1 **Title: Scapular Taping Alters Kinematics in Asymptomatic Subjects**

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21 **Abstract**

22 Background: Scapular taping is frequently used in the management of shoulder pain
23 and as a part of injury prevention strategies in sports. It is believed to alter scapular
24 kinematics and restore normal motion. However, there is little evidence to support its
25 use. The aim of the study was to investigate the effect of shoulder taping on the
26 scapular kinematics of asymptomatic subjects.

27 Method: Thirteen asymptomatic subjects performed elevations in the sagittal and
28 scapular planes with no tape and after the application of tape. A motion tracking
29 system and a scapula locator method were used to measure the shoulder
30 movement. Co-ordinate frames were defined for the thorax, humerus and scapula
31 and Euler angles were used to calculate joints rotations.

32 Results: Scapular taping increased the scapular external and upward rotations and
33 posterior tilt in elevations in the sagittal plane ($p < 0.001$). In the scapular plane,
34 taping increased scapular external rotation ($p < 0.05$).

35 Conclusions: Taping affects scapulothoracic kinematics in asymptomatic subjects.
36 The effect may be different for different planes of movement. The findings have
37 implications on the use of taping as a preventive measure in high-risk groups.
38 Further work is needed to assess the effect of taping on symptomatic populations.

39 **Keywords**

40 injury prevention, taping, shoulder, scapula, kinematics

41

42 **Introduction**

43 The repetitive placement of the arm in an overhead position is associated with the
44 development of a number of shoulder conditions. Overhead athletes and other
45 professionals that require use of the arm in a predominant overhead position are at a
46 high risk of developing associated shoulder pains and injuries. A number of studies
47 have reported high prevalence of shoulder pain and injury in swimmers [Lo et al.,
48 1990, Rupp et al., 1995, Su et al., 2004], tennis players [Cools et al., 2008], baseball
49 players [Hsu et al., 2009] and other overhead throwing athletes [Laudner et al., 2006,
50 Lo et al., 1990, Wilk et al., 2002]. Shoulder impingement accounts for the majority of
51 the reported complaints [Michener et al., 2003].

52 The application of tape for the management and prevention of joint injury is
53 increasing in popularity in both orthopaedic [Christou et al., 2003, Lewis et al., 2005]
54 and sports medicine [Bradley et al., 2009, Briem et al., 2011] ; taping of the shoulder
55 is now a frequently used adjunct to physical rehabilitation in post-injury management
56 [Host, 1995, Lewis et al., 2005] as well as a part of injury prevention strategies in
57 professional athletes [Bahr and Bahr, 1997, Callaghan, 1997, Kase, 2003] .

58 Shoulder taping is believed to help reduce pain and restore normal functionality
59 [Lewis et al., 2005, Thelen et al., 2008]. However, its use is mostly based on
60 anecdotal observations [Kase, 2003] and there is little evidence to support the
61 benefits and efficacy of taping [Williams et al., 2012]. How taping achieves its
62 beneficial effects is also poorly understood; the literature presents a number of
63 hypotheses to explain the underlying mechanism of taping. It has been proposed
64 that taping enhances the muscle force produced by altering the length/tension
65 relationship of muscles [Host, 1995, Morrissey, 2000] . Another hypothesis is that

66 taping affects neuromuscular control [Alexander et al., 2008, De Pandis et al., 2010,
67 Lohrer et al., 1999] and results in an increased proprioceptive awareness [De
68 Pandis et al., 2010, Morrissey, 2000, Robbins et al., 1995]. Some have attributed the
69 outcomes of taping to be simply due to a placebo effect [Sawkins et al., 2007].
70 Another possible mechanism is that taping increases joint stability via a
71 biomechanical realignment of the joints [Bennell et al., 2000, Host, 1995, Lewis et
72 al., 2005] and a restriction to the joint range [Bradley et al., 2009, McConnell et al.]
73 and speed [Wilkerson, 2002] of motion.

74 Some studies have investigated the effect of scapular taping on the
75 electromyographic activity of surrounding muscles. These studies have reached
76 different conclusions; whilst some found that it had no effect on the
77 electromyographic activity of the muscles [Cools et al., 2002], others found that it
78 inhibits [Alexander et al., 2003] or facilitates [Ackermann et al., 2002] the muscle
79 depending on the application technique. However, the resultant effect on scapular
80 kinematics and movement has not been sufficiently tested.

