Effect of elastic scapular taping on shoulder and spine kinematics in adolescents with idiopathic scoliosis

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ABSTRACT

Objective: The aim of this study was to investigate the short-term effects of scapular repositioning using an elastic taping technique on the three-dimensional (3-D) shoulder and thoracic kinematics during various activities of daily living (ADLs) in adolescents with idiopathic scoliosis (IS).

Methods: Shoulder and spine kinematics during five ADL movement tasks were assessed in 24 adolescents with IS (3 males and 21 females; mean age: 15.8 years; age range: 14–17 years) before and 15 min after elastic scapular taping. All the participants had a moderate curve magnitude (Cobb angle: 20°–45°), with a primary thoracic curve. A 3-D electromagnetic tracking system (Ascension Technology Corporation, Shelburne, VT, USA) was used to record 3-D shoulder and thoracic kinematics. ADL movement tasks included touching the mouth/drinking, touching the back, touching the contralateral shoulder, reaching upward, and bilateral 4-kg weight lifting. Two separate strips of elastic tape were applied using the same correction technique for each shoulder and scapular region to control scapular alterations in the resting position.

Results: Elastic scapular taping significantly improved scapular external rotation and scapular upward rotation. Similarly, humeral horizontal adduction, external rotation, thoracic flexion, and lateral bending significantly increased in the taped condition depending on the specific task (p<0.05).

Conclusion: Elastic scapular taping can change scapular orientations on the convex and concave sides, thereby affecting upper extremity and trunk kinematics. Thus, the dynamic stability of the scapula increases to produce larger movements during functional activities.

Level of Evidence: Level III, Therapeutic study

The normal function and stability of the scapula is essential for optimal upper limb function in activities of daily living (ADLs). It relies on a balance between the muscular and capsule-ligamentous structures (1). Coordination of muscle action around the scapulothoracic and glenohumeral joints is regulated by the neural subsystem, in which proprioception plays an important role (2). A task-oriented view of motor performance has been utilized to assess motor function. Balance, coordination, muscle linkages, degrees of freedom, and environmental features during normal human movement are essential components in organizing the movements to perform a given task (3). Therefore, kinematic behavior of the scapula, shoulder, and thorax must be investigated during ADLs (4).

Idiopathic scoliosis (IS) is a complex spine deformity with lateral deviation and rotation accompanied by postural alterations as well as asymmetries in the head, trunk, shoulders, and scapular region (5, 6). These postural alterations are associated with deficits in the sensory and motor system, namely, poor postural control, muscular imbalance, and proprioceptive deficits (7). Lin et al. reported altered shoulder kinematics and muscle activity in individuals with IS (5). They observed decreased scapular posterior tilt related to increased lower trapezius muscular activity on the convex side. Furthermore, they identified increased scapular upward rotation related to decreased lower trapezius and serratus anterior muscular activity on the concave side. In addition, they proposed motor control alterations in kinematic linkage among the thoracic spine, scapula, and arm as a cause of changes in muscle activity. Recently, we identified various scapular alterations that can be considered as an adaptive compensation.
strategies in adolescents with IS (8). During arm elevation, the scapula was more internally and anteriorly tilted on the convex side, whereas it was more externally and downwardly rotated and posteriorly tilted on the concave side in participants with IS. Peak humerothoracic elevation decreased bilaterally. Altered shoulder kinematics and poor scapular control are clinically associated with upper extremity dysfunction; therefore, these are considered as risk factors for multiple musculoskeletal disorders (9). Therefore, in cases of kinematic alterations, clinicians must design clinical applications to improve scapulothoracic control.

Exercise, manual mobilization methods, bracing, and taping are specific therapeutic approaches for the maintenance of dynamic scapular stabilization (10). Taping is one of the most common interventions for the management of musculoskeletal conditions. This method facilitates and inhibits muscle activity, repositions joints, protects against injury, and improves proprioception (11). Elastic taping, an adhesive therapeutic taping, provides support to mimic the thickness and flexibility of the skin. In contrast with the standard rigid taping techniques, it provides mechanical support without restricting movement (1). Scapular elastic taping positions the scapula in the ideal postural position and improves joint position as well as kinesthetic awareness during movements (12). Numerous studies have indicated that scapular elastic taping corrects alignment, improves neuromuscular control, increases proximal stability, enables free humeral movements without pain, and ensures a position likely to produce optimal rotator cuff function (13–16). These studies have been conducted on patients with brachial plexus birth palsy and distal radius fracture as well as on healthy athletes (12, 13, 16). In addition, elastic taping reduces symptoms and facilitates a return to sports participation for patients with impingement syndrome, in addition to reducing disability and pain in people with chronic nonspecific low back pain (17, 18). Wright et al. suggested taping for decreasing the risk of ankle sprain injury (19).

Scapular kinematic alterations in individuals with IS have been previously demonstrated (8).

This study hypothesized that taping may affect shoulder and thoracic kinematics during selected ADL tasks by scapular repositioning in adolescents with IS. Therefore, this study aimed to quantify the short-term effects of repositioning both scapula with elastic taping on the three-dimensional (3-D) kinematics of scapula, thoracic spine, and humerus in five ADLs in adolescents with IS.

