Title: Scapular Taping Alters Kinematics in Asymptomatic Subjects

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Abstract

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

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

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

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

Keywords

injury prevention, taping, shoulder, scapula, kinematics
Introduction

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

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

Shoulder taping is believed to help reduce pain and restore normal functionality [Lewis et al., 2005, Thelen et al., 2008]. However, its use is mostly based on anecdotal observations [Kase, 2003] and there is little evidence to support the benefits and efficacy of taping [Williams et al., 2012]. How taping achieves its beneficial effects is also poorly understood; the literature presents a number of hypotheses to explain the underlying mechanism of taping. It has been proposed that taping enhances the muscle force produced by altering the length/tension relationship of muscles [Host, 1995, Morrissey, 2000]. Another hypothesis is that
taping affects neuromuscular control [Alexander et al., 2008, De Pandis et al., 2010, Lohrer et al., 1999] and results in an increased proprioceptive awareness [De Pandis et al., 2010, Morrissey, 2000, Robbins et al., 1995]. Some have attributed the outcomes of taping to be simply due to a placebo effect [Sawkins et al., 2007]. Another possible mechanism is that taping increases joint stability via a biomechanical realignment of the joints [Bennell et al., 2000, Host, 1995, Lewis et al., 2005] and a restriction to the joint range [Bradley et al., 2009, McConnell et al.] and speed [Wilkerson, 2002] of motion.

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

There is evidence that suggests the association of altered scapular kinematics with shoulder pathology and pain [Ludewig and Cook, 2000, Ludewig and Reynolds, 2009]. Consequently, a number of taping techniques presented in the literature and commonly used in clinical practise claim to improve symptoms through a correction of the scapular position at rest and during motion [Lewis et al., 2005]. It has also been suggested that taping aids in promoting proper alignment of the scapula [Host, 1995]. However, there is limited information about the effects of these taping techniques on scapular kinematics.
This is partly due to the difficulty in obtaining an accurate continuous measure of the scapular movement [Hill et al., 2007]. The difficulty is caused by the large range-of-motion of the shoulder and the thick layer of skin covering the whole of the scapula which can move differently to the underlying bone and can also obstruct access to bone movement [Anglin and Wyss, 2000]. However, recent developments in scapular measurement techniques [Shaheen et al., 2011b] suggest that it is now possible to quantify subtle changes in scapular kinematics.

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

**Methods**

*Power Analysis*

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

*Study Population*

Postgraduate students were recruited to participate in the study. Subjects were included if they had a fully functional shoulder as assessed by the Oxford Shoulder Score [Dawson et al., 2009] and subjects had no current or recurrent history of shoulder pain or surgery. A total of thirteen (5 males) subjects with a mean age of 23.69 ± 1.75 years met these criteria and consented to participate in the study (Table
Participating subjects signed an informed consent sheet approved by Central London Research Ethics Committee.

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

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

**Data Analysis**

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

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

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

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

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

In the scapular plane, taping has a significant effect on the internal rotation but not on the upward rotation and tilt. As with the sagittal plane, taping increased the 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°). 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° for the scapular internal rotation, 2.5-3.5° for the upward rotation and 0.8-1.4° 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
in the scapular plane is small and it is possible that the difference is a result of a measurement error rather than a real change in kinematics.

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

The results of this study show a disparity in the effects of taping on scapular kinematics between the two planes of motion. One theory which may explain this variation is the difference in the biomechanical effect caused by the pull of tape when also considering the different scapular orientations in the two planes of elevation. In this study, the tape was applied along the spine and diagonally. This would suggest that further movements in the direction of internal rotation and anterior tilt are restrained by the pull of tape. It is hypothesised that this restraining effect will be more evident in the sagittal plane because the scapula in this plane is more internally rotated and anteriorly tilted than in the scapular plane (Figures 3 and 4). Thus a biomechanical constraint caused by the pull of tape would be expected to result in a
decrease in internal rotation, an increase in posterior tilt and consequently an
increase in upward rotation. These are also the changes observed in this study.
Nevertheless, the evidence is not sufficient to confirm this theory. It is important to
emphasise that this study only focused on the effects of a specific taping technique
on scapular kinematics. The effect of taping on other variables such as muscle
activity and proprioception have not been measured as part of this work and may
offer other theories to explain these differences. In addition, it is possible that the
effects of taping on kinematics would be different if subjects were asked to perform
elevations while standing or if subjects performed different shoulder movements
such as lowering and humeral rotation. The results are also in contradiction to those
of Lewis et al (2005) who found no discrepancy in the effect of taping between
different elevation planes. In their study scapular taping had the same effect on the
pain-free range-of-motion in both sagittal and scapular plane movements, thus
signifying that the effects of taping may not be entirely biomechanical. However, the
variables considered in their study included the range of elevation, the pain-free
range-of-motion and posture but did not include the effect of taping on scapular
kinematics which is the focus of this study.