81 There is evidence that suggests the association of altered scapular kinematics with
82 shoulder pathology and pain [Ludewig and Cook, 2000, Ludewig and Reynolds,
83 2009]. Consequently, a number of taping techniques presented in the literature and
84 commonly used in clinical practise claim to improve symptoms through a correction
85 of the scapular position at rest and during motion [Lewis et al., 2005]. It has also
86 been suggested that taping aids in promoting proper alignment of the scapula [Host,
87 1995]. However, there is limited information about the effects of these taping
88 techniques on scapular kinematics.

89 This is partly due to the difficulty in obtaining an accurate continuous measure of the
90 scapular movement [Hill et al., 2007]. The difficulty is caused by the large range-of-
91 motion of the shoulder and the thick layer of skin covering the whole of the scapula
92 which can move differently to the underlying bone and can also obstruct access to
93 bone movement [Anglin and Wyss, 2000]. However, recent developments in
94 scapular measurement techniques [Shaheen et al., 2011b] suggest that it is now
95 possible to quantify subtle changes in scapular kinematics.

96 The aim of this study was to investigate the effect of taping on scapular kinematics,
97 thereby testing the hypothesis that taping alters the movement pattern of the
98 scapula.

99 **Methods**

100 *Power Analysis*

101 The required sample size was calculated to be 8 subjects. This was based on a
102 power analysis for a repeated-measures ANOVA design, a significance level of 0.05
103 and a statistical power of 0.9. An effect size of $r=0.5$ was estimated based on the
104 results of a pilot study.

105 *Study Population*

106 Postgraduate students were recruited to participate in the study. Subjects were
107 included if they had a fully functional shoulder as assessed by the Oxford Shoulder
108 Score [Dawson et al., 2009] and subjects had no current or recurrent history of
109 shoulder pain or surgery. A total of thirteen (5 males) subjects with a mean age of
110 23.69 ± 1.75 years met these criteria and consented to participate in the study (Table

1). Participating subjects signed an informed consent sheet approved by Central London Research Ethics Committee 4.

Instrumentation and Laboratory Setup

An Optical Motion Tracking system (Vicon, Oxford) running at 100 Hz was used to track the trajectories of retro-reflective markers. The markers were attached to landmarks on the thorax, the humerus and on the scapula locator [Wu et al., 2005], additional markers were also attached to monitor the positions of the head and hand but were not used in analysis of the data.

The scapula locator is a tripod device with three pins adjusted to fit the acromial angle (AA), the inferior angle (AI) and the root of the scapular spine (TS) (Figure 1). A previous study by Karduna et al (2001) has shown that measurements obtained from a scapula mounted device have errors smaller than 5° when compared to measurements from bone-pins [Karduna et al., 2001]. A number of studies have also reported intra-observer and inter-observer reliabilities of the locator; the values are in the ranges of 3-5° for the intra-observer and 4-6° for the inter-observer errors [de Groot, 1997, Meskers et al., 1998] . The intra-observer errors were further improved to 1-3.5° by Shaheen et al (2011a). The locator was used to obtain a continuous measure of the scapular position during movement. This was achieved with the addition of feedback from pressure-sensors attached to the probes of the locator to aid the observer in regulating the pressures applied on the scapular landmarks and to ensure contact of the locator with the landmarks at all times [Shaheen et al., 2011b].

Subjects were comfortably seated on a backless stool in the middle of the capture volume with arms hanging beside the body; a seated position was chosen to provide comfort to the subjects thus increasing stability and reducing the effect of fatigue.

Two tracks were marked on the floor and wall using colourful masking tape; one track was used for scapular plane elevations and the other was used for sagittal plane elevations. Prior to the start of the experiment, the position of the stool was adjusted so that elevations in these two planes with the subject seated corresponded to the marked tracks. Subjects were asked to follow these tracks during measurements.

Subjects performed bilateral elevations in the sagittal and scapular planes with fully extended arms. The order of elevation planes was randomised. Measurements were obtained before and after the application of tape; this order ensured that any lasting effects of taping after its removal does not affect the – no tape – condition.