Materials and Methods

Participants

This study was approved by the University of Hacettepe institutional research ethics committee. The study included 24 adolescents with IS (21 females and 3 males) (Table 1). Assent was obtained from all patients, and their parents provided parental informed consent prior to inclusion. The inclusion criteria were as follows: age between 14 and 17 years, having a moderate curve magnitude (Cobb angle: 20°–45°), having primary thoracic curves, no prior treatment, and right-arm dominance. The exclusion criteria were as follows: arm, shoulder, and back pain or symptoms; previous history of serious musculoskeletal injury (e.g., fracture or surgical intervention) or neurologic disease; and altered sensation within the taping area.

The Cobb angle and axial trunk rotation were measured at baseline by an experienced physician (20, 21). The Cobb angle of the curve was measured using standard standing full-length posteroanterior spinal x-rays on a computer screen to evaluate the lateral curvature of the spine and was recorded in degrees (20). The axial trunk rotation of the participants was assessed using a scoliometer in the forward bending test. The axial trunk rotation values were obtained by positioning the center of the scoliometer over the spinous process and perpendicular to the spine on the curve apex and were recorded in degrees (21).

Instrumentation

A 3-D electromagnetic tracking system (Ascension Technology Corporation, Shelburne, VT, USA) was used to collect 3-D kinematics. This system comprises an electronic unit, a standard range transmitter, five sensors (25.4×25.4×20.3 mm), and one digitizer, interfaced with the Motion Monitor software program (Innovative Sports Training, Inc., Chicago, IL, USA). Data were collected at a sampling rate of 100 Hz per sensor. Data were subsequently filtered using the system’s Butterworth filter software, with a 6-Hz low-pass cutoff frequency. Data collected using this system are reliable and features calculated trial-to-trial, within-day, without removal of sensors intraclass correlation coefficient values ranging from 0.72 to 0.99 for our laboratory (22).

Experimental procedure and tasks

Prior to recording, the procedure and each ADL movement task was precisely described and demonstrated to the participants. Each participant performed two repetitions of each movement task to warm-up and become familiar with the movements at baseline before sensor placement and digitiza-
tion. Additionally, all metal objects worn by the participants were removed to avoid interference with the magnetic field of the system. Then, five sensors were directly attached to the skin: one sensor over the flattest aspect of per acromion process (one on each shoulder), one sensor over the posterolateral aspect of each humerus distal to the belly of the triceps (one on each arm), and one sensor over the T1 thoracic vertebrae using double-sided adhesive tape that was further secured using non-elastic tape (Figure 1). Specific bony landmarks (processus spinosus of T1, T8, T12, angle of acromion (posterior), trigonum spinae scapula, angulus inferior of the scapula, processus coracoideus, and lateral and medial epi-
condyles) were digitized with a stylus based on the Interna-
tional Society of Biomechanics (ISB) standard protocol while participants were standing with their arms relaxed to create segmental axes (23).

The bilateral scapular orientation data in the resting position were collected for 5 s in the standing posture with arms relaxed at the sides. Five ADL movement tasks commonly used for evaluating shoulder functions were then assessed in the sitting position. Participants were asked to sit on a chair without back support, with their hips and knees at a 90° angle, their feet positioned at shoulder width apart on the floor, arms relaxed at the side of their body, and hands on their thighs at baseline. Tasks included touching the mouth/drinking, touching the middle of the back with the dorsal side of the hand, touching the contralateral shoulder, reaching upward, and bilateral 4-kg weight lifting (Figure 2). Using 3 s to reach the end range of each task, participants performed three repetitions of a bilateral movement for the lifting task and unilateral movements for the other four tasks at a comfortable speed matching the beat of a metronome set at 60 beats per minute. The participants completed each task and maintained the position for 3 s at the completion of the task. The point of task completion was defined as the position essential for the performance of a movement that easily demonstrated the greatest range of motion. The kinematic data were recorded throughout the movement task, and the recordings were taken at the point of completion. The order of the tasks was randomized using a random number generator. The recordings were taken at 30 s intervals between each task to avoid muscle fatigue. Taped testing began 15 min after elastic taping was applied to allow activation of the tape’s adhesive (24). All kinematic tests were performed by a second researcher, with the order of no tape and taped condition randomized.

Tape application
The tape was an approximately 5´28-cm piece of Kinesio tape (Kinesio Tex, KT-X-050, Tokyo, Japan). The tape was cut into an I shape and applied with moderate (50% of available) tension to provide scapular positional correction and proprioceptive feedback and not to prevent full range of shoulder

| Table 1. Personal and Clinical Characteristics of the Participants |
|---------------------------------------------------------------|
|                                                                 |
| **Participants**                                                                                                      |
| **Mean (SD)** | **Min** | **Max** |
| Age (years) | 15.8 (0.8) | 14  | 17 |
| Height (cm) | 163.5 (7.6) | 150 | 183 |
| Mass (kg) | 50.6 (4.9) | 41  | 59 |
| BMI (kg/m²) | 18.9 (1.4) | 16.3 | 20.7 |
| Curve Pattern (n; %)                                                                                                       |
| Right thoracic left lumbar | 10 (41.7%) | n/a  |
| Right thoracic | 14 (58.3%) | n/a  |
| Cobb Angle (°)                                                                                                                |
| Thoracic | 30.3 (8.2) | 20  | 45 |
| Lumbar | 27.0 (7.1) | 20  | 40 |
| Axial trunk rotation (°)                                                                                                     |
| Thoracic | 8.8 (3.6) | 3   | 15 |
| Lumbar | 5.3 (1.9) | 3   | 8  |

