of taping; it has been suggested that taping alters muscle force (Host, 1995; Morrissey, 2000), neuromuscular control...
(Alexander et al., 2008; Lin et al., 2011; Lohrer et al., 1999) and proprioception (Lin et al., 2011; Morrissey, 2000). One of the other proposed theories suggests that taping achieves its effects via a biomechanical realignment of the joints (Bennell et al., 2000; Host, 1995; Lewis et al., 2005a) and restrictions to the joint range of motion (Bradley et al., 2009; McConnell et al., 2011). This poor understanding contributes to the variations in the taping techniques used by different clinicians. For example, many application techniques have been presented in the literature for the management of SIS alone (Host, 1995; Hsu et al., 2009; Kaler et al., 2011; Kaya et al., 2011; Lewis et al., 2005b; Selkowitz et al., 2007; Smith et al., 2009; Thelen et al., 2008).

The popularity of using taping with the shoulder is not supported by sufficient scientific evidence. It is generally believed that taping helps in reducing pain and normalising scapular kinematics, however, these claims are often based on anecdotal observations. Recent systematic reviews that investigated the effect of Elastic taping on musculoskeletal conditions highlight the shortage of supporting evidence (Mostafavifar et al., 2012; Williams et al., 2012). The reviews included small numbers (10 and 6 respectively) of studies covering a wide range of musculoskeletal joints and many outcome measures including pain, range of motion, proprioception and muscle strength. As a result, it is still not possible to prove or discount any beneficial effects of taping (Mostafavifar et al., 2012; Williams et al., 2012).

In addition, few studies have investigated the effects of taping on kinematics despite the association of altered scapular resting position (Borstad, 2006) and kinematics (Ludewig and Reynolds, 2009) with shoulder pathology. This is in part because of the difficulties involved in obtaining in-vivo measurements of the scapular movement (Hill et al., 2007; Kontaxis et al., 2009). Recently, a number of studies have developed methods to obtain scapular kinematics in-vivo with relatively high accuracies (Brochard et al., 2011; Prinold et al., 2011; Shaheen et al., 2011a,b; Warner et al., 2012).

One of these methods (Karduna et al., 2001) was utilised by Hsu et al. (2009) who investigated the effects of an Elastic tape applied to the envelope of the trapezius muscle on shoulder kinematics and muscle activity in a group of baseball players with SIS. The study found that taping increased posterior tilt (approximately 1°) in low humeral elevations in scapular plane movements.

Shaheen et al. (2013) also utilised a scapular tracking method (Shaheen et al., 2011b) to measure subtle changes in scapular kinematics caused by Rigid taping. In the aforementioned study, taping was applied bilaterally in a non-symptomatic subject group according to the method described by Lewis et al. (2005b). The study showed that taping increased scapular external rotation, upward rotation and posterior tilt compared to baseline measurements (Shaheen et al., 2013). The magnitudes of these alterations (3–6°) were significantly higher than those reported by Hsu et al. (2009).

The results of previous studies point towards a positive effect of taping on scapular kinematics; the reported alterations are believed to reverse the effects of SIS on scapular kinematics and can contribute to an increase in the subacromial space (Lewis et al., 2005a; Ludewig and Cook, 2000) thus possibly resulting in pain relief. However, both studies have obtained measurements in either pain-free subjects or a pain-free state (Hsu et al., 2009), hence it is not possible to make any conclusions regarding the association of these alterations with pain relief.

In addition, the magnitudes as well as some of these alterations (scapular external and upward rotations) are different in the two studies. This may be caused by differences in the subject groups, the measurement method or the different application techniques. To date, no studies have attempted to investigate the effects of Elastic and Rigid tape application designed to treat the same symptoms on a single subject group.

The aim of this study was to investigate the effects of taping on scapular kinematics and pain in patients with SIS when two different taping techniques designed for the management of SIS are used; a Rigid tape application and an Elastic tape application.

2. Method

2.1. Participants

Subjects were included in the study if they experienced pain in elevation of the shoulder and if they tested positive to at least 4 of the following tests: (1) Neer impingement sign (2) Hawkins sign (3) pain during supraspinatus empty can test (4) painful arc between 60° and 120° and (5) tenderness when palpating the greater tuberosity of the humerus. Subjects were excluded if they experienced pain with cervical spinal tests, had a history of spinal or upper-limb fractures or had systemic illnesses. Subjects who fit these criteria and consented to participating in the study signed a consent sheet approved by Central London REC 4.