The locator was used by an experienced observer to obtain a continuous measure of the scapular movement in the dominant shoulder only during motion. The observer used the locator to palpate the landmarks of the scapula prior to movement. The locator was then used to track the movement of the scapula whilst maintaining low pressures on the scapular landmarks during motion as described in Shaheen *et al.* (2011) and shown in Figure 1.

Tape Application

A number of tape types and application techniques for the shoulder have been presented in the literature [Ackermann *et al.*, 2002, Hsu *et al.*, 2009, Lewis *et al.*, 2005, Thelen *et al.*, 2008]. Given that the objective of this study was to investigate whether taping affects scapular kinematics, a taping technique that was specifically developed to correct the scapular position has been employed. The technique was

158 presented in a paper by Lewis *et al* (2005) and it is commonly used in clinical
159 rehabilitation settings.

160 A combination pack of zinc oxide tape and protective tape was used (Physio-Med,
161 Derbyshire). Taping was applied following the method of Lewis *et al.* (2005). The
162 protective tape was applied first with no tension. Subjects were asked to extend their
163 thoracic spine. The rigid tape was applied bilaterally from the first thoracic vertebra to
164 the twelfth thoracic vertebra as shown in Figure 2. Subjects were instructed to retract
165 and depress the scapula and two pre-tensioned strips of rigid tape were then applied
166 diagonally from the middle of the scapular spine to the twelfth thoracic vertebra as
167 shown in Figure 2. Subjects were not required to actively maintain this posture after
168 the application of tape.

169 *Data Analysis*

170 Anatomical co-ordinate frames for the humerus, thorax and scapula were defined as
171 recommended by the International Society of Biomechanics [Wu et al., 2005]. Euler
172 angle rotations were used to determine the humerothoracic and glenohumeral
173 rotations in the sequence of z-x'-y'' (flexion, abduction and axial rotation) for
174 elevations in the sagittal plane, and in the sequence of x-z'-y'' (abduction, flexion and
175 axial rotation) for elevations in the scapular plane [Kontaxis et al., 2009].
176 Scapulothoracic rotations were calculated in the sequence of y-x'-z'' (internal
177 rotation, upward rotation and tilt).

178 Two-factor repeated measures ANOVA tests were used to compare the measured
179 scapulothoracic rotations (internal, upward and tilt). The first factor defined the taping
180 condition: "no tape" and "with tape". The second factor was selected angles of
181 elevation: from 30° to 130° at 10° intervals; this range was selected because it is the

182 range covered by all participating subjects. The significance level was set to $p <$
183 0.05.

184 **Results**

185 The results of the ANOVA tests show that taping the scapula had a significant effect
186 on the scapular internal rotation, upward rotation and tilt in the sagittal plane, and on
187 the internal rotation only in the scapular plane (Table 2).

188 In the sagittal plane, the application of tape increased the scapular external rotation
189 by a mean of 3.8° . The magnitude of change varied with different subjects but
190 ranged from $2-5^\circ$ as shown in Table 3 and Figure 3. Similarly, taping increased
191 upward rotation by a mean of 5.9° (ranging from $2-10^\circ$) and increased the scapular
192 posterior tilt by a mean of 4° (ranging from $1-7^\circ$). This effect occurred over the entire
193 range of elevation and for all participating subjects as shown by the 95% confidence
194 intervals of the difference for the three rotations in Figure 3. Statistical significance is
195 demonstrated graphically where the confidence intervals do not cross the horizontal
196 axis.

197 Table 2 shows that an interaction effect in upward rotation between taping and the
198 angle of elevation is significant ($p < 0.05$); this can be explained by the change in the
199 magnitude of the difference over the whole range of elevation. Figure 3 shows that
200 the mean change in upward rotation increases until it maximises to approximately 7°
201 in the mid range of elevation (90°) and then is reduced again to approximately 4°
202 towards the end of motion.