Data are shown as mean (SD) degree
Figure 2. a-e. Illustration of five movement tasks. (a) Touching mouth/drinking. The hand was placed on the knee in the resting position, and a cup filled with water was held in the hand. The participant was instructed to move the cup to his/her mouth and take a sip, after which the end position was reached. (b) Touching the back. The arm was in the anatomical position, with hand hanging beside the body in a relaxed and neutral position. The participant was instructed to move his/her hand to the back and touch the upper back with the dorsal surface of the hand, after which the end position was reached. (c) Touching the contralateral shoulder. The start position was the anatomical position as described in task B. The end point was reached when the hand touched the contralateral shoulder joint. (d) Reaching upward. The start position was the anatomical position as described in task B. The participant was instructed to elevate his/her arm to the upward position and reach with the hand as high as possible. (e) Weight lifting. The hands were placed on the knee at the start position. The participant was instructed to lift a 4-kg bag from the ground with both the hands in front of the body.

Figure 3. a, b. (a) Clinical photo: An adolescent with right thoracic left lumbar scoliosis with no tape (b) with elastic tape application
movement (25). Based on our clinical experience and observational clinical assessment of patients, bilateral scapular positional fault includes increased anterior tilt and internal rotation (scapular winging) in patients with primary thoracic IS. Therefore, the taping aimed to facilitate bilateral symmetrical scapular position by reducing scapular anterior tilt and internal rotation. The first piece of tape was diagonally applied from the anterior aspect of the humeral head, immediately lateral to the acromion process, up to the inferior angle of the scapula. The second piece of tape was applied from the inferior margin of the medial 1/3 clavicle to T12 (Figure 3). The opposite hand of the researcher lifted the humeral head up and back during taping, and the patient retracted and depressed the scapula, extending the trunk in an erect posture.

**Statistical analysis**

We followed the ISB guidelines for constructing a shoulder joint coordinate system (23). Scapular kinematics according to the ISB recommendations were described in the following rotations: internal (+)/external (-) rotation; downward (+)/upward (-) rotation, posterior (+)/anterior (-) tilt, humerothoracic (shoulder) horizontal adduction (+)/abduction (-), flexion (+)/extension (-) internal (+)/external (-) rotation, and thoracic spine flexion (+)/extension (-), clockwise (+)/counterclockwise (-) axial rotation, and right (+)/left (-) lateral bending angles were presented as degrees. Scap int–ext rot, scapular internal–external rotation; scap down–upw rot, scapular downward–upward rotation; scap post–ant tilt, scapular posterior–anterior tilt; ht add–abd, humero–thoracic horizontal adduction–abduction; ht flex–ext, humero–thoracic flexion–extension; ht int–ext, humero–thoracic internal–external rotation; thoracic flex–ext, thoracic spine flexion–extension; thoracic clock–counter, thoracic spine clockwise–counterclockwise axial rotation. Data are mean (SD). * represents statistical significance between no tape and taped conditions by paired sample t-test (* indicates p<0.05, ** indicates p<0.001)

The sample size was calculated in accordance with a pilot study conducted with eight patients (α=0.05, power=0.80, mean difference of 8.0° [11.0]° of upward scapular rotation). The minimum number of participants was 14. The Statis-

Figure 4. The position and orientation data of the scapula and shoulder at the resting position and at the completion of touching the mouth and touching the back tasks for the convex and concave sides of the curve. Scapular internal (+)/external (-) rotation, downward (+)/upward (-) rotation, posterior (+)/anterior (-) tilt, humerothoracic (shoulder) horizontal adduction (+)/abduction (-), flexion (+)/extension (-) internal (+)/external (-) rotation, and thoracic spine flexion (+)/extension (-), clockwise (+)/counterclockwise (-) axial rotation, and right (+)/left (-) lateral bending angles were presented as degrees. Scap int–ext rot, scapular internal–external rotation; scap down–upw rot, scapular downward–upward rotation; scap post–ant tilt, scapular posterior–anterior tilt; ht add–abd, humero–thoracic horizontal adduction–abduction; ht flex–ext, humero–thoracic flexion–extension; ht int–ext, humero–thoracic internal–external rotation; thoracic flex–ext, thoracic spine flexion–extension; thoracic clock–counter, thoracic spine clockwise–counterclockwise axial rotation. Data are mean (SD). * represents statistical significance between no tape and taped conditions by paired sample t-test (* indicates p<0.05, ** indicates p<0.001)
Table 2. Scapular kinematics at resting position and at selected daily activities for the untaped and taped conditions