2.2. Intervention

2.2.1. Taping techniques

Two taping techniques commonly used for SIS were applied. The first technique uses Rigid tape and is applied bilaterally (Lewis et al., 2005b). In the Rigid tape application, a combination pack of zinc oxide tape and protective tape was used. The protective tape was applied first with no tension. To apply the Rigid tape, subjects placed their thoracic spine in a neutral position, the Rigid tape was applied bilaterally from the first to the twelfth thoracic vertebra (Fig. 1). Subjects were then asked to retract and depress the scapula; this was demonstrated by the investigator. Rigid tape was applied diagonally from the middle of the scapular spine to the twelfth thoracic vertebra; this was also applied bilaterally.

The second taping technique used Elastic tape and was applied on the symptomatic side only (Kase and Kase, 2003). Placing the arm in various positions before application of each strip, firstly, a Y-strip was applied from the insertion to the origin of the supraspinatus with no additional stretch, another Y-strip was applied from the insertion to the origin of the deltoid with no additional stretch and a final I-strip was applied from the coracoid process to the posterior deltoid with approximately 75% stretch and a downward pressure (Fig. 1).

2.3. Outcome measures

2.3.1. Experimental setup

A 10-camera motion capture system was used to track the trajectories of reflective markers attached to the thorax, humerus and the scapula locator (Shaheen et al., 2011b).

Subjects were asked to attend one laboratory session. The sessions lasted between 60 and 90 min. Subjects were seated on a backless stool with the feet at a comfortable width apart. Subjects performed three bilateral elevations and lowerings in the scapular and sagittal planes at a comfortable pace; the order of planes was randomised. During this session, movements were repeated for three conditions: Baseline, Rigid taping and Elastic taping. Subjects were allowed short breaks between conditions, the durations of which were determined by the subjects. The markers were not removed during these breaks.

Baseline measurements were always obtained at the start. The order of the Rigid and Elastic taping was randomised. Visual Analogue Scales (VAS) were used to assess the intensity of pain at rest and during movements in the scapular and sagittal planes for the three conditions. The scales were horizontal lines of 10 cm in
length, where one end represented “No pain” and the other end represented “Maximum pain”.

2.3.2. Scapular tracking

Measurements of the scapular movement in the symptomatic shoulder were obtained using the method described by Shaheen et al. (2011a,b) (Shaheen et al., 2011b). The scapula locator: a tripod device with three pegs on the scapula acromial angle, inferior angle and the root of the scapular spine was used to obtain the scapular measurements. An experienced observer used the scapula locator to track the movement of the scapula during shoulder elevations and lowerings whilst keeping low pressures on the three scapular landmarks. Feedback on the pressures were displayed on a computer screen and used to ensure that that high pressures, which may influence the physiological movement of the scapula are avoided (Shaheen et al., 2011b). The method provided a continuous measure of the scapular position and orientation during movement.

The inter-observer and intra-observer reliabilities of the method have been assessed in previous studies (Shaheen et al., 2011a,b). The intra-observer errors of an experienced observer have been reported to range from 1.7° to 2° for scapular internal rotation, 2.7–3° for scapular upward rotation and 1–1.5° for scapular tilt (Shaheen et al., 2011a).

2.4. Data analysis

Coordinate frames for the humerus, thorax and the scapula were defined according to the ISB recommendations (Wu et al., 2005). Humerothoracic angles were calculated using Euler angle rotations in the sequence of x–z–y′ abduction, flexion and axial rotation for elevations in the scapular plane and in the sequence of z–x′–y″ flexion, abduction and axial rotation for elevations in the sagittal plane (Kontaxis et al., 2009). Scapulothoracic rotations were calculated in the sequence of y–x–z′ internal rotation, upward rotation and tilt. Scapular displacements were computed using the position of the acromial angle in the thoracic coordinate frame. Anterior displacements were measured using the displacement of the acromial angle in the positive direction of the x-axis of the thoracic coordinate frame, scapular elevation was the displacement in the positive direction of the y-axis and scapular protraction was the displacement in the positive direction of the z-axis (Hsu et al., 2009).