203 In the scapular plane, taping has a significant effect on the internal rotation but not
204 on the upward rotation and tilt. As with the sagittal plane, taping increased the
205 scapular external rotation. However, this increase was smaller in magnitude (Table

3) and had a mean of 1.9° (ranging from $0.3 - 3.5^{\circ}$). This increase also reduced with elevation as can be seen in Figure 4. The effect of taping on the scapular upward rotation and tilt in the scapular plane was inconsistent across subjects as shown in Figure 4. The effect of taping on these rotations was also inconsistent across the elevation angles as can be seen in Figure 4. Taping resulted in an increase in upward rotation initially but this changed to a downward rotation at higher elevation angles. Similarly, taping resulted in an increase in the scapular posterior tilt at low elevation angles but this moved towards a more anterior position with higher angles of elevation. This variation in the pattern of the differences caused by taping explains the significance in the interaction effect between the taping condition and angle of elevation (Table 3).

Discussion

In this study, the effects of a scapular taping technique on the scapular kinematics of an asymptomatic group were investigated. The results suggest that taping has an effect on the scapulothoracic kinematics. In the sagittal plane, taping was found to position the scapula in a significantly more externally rotated, upwardly rotated and posteriorly tilted position. On the contrary the effects of taping on the scapular plane were significant only for the internal rotation. However, to ensure that the observed effects are real, they should be studied in light of the reliability of the scapula locator method used in this study. The method has measurement errors of $1.3-2^{\circ}$ for the scapular internal rotation, $2.5-3.5^{\circ}$ for the upward rotation and $0.8-1.4^{\circ}$ for the scapular tilt [Shaheen et al., 2011a]. The magnitudes of change in the sagittal plane exceed the measurement method errors; therefore suggesting a real change in kinematics. On the other hand, the magnitude of change in internal rotation observed

230 in the scapular plane is small and it is possible that the difference is a result of a
231 measurement error rather than a real change in kinematics.

232 There is limited information in the literature with regard to the effect of taping on
233 scapular kinematics [Host, 1995, Hsu et al., 2009]. In a case study by Host (1995),
234 the effects of a similar taping technique on scapular kinematics was investigated and
235 it was suggested that taping aids in restoring normal kinematics by reducing scapular
236 elevation, anterior tilt and internal rotation. Another study by Hsu et al (2009) also
237 found that taping reduced anterior tilt (increased posterior tilt) in scapular plane
238 elevation. The results of our study are largely in agreement with previous research.
239 Although it should be noted that while Hsu et al (2009) found that taping significantly
240 increased posterior tilt in scapular plane elevation, this study found that taping
241 increased posterior tilt but only in elevations in the sagittal plane. However, Hsu et al
242 (2009) did not investigate the effects of taping on kinematics in sagittal plane
243 movements. They also used a tape of different material properties (Elastic tape) and
244 a different taping application technique to the one presented here.

245 The results of this study show a disparity in the effects of taping on scapular
246 kinematics between the two planes of motion. One theory which may explain this
247 variation is the difference in the biomechanical effect caused by the pull of tape when
248 also considering the different scapular orientations in the two planes of elevation. In
249 this study, the tape was applied along the spine and diagonally. This would suggest
250 that further movements in the direction of internal rotation and anterior tilt are
251 restrained by the pull of tape. It is hypothesised that this restraining effect will be
252 more evident in the sagittal plane because the scapula in this plane is more internally
253 rotated and anteriorly titled than in the scapular plane (Figures 3 and 4). Thus a
254 biomechanical constraint caused by the pull of tape would be expected to result in a

255 decrease in internal rotation, an increase in posterior tilt and consequently an
256 increase in upward rotation. These are also the changes observed in this study.
257 Nevertheless, the evidence is not sufficient to confirm this theory. It is important to
258 emphasise that this study only focused on the effects of a specific taping technique
259 on scapular kinematics. The effect of taping on other variables such as muscle
260 activity and proprioception have not been measured as part of this work and may
261 offer other theories to explain these differences. In addition, it is possible that the
262 effects of taping on kinematics would be different if subjects were asked to perform
263 elevations while standing or if subjects performed different shoulder movements
264 such as lowering and humeral rotation. The results are also in contradiction to those
265 of Lewis et al (2005) who found no discrepancy in the effect of taping between
266 different elevation planes. In their study scapular taping had the same effect on the
267 pain-free range-of-motion in both sagittal and scapular plane movements, thus
268 signifying that the effects of taping may not be entirely biomechanical. However, the
269 variables considered in their study included the range of elevation, the pain-free
270 range-of-motion and posture but did not include the effect of taping on scapular
271 kinematics which is the focus of this study.