| Kinematics | Resting Position | Touching mouth | Touching the back |
|------------|------------------|---------------|------------------|
|            | Untaped Mean (SD)| Taped Mean (SD)| Untaped Mean (SD)| Taped Mean (SD)| Untaped Mean (SD)| Taped Mean (SD)|
| Convex side (°) |                   |               |                   |               |                   |               |
| Scapular int–ext rotation | 32.5 (6.9) | 25.0 (6.9)** | 36.0 (8.1) | 30.0 (8.6)** | 39.2 (7.2) | 35.5 (10.2)* |
| Scapular down–upw rotation | 8.2 (6.9) | 5.4 (7.7)* | −5.0 (7.2) | −7.0 (8.6) | 20.1 (6.6) | 14.9 (12.8)* |
| Scapular post–ant tilt | −15.9 (5.6) | −14.9 (5.9) | −20.1 (7.6) | −14.6 (7.0)** | −22.0 (5.2) | −18.3 (4.7)* |
| HT horizontal add–abd | 22.1 (66.9) | 56.0 (39.2)* | −71.5 (18.4) | −69.8 (36.5) | 87.1 (40.5) | 46.4 (59.7)* |
| HT flexion–extension | 5.8 (10.6) | 10.0 (12.7)* | 13.1 (38.2) | 8.0 (29.7) | 31.8 (26.8) | 23.9 (31.9) |
| HT int–ext rotation | 40.1 (70.2) | 83.2 (38.5)* | −37.4 (20.1) | −40.2 (35.8) | 155.3 (34.0) | 118.5 (65.5)* |
| Thoracic spine for convex side extremity movement (°) |                   |               |                   |               |                   |               |
| Thoracic flexion–extension | 5.5 (8.1) | 9.1 (8.7)* | 6.3 (7.2) | 8.0 (9.5) | 7.4 (6.3) | 10.6 (6.6)* |
| Thoracic rotation | 0.8 (6.5) | 1.7 (7.1) | 3.6 (8) | 2.4 (8.6) | −2.4 (7.5) | −2.4 (7.0) |
| Thoracic right–left bending | −0.4 (3.4) | −1.7 (4.1) | 0.4 (3.3) | −1.3 (5.4) | 2.0 (4.9) | 0.1 (3.7) |
| Concave side (°) |                   |               |                   |               |                   |               |
| Scapular int–ext rotation | 24.8 (7.8) | 17.1 (10.3)** | 27.3 (9.1) | 22.9 (11.9)* | 33.3 (7.8) | 28.5 (10.1)* |
| Scapular down–upw rotation | 6.0 (7.4) | 3.1 (9.8)* | −5.3 (9.0) | −6.3 (10.3) | 16.8 (6.9) | 14.6 (10.0)** |
| Scapular post–ant tilt | −11.5 (6.4) | −9.5 (9.1) | −13.9 (7.7) | −9.2 (8.7)* | −18.3 (7.5) | −15.9 (11.7) |
| HT horizontal add–abd | 33.1 (56.5) | 29.9 (67.0) | −75.5 (37.2) | −78.2 (20.7) | 84.0 (43.2) | 78.6 (71.8) |
| HT flexion–extension | 9.2 (5.6) | 11.1 (9.6) | 29.0 (21.4) | 30.1 (20.6) | 19.7 (25.1) | 14.4 (29.7) |
| HT int–ext rotation | 63.6 (51.5) | 71.5 (46.0) | −54.3 (14.7) | −53.7 (16.5) | 157.0 (33.4) | 142.3 (64.9) |
| Thoracic Spine for concave side extremity movement (°) |                   |               |                   |               |                   |               |
| Thoracic flexion–extension the same with convex side as reported above | 6.4 (6.8) | 9.1 (8.0)* | 7.4 (7.3) | 10.7 (6.0)* |
| Thoracic rotation reported above | 1.9 (6.2) | 1.7 (6.8) | −7.6 (9.8) | −7.7 (8.9) |
| Thoracic right–left bending | 0.4 (3.1) | −0.4 (5.0) | 3.4 (5.0) | 2.5 (5.3) |

| Kinematics | No tape Mean (SD) | Taped Mean (SD) |
|------------|-------------------|-----------------|
| Convex side (°) |                   |                 |
| Scapular int–ext rotation | 41.9 (9.3) | 38.6 (10.1)* |
| Scapular down–upw rotation | −4.3 (7.4) | −7.5 (9.2) |
| Scapular post–ant tilt | −19.6 (7.5) | −18.1 (6.7) |
| HT horizontal add–abd | −35.5 (67.1) | −134.0 (49.7)** |
| HT flexion–extension | 12.2 (25.6) | 17.0 (33.9) |
| HT int–ext rotation | 130.3 (46.5) | 138.8 (43.4) |
| Thoracic Spine for convex side extremity movement (°) |                   |                 |
| Thoracic flexion–extension | 2.9 (5.8) | 7.6 (6.8)** |
| Thoracic rotation | −3.3 (5.2) | −4.1 (5.9) |
| Thoracic right–left bending | −1.6 (3.8) | −3.2 (4.1)* |
| Concave side (°) |                   |                 |
Figure 5. The position and orientation data of the scapula and shoulder at the completion of touching the contralateral shoulder, reaching upward, and lifting weight tasks under untaped and taped conditions for the convex and concave sides of the curve. Scapular internal (+)/external (-) rotation, downward (+)/upward (-) rotation, posterior (+)/anterior (-) tilt, humerothoracic (shoulder) horizontal adduction (+)/abduction (-), flexion (+)/extension (-) internal (+)/external (-) rotation, and thoracic spine flexion (+)/extension (-), clockwise (+)/counterclockwise (-) axial rotation, and right (+)/left (-) lateral bending angles were presented as degrees.