Two-factor repeated measures ANOVA tests were used to compare the measured scapulothoracic rotations and displacements. The first factor defined the testing condition: Baseline, Rigid taping or Elastic taping and the second factor consisted of selected angles of elevation: from 30° to 120° at 5° interval. A Bonferroni Posthoc test was used to find where the differences were.

Data obtained from VAS did not pass the normality check and hence non-parametric tests were used. Friedman’s related-samples test was used to compare the pain VAS results between the three testing conditions. Multiple related-samples Wilcoxon Signed Rank tests were conducted as a Posthoc test.

3. Results

Eleven subjects (8 males and 3 females) with confirmed SIS and a mean age of (45.7 ± 9.4) participated in the study. Subjects scored a mean of 33.1 ± 7.4 on the Oxford Shoulder score (Dawson et al., 2009).

There were no significant differences in pain VAS between the three conditions at rest; Baseline condition had a median of 0.5 cm (max = 5 cm, min = 0 cm), Rigid taping had a median of 0.5 cm (max = 2.9 cm, min = 0 cm) and Elastic taping had a median of 0.8 cm (max = 8.7 cm and min = 0 cm).

3.1. Sagittal plane

In the sagittal plane, differences were found for the scapular internal rotation (p < 0.05) between the Rigid taping and Elastic taping conditions and the baseline measurements in sagittal plane elevation and lowering (Table 1). Rigid and Elastic taping techniques externally rotated the scapula in sagittal plane elevation by means of 3.4° and 2.7° and in sagittal plane lowering by 2.5° and 2.8°, respectively (Fig. 2). Neither of the taping techniques altered the scapular upward rotation. Rigid taping was found to...
anteriorty tilt the scapula by a mean of 3.8° in elevation (p < 0.01) and 3.6° in lowering (p < 0.001) compared to the Baseline condition. There were no significant differences between the Elastic and Baseline conditions for the scapular tilt (Fig. 2).

The Rigid and Elastic taping techniques did not have a significant effect on scapular displacements (Table 1). Pain was significantly lower (p < 0.05) under the two taping conditions for movements in the sagittal plane compared to the Baseline condition; the Baseline condition had a median of 5.2 cm (max = 7.5 cm, min = 0 cm), Rigid taping had a median of 2.4 cm (max = 8.9 cm, min = 0 cm) and Elastic taping had a median of 4.6 cm (max = 10.0 cm, min = 0 cm). Table 2 shows a summary of the number of subjects with changes in their pain scores under the two taping conditions.

### 3.2. Scapular plane

In scapular plane elevation, no significant differences in scapular rotations were found between the taping conditions and Baseline. This was different to scapular plane lowering, where differences in scapular internal rotation under the Elastic taping condition reached statistical significance (p < 0.01). Elastic taping was found to externally rotate the scapula by a mean of 4.6° in scapular plane lowering. Rigid taping was found to anteriorly tilt the scapula in scapular plane lowering by a mean of 3.6° (Fig. 3).

Elastic taping had a significant effect on the scapular position in scapular plane elevation and lowering (Fig. 4). In elevation, Elastic taping positioned the scapula in a more posterior (p < 0.01) and retracted (p < 0.05) position. The effect of Elastic taping on the scapular retraction were greater at mid and high elevation angles which is the reason for the significance in the interaction effect of Taping and Elevation Angle (p < 0.05, Table 1). In lowering, the scapula was also more posterior (p < 0.01) under the Elastic tape condition. Rigid taping had no significant effect on the scapular displacements.

It is also interesting to note that although neither of the taping techniques were significantly different to the Baseline for the displacement in the superior-inferior direction (scapular elevation and depression), the two taping conditions differed from each other (p < 0.05). While Rigid taping depressed the scapula, Elastic taping caused a small elevation to the scapular position relative to the thorax (Fig. 4).

There was no significant difference in pain between the three conditions in scapular plane movements; Baseline had a median of 4.6 cm (max = 10.0 cm, min = 0 cm), Rigid taping had a median of 3.5 cm (max = 10.0 cm, min = 0 cm) and Elastic taping had a median of 2.8 cm (max = 10.0, min = 0 cm). Table 2 shows a summary of the number of subjects with changes in their pain scores under the two taping conditions.