272 The taping technique used in this study was developed for patients suffering from
273 shoulder impingement syndrome [Lewis et al., 2005], a common condition suffered
274 by overhead athletes. Interestingly, the majority of studies investigating the effect of
275 shoulder impingement on scapular kinematics have reported that people suffering
276 from this condition have an increase in scapular internal rotation [Hebert et al.,
277 2002], decrease in upward rotation [Endo et al., 2001, Lin et al., 2005, Ludewig and
278 Cook, 2000, Su et al., 2004] and a decrease in posterior tilt [Endo et al., 2001, Lin et
279 al., 2005, Ludewig and Cook, 2000, Lukasiewicz et al., 1999]. The results of this

study suggest that this taping technique reduces the three rotations normally associated with this condition, and hence may have a beneficial effect on patients suffering from shoulder impingement. However, further work is needed to investigate the effects of taping on patients with shoulder impingement before extending the conclusions of this study to the symptomatic group.

Other limitations of the study include the variability in the tape application technique and the tension generated by the tape in multiple applications on different subjects. Although tape was applied by the same observer, variability in the tape tension in different applications may have resulted in a different magnitude of change between subjects. Other factors that may have also influenced the degree of change is the subject original posture, scapular position before tape application, morphological variations and differences in the same subject movements (motor noise). However, it is important to note that the aim of the study was to investigate whether taping had an effect on kinematics and whether the direction of change could be related to a biomechanical effect of joint re-alignment. Further tests are needed to investigate whether the degree of alteration caused by taping is of clinical importance.

Conclusions

Scapular taping affects scapulothoracic kinematics in asymptomatic subjects, but the magnitude of change may be different for movements in different planes. The study has implications on the use of scapular taping to change scapular movement patterns as a preventive measure in asymptomatic individuals at high risk of injury such as overhead athletes. Further studies are needed to be able to transfer this understanding to symptomatic populations.