|               | No tape | Taped  |
|---------------|---------|--------|
| Scapular int–ext rotation | 34.0 (8.6) | 30.5 (10.8)* |
| Scapular down–upw rotation | −7.1 (8.2) | −9.3 (8.6) |
| Scapular post–ant tilt | −13.3 (6.6) | −11.8 (7.8) |
| HT horizontal add–abd | −73.3 (107.5) | −115.3 (46.8) |
| HT flexion–extension | 2.6 (17.2) | 26.7 (31.9)* |
| HT int–ext rotation | 153.2 (48.6) | 112.8 (60.3)* |

Thoracic Spine for concave side extremity movement (°)

|               | No tape | Taped  |
|---------------|---------|--------|
| Thoracic flexion–extension the same with convex sidereported above | 3.5 (5.9) | 8.0 (7.7)* |
| Thoracic rotation | −2.3 (5.6) | −2.4 (7.1) |
| Thoracic right–left bending | −0.7 (2.9) | −2.8 (3.5)* |

HT: humerothoracic; int–ext: internal–external; down–upw: downward–upward; post–ant: posterior–anterior; add–abd: adduction–abduction; ant–post: anterior–posterior. Thoracic rotation refers to clockwise–counterclockwise movement of the thoracic spine.

Data are shown as mean (SD) degree. *indicates p<0.05, **indicates p<0.001
tical Package for Social Sciences version 15.0 (SPSS Inc., Chicago, IL, USA) was used to perform statistical analysis. The assumption of normality was tested prior to the statistical analysis by inspecting skewness and kurtosis. Data were normally distributed. Descriptive statistics were expressed as mean (standard deviation). Paired samples t-test was used for paired comparisons between the untaped and taped conditions.

**Results**

The study included 24 adolescents with IS, with a mean age of 15.8 (0.8) years. Furthermore, 10 participants reported right thoracic left lumbar curve pattern, and 14 reported single thoracic curve pattern of IS. Table 1 summarizes the demographic and clinical data.

Figure 4, 5 and Table 2 illustrate the scapular, humeral, and thoracic spine kinematics observed at the resting position while performing specific upper extremity tasks in the untaped and taped conditions.

**Resting position**

The resting position for the taped condition indicated a greater scapular external rotation (p<0.001, mean difference: 7.5 [5.0]° and p<0.001, mean difference: 7.7 [5.8]° for the convex and concave sides, respectively) and scapular upward rotation (p=0.025, mean difference: 2.8 [5.6]° and p=0.023, mean difference: 2.9 [5.7]° for the convex and concave sides, respectively) for both the convex and concave sides of the curve. For the convex side, increased humeral horizontal adduction (p=0.027, mean difference: −33.9 [68.6]°), humeral flexion (p=0.028, mean difference: −4.2 [8.6]°), and internal rotation (p=0.012, mean difference: −43.2 [75.9]°) were obtained with taping. Thoracic spine flexion in the resting position increased in the taped condition (p=0.032, mean difference: −3.5 [7.4]°) (Figure 4).

**Touching the mouth/drinking**

As illustrated in Figure 4, scapular external rotation (p<0.001, mean difference: 6.0 [6.6]° and p=0.001, mean difference: 4.4 [5.6]° for the convex and concave sides, respectively) and scapular posterior tilt (p<0.001, mean difference: −5.5 [4.6]° and p=0.003, mean difference: −4.7 [7.1]° for the convex and concave sides, respectively) increased following taping on both the convex and concave sides of the curve. Thoracic spine flexion (p=0.006, mean difference: −2.7 [4.2]°) increased for the concave side movement.

**Touching the back**

Convex scapular external rotation (p=0.018, mean difference: 3.7 [7.2]°), scapular upward rotation (p=0.013, mean difference: 5.2 [9.5]°), and scapular posterior tilt (p=0.002, mean difference: −3.7 [5.3]°) increased. Concave scapular external rotation (p=0.003, mean difference: 4.7 [6.8]°) and scapular upward rotation (p<0.001, mean difference: 23.9 [7.3]°) increased. Increased humeral horizontal abduction (p=0.030, mean difference: 4.07 [86.3]°) and humeral external rotation (p=0.015, mean difference: 36.9 [68.5]°) was observed only for the convex side with taping. In both the convex and concave side movements, thoracic spine flexion (p=0.002, mean difference: −3.2 [4.4]° and p=0.002, mean difference: −3.3 [4.7]° for the convex and concave sides, respectively) increased in the taped condition (Figure 4).