### 4. Discussion

The results suggest that taping techniques have effects on scapular kinematics and pain, these effects are different for different planes of movement and they may be of different magnitudes for elevation and lowering in the same plane.

Both Rigid and Elastic taping techniques externally rotated the scapula in sagittal plane movements. In the scapular plane, only Elastic taping significantly increased scapular external rotation in lowering. A number of studies have shown that patients with SIS have increased scapular internal rotation compared to a healthy control group (Hebert et al., 2002; Ludewig and Cook, 2000; Ludewig and Reynolds, 2009). The results in this study would suggest that both taping techniques help in reducing the scapular internal rotation and therefore in normalising scapular kinematics. However, this is only consistent for movements occurring in the sagittal plane. Both taping techniques also resulted in a clinically significant (Farrar et al., 2001) reduction in pain in sagittal plane movements (difference of more than 2 cm on the median of VAS scores). Other studies that have investigated the effect of taping on shoulder pain reported an increase in the pain-free range-of-motion but no change to the intensity of pain (Lewis et al., 2005a; Theilen et al., 2008).

Interestingly, Hebert et al. (2002) suggested the use of scapular internal rotation as an indicator for the severity of SIS. The authors also suggested that rehabilitation protocols should focus on restoring scapular kinematics in the sagittal plane and particularly on restoring scapular external rotation (Hebert et al., 2002). These suggestions are in line with the findings of this study.
SIS has been associated with a decrease in scapular upward rotation (Endo et al., 2001; Ludewig and Cook, 2000; Su et al., 2004) and posterior tilt (Endo et al., 2001; Lukasiewicz et al., 1999). The two taping techniques did not seem to have an effect on upward rotation. In addition, Rigid taping increased anterior tilt in sagittal plane movements. Although this suggests that Rigid taping exaggerates an already increased anterior tilt in patients with SIS, the results may be caused by an angle calculation artifact caused by thoracic extension. The reported scapular rotations are calculated relative to a coordinate frame of the thorax which is defined relative to four bony landmarks on the thorax (Wu et al., 2005) rather than a coordinate system based on the thoracic spine alone. This means that an increase in the thorax extension angle may be falsely perceived as scapular anterior tilt. Indeed, one of the aims of the Rigid tape application technique is to extend the thoracic spine from a flexed starting position (Lewis et al., 2005a). Calculating the rotations of the thoracic coordinate frame relative to a global frame revealed that the thorax extended by a range of 2–5°. Contrary to the results of this study; Hsu et al. (2009) found that Elastic taping significantly increased the scapular posterior tilt, but the magnitude of change was very small (approximately 1°) and it only occurred...
in low elevation angles in scapular plane elevations (Hsu et al., 2009).

It is also interesting to note that although the Rigid taping application and the measurement method used in this study is directly comparable to that of Shaheen et al. (2013), there are a number of differences in the results of the two studies. Whilst Rigid taping was found to increase scapular external rotation in sagittal plane elevations in both studies, it was not found to have an effect on upward rotation in this study. Rigid taping was also found to have the opposite effect on scapular tilt. This however may be due to the difference in subjects' posture in the two studies, the study of Shaheen et al. (2013) tested younger non-symptomatic volunteers who may have had better postures and were therefore less affected by the artifact caused by thoracic extension. Both studies however found that changes in kinematics were only present in sagittal plane movements.

The Rigid taping technique employed in this study is also believed to retract and depress the scapula (Lewis et al., 2005b). There is a trend which suggests that Rigid taping did depress the scapula in scapular plane movements. Although this change in kinematics did not reach statistical significance compared to the baseline, it is interesting to note that Rigid taping did position the scapula in a more depressed position compared to the Elastic taping and that this difference was statistically significant. The Elastic taping technique on the other hand increased scapular retraction in scapular plane movement. This effect was significant in scapular plane elevation at mid and high elevation angles. Elastic taping also placed the scapula in a more posterior position in scapular plane movements. However, these changes do not seem to relate to the intensity of pain during scapular plane movements.