304

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References

- ACKERMANN, B., ADAMS, R. & MARSHALL, E. 2002. The effect of scapula taping on electromyographic activity and musical performance in professional violinists. *Aust J Physiother*, 48, 197-203.
- ALEXANDER, C. M., MCMULLAN, M. & HARRISON, P. J. 2008. What is the effect of taping along or across a muscle on motoneurone excitability? A study using triceps surae. *Man Ther*, 13, 57-62.
- ALEXANDER, C. M., STYNES, S., THOMAS, A., LEWIS, J. & HARRISON, P. J. 2003. Does tape facilitate or inhibit the lower fibres of trapezius? *Manual Therapy*, 8, 37-41.
- ANGLIN, C. & WYSS, U. P. 2000. Review of arm motion analyses. *Proc Inst Mech Eng H*, 214, 541-55.
- BAHR, R. & BAHR, I. A. 1997. Incidence of acute volleyball injuries: a prospective cohort study of injury mechanisms and risk factors. *Scand J Med Sci Sports*, 7, 166-71.
- BENNEL, K., KHAN, K. & MCKAY, H. 2000. The role of physiotherapy in the prevention and treatment of osteoporosis. *Manual Therapy*, 5, 198-213.
- BRADLEY, T., BALDWICK, C., FISCHER, D. & MURRELL, G. A. 2009. Effect of taping on the shoulders of Australian football players. *Br J Sports Med*, 43, 735-8.
- BRIEM, K., EYTHORSDDOTTIR, H., MAGNUSDOTTIR, R. G., PALMARSSON, R., RUNARSDOTTIR, T. & SVEINSSON, T. 2011. Effects of kinesio tape compared with nonelastic sports tape and the untaped ankle during a sudden inversion perturbation in male athletes. *J Orthop Sports Phys Ther*, 41, 328-35.
- CALLAGHAN, M. J. 1997. Role of ankle taping and bracing in the athlete.
- CHRISTOU, E. A., YANG, Y. & ROSENGREN, K. S. 2003. Taiji training improves knee extensor strength and force control in older adults. *J Gerontol A Biol Sci Med Sci*, 58, 763-6.
- COOLS, A. M., DECLERCQ, G., CAGNIE, B., CAMBIER, D. & WITVROUW, E. 2008. Internal impingement in the tennis player: rehabilitation guidelines. *Br J Sports Med*, 42, 165-71.
- COOLS, A. M., WITVROUW, E. E., DANNEELS, L. A. & CAMBIER, D. C. 2002. Does taping influence electromyographic muscle activity in the scapular rotators in healthy shoulders? *Man Ther*, 7, 154-62.
- DAWSON, J., ROGERS, K., FITZPATRICK, R. & CARR, A. 2009. The Oxford shoulder score revisited. *Archives of Orthopaedic and Trauma Surgery*, 129, 119-123.
- DE GROOT, J. H. 1997. The variability of shoulder motions recorded by means of palpation. *Clin Biomech (Bristol, Avon)*, 12, 461-472.
- DE PANDIS, M. F., GALLI, M., VIMERCATI, S., CIMOLIN, V., DE ANGELIS, M. V. & ALBERTINI, G. 2010. A new approach for the quantitative evaluation of the clock drawing test: preliminary results on subjects with Parkinson's disease. *Neurol Res Int*, 2010, 283890.
- ENDO, K., IKATA, T., KATOH, S. & TAKEDA, Y. 2001. Radiographic assessment of scapular rotational tilt in chronic shoulder impingement syndrome. *J Orthop Sci*, 6, 3-10.
- HEBERT, L. J., MOFFET, H., MCFADYEN, B. J. & DIONNE, C. E. 2002. Scapular behavior in shoulder impingement syndrome. *Arch Phys Med Rehabil*, 83, 60-9.
- HILL, A. M., BULL, A. M., DALLALANA, R. J., WALLACE, A. L. & JOHNSON, G. R. 2007. Glenohumeral motion: review of measurement techniques. *Knee Surg Sports Traumatol Arthrosc*, 15, 1137-43.
- HOST, H. H. 1995. Scapular taping in the treatment of anterior shoulder impingement. *Phys Ther*, 75, 803-12.
- HSU, Y. H., CHEN, W. Y., LIN, H. C., WANG, W. T. & SHIH, Y. F. 2009. The effects of taping on scapular kinematics and muscle performance in baseball players with shoulder impingement syndrome. *J Electromyogr Kinesiol*, 19, 1092-9.
- KARDUNA, A. R., MCCLURE, P. W., MICHENER, L. A. & SENNETT, B. 2001. Dynamic measurements of three-dimensional scapular kinematics: a validation study. *J Biomech Eng*, 123, 184-90.