**Touching the contralateral shoulder**

For the convex side, increased scapular external rotation (p=0.008, mean difference: 3.4 [5.7]°) and humeral horizontal abduction (p<0.001, mean difference: 98.4 [72.1]°) was reported with taping. For the concave side, increased scapular external rotation (p=0.020, mean difference: 3.5 [6.9]°), humeral flexion (p=0.005, mean difference: −24.1 [37.7]°), and humeral external rotation (p=0.008, mean difference: 40.4 [68.0]°) was observed in the taped condition. In both the convex and concave side movements, thoracic spine flexion (p<0.001, mean difference: −4.7 [5.3]° and p=0.001, mean difference: −4.5 [5.8]° for the convex and concave sides, respectively) and left lateral bending (p=0.042, mean difference: 1.6 [3.6]° and p=0.005, mean difference: 2.1 [3.3]° for the convex and concave sides, respectively) increased with taping (Figure 5).

**Reaching upward**

No statistically significant differences were observed for the thoracic spine flexion between the untaped and taped conditions (p>0.05). However, concave scapular external rotation (p=0.008, mean difference 8.5 [14.3]°) increased with taping, and thoracic spine flexion (p=0.029, mean difference: −2.8 [6.0]°) increased for the concave side movement (Figure 5).

**Weight lifting**

Convex and concave side scapular external rotation (p<0.001, mean difference: 5.3 [5.2]° and p<0.001, mean difference: 5.4 [5.6]° for the convex and concave sides, respectively); scapular upward rotation (p=0.003, mean difference: 4.1 [6.0]° and p=0.003, mean difference: 3.4 [4.9]° for the convex and concave sides, respectively); scapular posterior tilt (p<0.001, mean difference: −2.8 [2.7]° and p=0.005, mean difference: −3.1 [4.9]° for the convex and concave sides, respectively); humeral horizontal abduction (p=0.005, mean difference: 35.8 [56.3]° and p=0.018, mean difference: 44.8 [86.0]° for the convex and concave sides, respectively); humeral flexion (p=0.016, mean difference: −8.6 [16.2]° and p=0.010, mean difference: −9.9 [17.4]° for the convex and concave sides, respectively); and humeral external rotation (p=0.041, mean difference: 28.2 [63.8]° and p=0.041, mean difference: 37.7 [85.2]° for the convex and concave sides, respectively) increased with taping.Thoracic spine flexion (p<0.001, mean difference: −4.9 [3.1]°) and left lateral bending (p=0.018,
mean difference: 1.7 [3.2]° increased with taping during the lifting task (Figure 5).

Discussion

Kinematic analysis during functional tasks used in clinical evaluations of ADLs showed that scapular repositioning using elastic tape affected shoulder kinematics and thoracic spine position in adolescents with IS. In general, during five tasks, significant increases in scapular external rotation, upward rotation, and posterior tilt; changes in humeral internal-external rotation, horizontal adduction–abduction, and flexion-extension with regard to tasks; and increase in thoracic spine flexion were reported 15 min after the application of elastic taping. Overall, these results supported our hypothesis. To the best of our knowledge, this is the first study demonstrating the effects of elastic taping on scapular and thoracic kinematics during functional ADL tasks in adolescents with IS.

The ideal scapular resting position on the thorax has been reported to include a slight upward rotation, anterior tilt, and internal rotation as bilaterally symmetrical. During humeral elevation, the scapula moves into a progressively upward rotation, with a slight external rotation at higher elevation angles and a decreased anterior tilt (26). We previously observed that the scapula was more internally rotated and anteriorly tilted on the convex side, whereas it was more externally and downwardly rotated and posteriorly tilted on the concave side in adolescents with IS when compared with healthy controls (8). In this study, we examined the effects of taping on altered 3-D upper body kinematics in IS. We observed various significant changes in kinematics while performing functional tasks. The tasks selected for this study, i.e., touching the mouth/drinking, touching the back, touching the contralateral shoulder, reaching upward, and weight lifting, were based on functional ADL tasks that involve several muscles of the shoulder girdle and spine. Elastic taping has been previously reported to affect scapulothoracic kinematics and has been suggested for the restoration of normal functionality or for the prevention or management of joint injury (27). However, little evidence exists to support the benefits and efficacy of elastic taping (28). However, the findings of this study provide evidence on the immediate effect of taping on scapular, shoulder, and thoracic kinematics in the resting position in adolescents with IS.

Several methods, including exercise and taping, are involved in the restoration of scapular or humeral movement alterations. We selected elastic taping owing to its easy accessibility, wide range of applications, and therapeutic effects. In this study, adolescents with IS demonstrated an increased scapular external rotation, upward rotation, posterior tilt, and humeral flexion. Some changes were observed in the humeral horizontal adduction–abduction and internal–external rotation for the convex and/or concave sides of the curve with taping during touching the mouth/drinking, touching the back, touching the contralateral shoulder, reaching upward, and weight lifting. These results suggested that taping could change upper extremity and trunk kinematics, thereby increasing the dynamic stability of the scapula to increase the range of movement during functional activities. Therefore, taping can increase humeral flexion in the frontal and sagittal plane during these activities. However, further studies are needed to examine the effect of these kinematic changes on patients’ self-reported function in ADLs. A potential mechanism may result in these kinematic alterations with taping, including increase in proprioceptive awareness for the shoulder and scapulothoracic regions (12, 14). However, we did not measure this parameter. In contrast, studies have indicated no significant difference in joint position sense or proprioception with elastic taping (29, 30). In a previous study, adolescents with IS demonstrated 13° limitation in humerothoracic elevation for both convex and concave sides of the curve when compared with healthy controls (8). In the present study, we found up to 24° increase in shoulder flexion during selected activities. Therefore, taping helped to move the muscles, fascia, or the joint into a more desirable position and to perform selected activities in greater ranges of motion. A difference of 5° between conditions for all scapular kinematics was previously recommended for a minimal detectable clinical change (31).