The key alteration to scapular kinematics caused by taping is the reduction in scapular internal rotation, this alteration occurs mainly in the sagittal plane where a significantly reduced pain was also found. Thus, it is reasonable to suggest that the reduction in pain could be associated with the change in the scapular internal rotation. One possible mechanism by which this reduction of pain occurs is that an externally (less internally) rotated scapula increases the subacromial space and relieves pain caused by soft-tissue impingement as illustrated in Fig. 5; this has also been suggested in previous studies (Ludewig and Reynolds, 2009).

Interestingly, despite the differences in the type of tape (Rigid vs. Elastic) and how it is applied (Unilateral vs. Bilateral), the

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<td>Median, maximum and minimum VAS scores for Rigid and Elastic taping conditions in the sagittal and scapular plane movements. The table also shows the number of subjects with VAS of less than 2 cm at baseline, the number of subjects with reduced and increased pain scores.</td>
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<th>Sagittal plane movements</th>
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<td>Rigid taping</td>
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<td>Number of subjects with reduced pain</td>
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* Pain reduction or increase is defined as a change of 2 cm or more on VAS.

**Fig. 3.** Means of scapulothoracic rotations in scapular plane movements affected by taping and 95% confidence intervals of the difference between measurements obtained under the Rigid and Elastic taping conditions Baseline measurements.
effects of taping on scapular kinematics on the whole are similar. It is however interesting to note that 10 out 11 subjects pre-
ferred the Elastic tape application, this was mainly due to the
restriction to the range of movement of the thorax caused by
Rigid taping. Nonetheless, the effects on pain seen in this study
do not suggest a more beneficial effect of one taping technique
over the other. In addition, although small differences were
found in the effects of the two taping techniques on scapular
plane kinematics, these cannot be used to indicate an added
advantage of a taping technique over the other due to the
absence of a concomitant effect on pain and the existing discrep-
ancy in the literature with regards to the movements that taping
needs to normalise in patients with SIS (Ludewig and Reynolds,
2009).

Fig. 4. Means of scapular displacements in scapular plane movements affected by taping and 95% confidence intervals of the difference between measurements obtained under the Rigid and Elastic taping conditions Baseline measurements.

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4.1. Study limitations

The effects of scapular taping on muscular control or proprioception have not been investigated as part of this work and may have contributed to the pain reduction or to the observed changes in kinematics. In addition, the study only investigated immediate effect of taping on kinematics. This set-up allowed a comparison when subjects were experiencing the same level of pain at rest and also reduced inter-session measurement errors. However, the long term effects of taping as well as the effects of coupling these taping techniques to an exercise regime were not investigated.

There are also limitations associated with the measurement method used in this study. The study employed the scapular tracking method proposed by Shaheen et al. (2011b). Although the method has improved intra-observer reliability compared to other scapula tracking methods, the method is still dependent on the ability of the observer to correctly identify and track scapular landmarks. It is however believed that errors introduced by the observer would not have contributed to the differences shown by taping, particularly as the significant changes caused by taping in kinematics were consistent across subjects as shown by the 95% confidence intervals shown in Figs. 2–4. Another limitation is the way that scapular displacements were quantified in this study. The method uses the position of the acromial angle relative to the thorax coordinate system. These displacements are used to provide a measure of the changes in the position of the scapula due to taping but they may not be representative of true scapulo-thoracic translations.

Other factors that could have contributed to the variations in the effects of taping on kinematics of different subjects include the inconsistencies introduced by the taping application. The effects of these were assessed in a pilot study that looked at re-taping a non-symptomatic cohort using the same Rigid tape application technique, the results of the pilot study showed that there were no significant differences in kinematics between the two applications (Villa, 2010).

5. Conclusions

Rigid and Elastic taping techniques reduce the scapular internal rotation in patients suffering from SIS. This effect corresponds with a reduction in the intensity of pain experienced by patients and is only observed in movements in the sagittal plane. The Elastic taping technique positions the scapula more posteriorly and increase scapular retraction in sagittal plane movements; however these alterations to kinematics did not have a corresponding effect on the pain.

 Suppliers

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(b). Kinesio UK. Cobalt 3.1, Silverfox Way, Newcastle Upon Tyne, NE27 0QJ.
(c). Vicon. 14 Minns Business Park Oxford OX2 0JB.

Ethical approval

This research has been approved by Central London REC 4.

Conflict of interest

None declared.

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