- KASE, K. W., J. KASE, T. 2003. *Clinical Therapeutic Applications of the Kinesio Taping Method.*, Tokyo, Japan., Ken Ikai Co Ltd.
- KONTAXIS, A., CUTTI, A. G., JOHNSON, G. R. & VEEGER, H. E. 2009. A framework for the definition of standardized protocols for measuring upper-extremity kinematics. *Clin Biomech (Bristol, Avon)*, 24, 246-53.
- LAUDNER, K. G., MYERS, J. B., PASQUALE, M. R., BRADLEY, J. P. & LEPHART, S. M. 2006. Scapular dysfunction in throwers with pathologic internal impingement. *J Orthop Sports Phys Ther*, 36, 485-94.
- LEWIS, J. S., WRIGHT, C. & GREEN, A. 2005. Subacromial impingement syndrome: the effect of changing posture on shoulder range of movement. *J Orthop Sports Phys Ther*, 35, 72-87.
- LIN, J. J., HANTEN, W. P., OLSON, S. L., RODDEY, T. S., SOTO-QUIJANO, D. A., LIM, H. K. & SHERWOOD, A. M. 2005. Functional activity characteristics of individuals with shoulder dysfunctions. *J Electromyogr Kinesiol*, 15, 576-86.
- LO, Y. P., HSU, Y. C. & CHAN, K. M. 1990. Epidemiology of shoulder impingement in upper arm sports events. *Br J Sports Med*, 24, 173-7.
- LOHRER, H., ALT, W. & GOLLHOFER, A. 1999. Neuromuscular properties and functional aspects of taped ankles. *Am J Sports Med*, 27, 69-75.
- LUDEWIG, P. M. & COOK, T. M. 2000. Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. *Phys Ther*, 80, 276-91.
- LUDEWIG, P. M. & REYNOLDS, J. F. 2009. The association of scapular kinematics and glenohumeral joint pathologies. *J Orthop Sports Phys Ther*, 39, 90-104.
- LUKASIEWICZ, A. C., MCCLURE, P., MICHENER, L., PRATT, N. & SENNETT, B. 1999. Comparison of 3-dimensional scapular position and orientation between subjects with and without shoulder impingement. *J Orthop Sports Phys Ther*, 29, 574-83; discussion 584-6.
- MCCONNELL, J., DONNELLY, C., HAMNER, S., DUNNE, J. & BESIER, T. Effect of shoulder taping on maximum shoulder external and internal rotation range in uninjured and previously injured overhead athletes during a seated throw. *J Orthop Res*, 29, 1406-11.
- MESKERS, C. G., VERMEULEN, H. M., DE GROOT, J. H., VAN DER HELM, F. C. & ROZING, P. M. 1998. 3D shoulder position measurements using a six-degree-of-freedom electromagnetic tracking device. *Clin Biomech (Bristol, Avon)*, 13, 280-292.
- MICHENER, L. A., MCCLURE, P. W. & KARDUNA, A. R. 2003. Anatomical and biomechanical mechanisms of subacromial impingement syndrome. *Clin Biomech (Bristol, Avon)*, 18, 369-79.
- MORRISSEY, D. 2000. Proprioceptive shoulder taping. *Journal of Bodywork and Movement Therapies*, 4, 189-194.
- ROBBINS, S., WAKED, E. & RAPPEL, R. 1995. Ankle taping improves proprioception before and after exercise in young men. *Br J Sports Med*, 29, 242-7.
- RUPP, S., BERNINGER, K. & HOPF, T. 1995. Shoulder problems in high level swimmers--impingement, anterior instability, muscular imbalance? *Int J Sports Med*, 16, 557-62.
- SAWKINS, K., REFSHAUGE, K., KILBREATH, S. & RAYMOND, J. 2007. The placebo effect of ankle taping in ankle instability. *Med Sci Sports Exerc*, 39, 781-7.
- SHAHEEN, A. F., ALEXANDER, C. M. & BULL, A. M. 2011a. Effects of attachment position and shoulder orientation during calibration on the accuracy of the acromial tracker. *J Biomech*, 44, 1410-3.
- SHAHEEN, A. F., ALEXANDER, C. M. & BULL, A. M. 2011b. Tracking the scapula using the scapula locator with and without feedback from pressure-sensors: A comparative study. *J Biomech*, 44, 1633-6.
- SU, K. P., JOHNSON, M. P., GRACEY, E. J. & KARDUNA, A. R. 2004. Scapular rotation in swimmers with and without impingement syndrome: practice effects. *Med Sci Sports Exerc*, 36, 1117-23.

- THELEN, M. D., DAUBER, J. A. & STONEMAN, P. D. 2008. The clinical efficacy of kinesio tape for shoulder pain: a randomized, double-blinded, clinical trial. *J Orthop Sports Phys Ther*, 38, 389-95.
- WILK, K. E., MEISTER, K. & ANDREWS, J. R. 2002. Current concepts in the rehabilitation of the overhead throwing athlete. *Am J Sports Med*, 30, 136-51.
- WILKERSON, G. B. 2002. Biomechanical and Neuromuscular Effects of Ankle Taping and Bracing. *J Athl Train*, 37, 436-445.
- WILLIAMS, S., WHATMAN, C., HUME, P. A. & SHEERIN, K. 2012. Kinesio taping in treatment and prevention of sports injuries: a meta-analysis of the evidence for its effectiveness. *Sports Med*, 42, 153-64.
- WU, G., VAN DER HELM, F. C., VEEGER, H. E., MAKHSOUS, M., VAN ROY, P., ANGLIN, C., NAGELS, J., KARDUNA, A. R., MCQUADE, K., WANG, X., WERNER, F. W., BUCHHOLZ, B. & INTERNATIONAL SOCIETY OF, B. 2005. ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion--Part II: shoulder, elbow, wrist and hand. *J Biomech*, 38, 981-992.