Clinical assessment of upper extremity movement patterns has been suggested to include the thoracic spine due to interactions between spinal kinematics and scapulohumeral motion (4). In the present study, scapular taping increased thoracic spine flexion in all tasks and thoracic left lateral bending during touching the contralateral shoulder and weight lifting tasks. Our study suggested that the current spinal movement strategy can be changed without the need for any interventions applied directly to the spine in individuals with IS. In IS, scapular asymmetries are believed to be caused by postural distortions related to trunk deformity (32). The present study demonstrated that elastic scapular taping could change convex and concave side scapular orientations, thereby affecting upper extremity and trunk kinematics and increasing the dynamic stability of the scapula to produce more efficient movement during functional activities. However, this finding should be investigated in terms of its therapeutic effect in future studies. Patients may benefit from scapular elastic taping for the conservative treatment of IS to provide more symmetrical scapulothoracic alignment and change kinematic alterations observed in the shoulder and trunk. However, further studies are warranted to investigate whether taping or other techniques, such as exercise training, may affect shoulder kinematics during ADLs in patients with IS.

One limitation of this study is the low number of individuals without IS. Therefore, the observed altered movement pat-
tern with or without taping cannot be compared with that of teens without IS. Another limitation is the lack of sham taping. It remains unclear whether taping restores normal scapulothoracic and scapulohumeral kinematics during various upper limb tasks. Based on our clinical assessment of patients with IS, we applied the same method for taping on both scapulae. Other methods of taping that attempt to realign the scapula in different directions may be applied. Furthermore, it remains unclear how long the observed changes would last given the cross-sectional nature of the study. Special training is required for tape application by the therapist. For the adolescents, we selected a weight with which they would produce a certain amount of effort and that they would be able to lift. Therefore, 4 kg was chosen for the bilateral weight lifting task to standardize the weight. We did not choose a weight proportional to the participant size as the demand may have varied between participants. However, testing on each side may illustrate unique kinematic differences. We may not generalize the findings to a broader population having IS with different age groups, curve magnitude, or curve pattern. This can be addressed in future studies in patients with IS of different age groups, curve patterns, and curve magnitudes.

In conclusion, the present study demonstrated that elastic scapular taping could change convex and concave side scapular orientations, thereby affecting upper extremity and trunk kinematics and increasing the dynamic stability of the scapulae to produce larger movement during functional activities. Generalizability may be limited as special training is required for tape application by the therapist. This knowledge may also encourage further studies to investigate therapeutic effects of such adjunctive treatment in short and long-term follow-ups in adolescents with IS.

Ethics Committee Approval: Ethics committee approval was received for this study from the Research Ethics Committee Hacettepe University (GO 16/80 -25).

Informed Consent: Written informed consent was obtained from the patients and parents of patients who participated in this study.