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

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References


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 3

Internal Rotation

Upward Rotation

Posterior Tilt

No Tape

With Tape

Difference (°)

Mean Rotation (°)

Humerothoracic Elevation (°)

External

Internal

External

Downward

Downward

Upward

Posterior Tilt

Anterior Tilt

Anterior

Figure 3
Figure 4

Internal Rotation

Upward Rotation

Posterior Tilt

Figure 4
Table 1: Information of participating subjects.

<table>
<thead>
<tr>
<th>Subject no.</th>
<th>Sex</th>
<th>Age (years)</th>
<th>Height (m)</th>
<th>Weight (kg)</th>
<th>Hand dominance</th>
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<td>22</td>
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<td>72</td>
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<tr>
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<td>23</td>
<td>1.51</td>
<td>48</td>
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<td>1.77</td>
<td>67</td>
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<td>F</td>
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<td>1.60</td>
<td>52</td>
<td>R</td>
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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

<table>
<thead>
<tr>
<th>Scapulothoracic Rotation</th>
<th>Taping condition</th>
<th>Mean rotation (°)</th>
<th>Standard error of measurement (S.E.M)</th>
<th>95% confidence interval</th>
<th>F-value</th>
<th>p-value</th>
<th>F-value</th>
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<td></td>
<td></td>
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<tr>
<td>Internal Rotation</td>
<td>No Tape</td>
<td>29.73</td>
<td>2.85</td>
<td>23.38 to 36.08</td>
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<td>1.74</td>
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<td>25.98</td>
<td>2.74</td>
<td>19.87 to 32.09</td>
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<tr>
<td>Upward Rotation</td>
<td>No Tape</td>
<td>20.71</td>
<td>1.59</td>
<td>17.18 to 24.25</td>
<td>31.89</td>
<td>0.000*</td>
<td>6.57</td>
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<td></td>
<td>With Tape</td>
<td>26.65</td>
<td>1.40</td>
<td>23.54 to 29.77</td>
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<td>Posterior Tilt</td>
<td>No Tape</td>
<td>-6.10</td>
<td>1.71</td>
<td>-9.92 to -2.28</td>
<td>31.49</td>
<td>0.000*</td>
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</tr>
<tr>
<td>Internal Rotation</td>
<td>No Tape</td>
<td>22.99</td>
<td>2.27</td>
<td>17.12 to 28.85</td>
<td>9.15</td>
<td>0.012*</td>
<td>4.30</td>
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<td>20.85</td>
<td>2.18</td>
<td>16.06 to 25.64</td>
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<tr>
<td>Upward Rotation</td>
<td>No Tape</td>
<td>29.32</td>
<td>1.50</td>
<td>26.02 to 32.63</td>
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<td>0.231</td>
<td>8.12</td>
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<td>25.67 to 30.11</td>
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<tr>
<td>Posterior Tilt</td>
<td>No Tape</td>
<td>-0.50</td>
<td>1.91</td>
<td>-4.70 to 3.71</td>
<td>0.755</td>
<td>0.403</td>
<td>5.037</td>
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<td>With Tape</td>
<td>0.39</td>
<td>1.77</td>
<td>-3.50 to 4.29</td>
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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.

<table>
<thead>
<tr>
<th>Scapulothoracic Rotation</th>
<th>Mean difference (°)</th>
<th>Standard error of measurement (S.E.M)</th>
<th>95% confidence interval</th>
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<tr>
<td><strong>Sagittal Plane</strong></td>
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<tr>
<td>Internal Rotation</td>
<td>-3.75</td>
<td>0.63</td>
<td>-5.15</td>
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<tr>
<td>Upward Rotation</td>
<td>5.94</td>
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<td>Posterior Tilt</td>
<td>4.00</td>
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<td>1.14</td>
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<td><strong>Scapular Plane</strong></td>
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<tr>
<td>Internal Rotation</td>
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<td>0.73</td>
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<tr>
<td>Upward Rotation</td>
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<tr>
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