Figure 1: The observer using the scapula locator to track the movement of the scapula during scapular plane abduction. The probes of the locator are placed in contact with the acromial angle (AA), root of the scapular spine (TS) and the inferior angle (AI). The observer palpates and tracks the positions of AA and AI and uses feedback displayed on the computer screen to maintain low pressure on the three landmarks thereby ensuring that the third probe is in contact with TS at all times during motion.

Figure 2: Taping is applied bilaterally using the Lewis et al (2005) technique. Two strips are used on either side, the first strip is applied from the first to the twelfth thoracic vertebrae and the second strip is applied diagonally from the centre of the scapular spine to the twelfth thoracic vertebra.

Figure 3: Mean scapulothoracic rotation for elevation in the sagittal plane when no taping is applied (solid black line with diamond markers) and after the application of tape (dashed grey lines with square markers) and the corresponding 95% confidence intervals of the difference caused by the application of tape for N=13 subjects.

Figure 4: Mean scapulothoracic rotations for elevations in the scapular plane when no taping is applied (solid black lines with diamond markers) and after the application of tape (dashed grey lines with square markers) and the corresponding 9% confidence intervals of the difference caused by the application of tape for N=13 subjects.

Figure 1

Figure 2

Figure 3

Figure 4

Table 1: Information of participating subjects.

Subject no.	Sex	Age (years)	Height (m)	Weight (kg)	Hand dominance
1	M	22	1.79	72	R
2	F	23	1.51	48	R
3	M	23	1.78	64	R
4	M	24	1.77	67	R
5	F	21	1.68	52	R
6	F	24	1.68	59	R
7	F	27	1.69	60	R
8	M	26	1.69	64	R
9	F	26	1.65	49	R
10	F	22	1.62	72	R
11	M	23	1.80	70	L
12	F	24	1.64	53	R
13	F	23	1.60	52	R

Table 2: The mean rotations, standard error of measurements and the 95% confidence intervals of the three scapulothoracic rotations in the two planes of elevation under the “no tape” and “with tape” conditions and the results of the repeated-measures ANOVA tests. *p<0.05

Scapulothoracic Rotation	Taping condition	Mean rotation (°)	Standard error of measurement (S.E.M)	95% confidence interval		Taping		Taping*Angle	
				Lower Bound	Upper Bound	F-value	p-value	F-value	p-value
Sagittal Plane									
Internal Rotation	No Tape	29.73	2.85	23.38	36.08	35.62	0.000*	1.74	0.212
	With Tape	25.98	2.74	19.87	32.09				
Upward Rotation	No Tape	20.71	1.59	17.18	24.25	31.89	0.000*	6.57	0.005*
	With Tape	26.65	1.40	23.54	29.77				
Posterior Tilt	No Tape	-6.10	1.71	-9.92	-2.28	31.49	0.000*	2.55	0.119
	With Tape	-2.10	1.49	-5.43	1.23				
Scapular Plane									
Internal Rotation	No Tape	22.99	2.27	17.12	28.85	9.15	0.012*	4.30	0.000*
	With Tape	20.85	2.18	16.06	25.64				
Upward Rotation	No Tape	29.32	1.50	26.02	32.63	1.61	0.231	8.12	0.006*
	With Tape	27.89	1.01	25.67	30.11				
Posterior Tilt	No Tape	-0.50	1.91	-4.70	3.71	0.755	0.403	5.037	0.031*
	With Tape	0.39	1.77	-3.50	4.29				

Table 3: The mean, standard error of measurement and the 95% confidence interval of the difference in rotations before and after the application of scapular tape. This is also shown in Figures 3 and 4.

Scapulothoracic Rotation	Mean difference (°)	Standard error of measurement (S.E.M)	95% confidence interval	
			Lower Bound	Upper Bound
Sagittal Plane				
Internal Rotation	-3.75	0.63	-5.15	-2.35
Upward Rotation	5.94	1.05	2.14	9.74
Posterior Tilt	4.00	1.49	1.14	6.87
Scapular Plane				
Internal Rotation	-1.89	0.73	-3.50	-0.27
Upward Rotation	-1.43	1.13	-5.67	2.80
Posterior Tilt	0.89	1.03	-2.78	4.56