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References

1. Mottram SL. Dynamic stability of the scapula. Man Ther 1997; 2: 123-31. [CrossRef]
2. Panjabi MM. The stabilizing system of the spine. Part I. Function, dysfunction, adaptation, and enhancement. J Spinal Disord 1992; 5: 383-9. [CrossRef]
3. Bernstein NA. The Coordination and Regulation of Movements. Oxford: Pergamon Press; 1967.
4. Aizawa J, Masuda T, Koyama T, et al. Three-dimensional motion of the upper extremity joints during various activities of daily living. J Biomech 2010; 43: 2915-22. [CrossRef]
5. Lin Jj, Chen WH, Chen PQ, Tsao YJ. Alteration in shoulder kinematics and associated muscle activity in people with idiopathic scoliosis. Spine (Phila Pa 1976) 2010; 35: 1151-7. [CrossRef]
6. Menon VK, Tahasildar N, Pillay HM, Anbuselvam M. Axial plane deformity of the shoulder in adolescent idiopathic scoliosis. Clin Spine Surg 2017; 30: E351-7. [CrossRef]
7. Simoneau M, Richer N, Mercier P, Allard P, Teasdale N. Sensory deprivation and balance control in idiopathic scoliosis adolescent. Exp Brain Res 2006; 170: 576-82. [CrossRef]
8. Turgut E, Gur G, Ayhan C, Yakut Y, Baltaci G. Scapular kinematics in adolescent idiopathic scoliosis: A three-dimensional motion analysis during multilobar humeral elevation. J Biomech 2017; 61: 224-31. [CrossRef]
9. Magermans DJ, Chadwick EKJ, Veeger HEJ, Van Der Helm FCT. Requirements for upper extremity motions during activities of daily living. Clin Biomech 2005; 20: 591-9. [CrossRef]
10. Cools AM, Ellenbecker TS, Michener LA. Rehabilitation of scapular dyskinesis. Kibler W, Sciascia A, editors. Disorders of the Scapula and Their Role in Shoulder Injury. Cham: Springer; 2017. p. 179-92. [CrossRef]
11. Morris D, Jones D, Ryan H, Ryan CG. The clinical effects of Kinesio® Tex taping: A systematic review. Physiotherapy Theory Pract 2013; 29: 259-70. [CrossRef]
12. Russo SA, Zlotolow DA, Chafetz RS, Rodriguez LM, Kelly D, Linamen H, et al. Efficacy of 3 therapeutic taping configurations for children with brachial plexus birthalsy. J Hand Ther 2018; 31: 357-70. [CrossRef]
13. Van Herzeel M, van Cingel R, Maenhout A, De Mey K, Cools A. Does the application of kinesiotape change scapular kinematics in healthy female handball players? Int J Sports Med 2013; 34: 950-5. [CrossRef]
14. Lin Jj, Hung CJ, Yang PL. The effects of scapular taping on electromyographic muscle activity and proprioceptive feedback in healthy shoulders. J Orthop Res 2011; 29: 53-7. [CrossRef]
15. McConnell J, McIntosh B. The effect of tape on glenohumeral rotation range of motion in elite junior tennis players. Clin J Sport Med 2009; 19: 90-4. [CrossRef]
16. Turgut E, Ayhan C, Baltaci G. Repositioning the scapula with taping following distal radius fracture: Kinematic analysis using 3-dimensional motion system. J Hand Ther 2017; 30: 477-82. [CrossRef]
17. Hsu YH, Chen WY, Lin HC, Wang WTJ, Shih YF. The effects of taping on scapular kinematics and muscle performance in baseball players with shoulder impingement syndrome. J Electromyogr Kinesiol 2009; 19: 1092-9. [CrossRef]
18. Castro-Sánchez AM, Lara-Palomó IC, Matarán-Periárrrocha GA, Fernández-Sánchez M, Sánchez-Labraca N, Arroyo-Morales M. Kinesio Taping reduces disability and pain slightly in chronic non-specific low back pain: A randomised trial. J Physiother 2012; 58: 89-95. [CrossRef]
19. Wright IC, Neptune RR, van den Bogert AJ, Nigg BM. The influence of foot positioning on ankle sprains. J Biomech 2000; 33: 513-9. [CrossRef]

20. Cobb JR. Outline for the study of scoliosis. In AAOS, Instructional Course Lectures Volume 5; Edited by: Edwards JW. Ann Arbor 1948: 261-275.

21. Bunnell WP. Outcome of spinal screening. Spine 1993; 18: 1572-80. [CrossRef]

22. Turgut E, Pedersen Ø, Duzgun I, Baltaci G. Three-dimensional scapular kinematics during open and closed kinetic chain movements in asymptomatic and symptomatic subjects. J Biomech 2016; 49: 2770-7. [CrossRef]

23. Wu G, Van der Helm FCT, Veeger HEJD, et al. 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 2005; 38: 981-92. [CrossRef]

24. Lumbroso D, Ziv E, Vered E, Kalichman L. The effect of kinesio tape application on hamstring and gastrocnemius muscles in healthy young adults. J Bodywork Mov Ther 2014; 18: 130-8. [CrossRef]

25. Kase K. Clinical Therapeutic Applications of the Kinesio Taping Methods. Tokyo: Ken Ikai Co Ltd; 2003.

26. McClure PW, Michener LA, Sennett BJ, Karduna AR. Direct 3-dimensional measurement of scapular kinematics during dynamic movements in vivo. J Shoulder Elbow Surg 2001; 10: 269-77. [CrossRef]

27. Shaheen AF, Villa C, Lee YN, Bull AM, Alexander CM. Scapular taping alters kinematics in asymptomatic subjects. J Electromyogr Kinesiol 2013; 23: 326-33. [CrossRef]

28. Williams S, Whatman C, Hume PA, Sheerin K. Kinesio taping in treatment and prevention of sports injuries. Sports Med 2012; 42: 153-64. [CrossRef]

29. Keenan KA, Akins JS, Varnell M, et al. Kinesiology taping does not alter shoulder strength, shoulder proprioception, or scapular kinematics in healthy, physically active subjects and subjects with Subacromial Impingement Syndrome. Phys Ther Sport 2017; 24: 60-6. [CrossRef]

30. Halseth T, McChesney JW, Debeliso M, Vaughn R, Lien J. The effects of kinesio” taping on proprioception at the ankle. J Sports Sci Med 2004; 3: 1-7.

31. Haik MN, Alburquerque-Sendín F, Camargo PR. Reliability and minimal detectable change of 3-dimensional scapular orientation in individuals with and without shoulder impingement. J Orthop Sports Phys Ther 2014; 44: 341-9. [CrossRef]

32. Raso VJ, Lou E, Hill DL, Mahood JK, Moreau MJ, Durdle NG. Trunk distortion in adolescent idiopathic scoliosis. J Pediatr Orthop 1998; 18: 222-6. [CrossRef]