Article Title: The Effects of Rigid Scapular Taping on the Subacromial Space in Athletes With and Without Rotator Cuff Tendinopathy: A Randomized-Controlled Study

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Running Head: Scapular taping and subacromial space

ABSTRACT

**Context**: Reduction of the subacromial space (SAS) during arm elevation may contribute to rotator cuff tendinopathy. The effects of scapular taping on the SAS in athletes with and without RC tendinopathy is unknown. **Objectives**: To investigate the immediate effects of scapular taping on the SAS in athletes with and without RC tendinopathy. **Design**: Randomized-controlled with repeated measures. **Setting**: University laboratory. **Participants**: Forty-three male volleyball players (17 asymptomatic and 26 with RC tendinopathy, mean age = 22.9±3.5 years) participated in the study. **Intervention**: Three scapular taping protocols – no taping (control), taping with tension (therapeutic taping) and taping without tension (sham taping). Main Outcome Measures: Ultrasound measurements of the SAS with the arm at 0° and 60° of shoulder abduction, and the change in the SAS between 0° and 60° of shoulder abduction (SAS0°-60°) were calculated. **Results**: Athletes with RC tendinopathy demonstrated larger SAS with therapeutic taping at 60° of shoulder abduction (6.9±1.9 mm vs. 5.8±1.7 mm, mean difference = 1.1 mm, 95% CI = -1.80 – -0.39, p=0.002) when compared to the no taping condition. The tendinopathy group also showed less reduction in the SAS with therapeutic taping during SAS0°-60° (2.0±1.4 mm vs. 2.8±1.4 mm, p=0.023) when compared to the no taping condition. When tape was applied to the scapula in asymptomatic athletes, our results showed a relatively small increase in the SAS with therapeutic taping during arm resting at 0° of abduction when compared to the no taping condition (8.7±0.9 mm vs. 8.3±0.8 mm, mean difference = 0.4 mm, 95% CI = -0.71 – -0.11, p=0.008). **Conclusions**: Athletes with RC tendinopathy demonstrated less reduction of the SAS with rigid scapular taping during early arm abduction. Such observation was not evidenced in asymptomatic athletes.

**Key Words**: Scapular taping, subacromial space, athletes, rotator cuff tendinopathy

## 1. Introduction

Rotator cuff (RC) tendinopathy is considered to be the principal cause of shoulder pain in orthopaedics and sports medicine,1,2 particularly in athletes with repetitive overhead activities.3 It is an umbrella term that includes a spectrum of pathological changes ranging from tendinopathy to partial or complete tears that is related to rotator cuff tendons and associated tissues such as long head of the biceps tendinopathy, subacromial bursitis, and shoulder impingement syndrome.2 Clinical symptoms include pain, weakness and disability during arm elevation, and affects health and quality of life by limiting sports and physical activity. 2,4 The supraspinatus tendon runs in the subacromial space (SAS) and is most commonly affected by pathological changes.5-7 Reduction of the SAS during arm elevation has been proposed as one of the possible mechanisms in the aetiology of RC tendinopathy.7-10 Maintenance of the SAS during arm elevation is thus essential for the prevention and rehabilitation of RC tendinopathy. Scapular taping has been proposed as a strategy to achieve this goal.11,12

Scapular taping has been used for the prevention and management of shoulder injury in professional athletes. One of the proposed mechanism of scapular taping is to provide mechanical correction of scapular position. 12,13,14 Previous study has reported a mean increase in external rotation angles in people with shoulder impingement syndrome has been seen; 13 however, other study showed minimal change in upward rotation angles in athletes with RC tendinopathy after therapeutic taping.14 Another proposed mechanism of taping is to stimulate the neuromuscular pathways of the scapular muscles.12,14 To support this assumptions, evidence exists that the application of scapular taping induces earlier activation of the middle trapezius, lower trapezius and serratus anterior in athletes with RC tendinopathy;14 increase the activities of lower trapezius in patients with shoulder impingement syndrome;

15 and decrease the activities of the upper trapezius in patients with subacromial impingement syndrome. 16 Although previous studies have demonstrated a significant increase in the subacromial space after rigid17 and elastic tape18 applied to the scapula in healthy shoulders;17,18 whether scapular taping can provide adequate mechanical correction of the scapular position and/or stimulate the neuromuscular pathways of the scapular muscles to increase the SAS during arm elevation in patients with RC tendinopathy is unknown.19

The aims of the present study were to determine the immediate effects of scapular taping on the SAS at different arm positions in athletes with and without RC tendinopathy. We hypothesized that scapular taping would effectively increase SAS in overhead athletes with RC tendinopathy, but there would be no change in the SAS in asymptomatic athletes.

## 2. Methods

### Sample size

Sample size was calculated using G*Power 3.0 software, and a sample of at least 32 (16 study participants and 16 controls) would give a power of 95% to detect a difference in the subacromial space, with an alpha value of 0.05 and effect size of 0.67.

### Participants

Participants were male amateur volleyball players (18 – 35 years) playing or training for more than 3 years with at least three training sessions per week. They were recruited from local volleyball teams. Physical examination and ultrasound imaging were conducted by an experienced physiotherapist (with more than 7 years of musculoskeletal ultrasound scanning) to allocate the participants into the RC tendinopathy group or the asymptomatic group. As proposed

previously, 14,20 the inclusion criteria for the tendinopathy group consisted of (1) presence of shoulder pain during training for more than three months, (2) three out of five positive results for the following: painful arc, pain or weakness with resisted external rotation, Neer test, Hawkins Kennedy test and Jobe test. The intensity of pain being provoked should be ≥ 3/10 on a visual analogue scale (VAS) from 0 to 10, with 0 indicating no pain, and 10 indicating the worst pain, and (3) ultrasound image showed the presence of non-homogeneity/fibrillary disruption in the supraspinatus tendon. 20,21 The supraspinatus tendon was scanned by using an Aixplorer ® ultrasound scanner (V4; SuperSonic Imagine, Aix-en-Provence, France) coupled with a linear transducer array (4-15 MHz; SuperLinear 15-4, Vermon Tours, France). The participant was asked to place the palmar side of the hand on the superior aspect of the iliac crest, with the elbow flexed and directed posteriorly towards the midline. 6 The supraspinatus tendon was scanned in the transverse view and non-homogeneity/fibrillary disruption of the tendon is defined as a clear discontinuity or irregularity of collagen fascicle/fibrils.21 In the asymptomatic group, participants had no shoulder pain during training, and physical examination and ultrasound imaging showed no positive results. The exclusion criteria for all participants were previous shoulder fractures, instability or dislocation (positive apprehension and relocation tests), frozen shoulders, previous shoulder surgery or clinical treatment for a shoulder injury, ultrasound imaging showing the presence of full-thickness tear in the supraspinatus tendon, symptoms referred from or related to the spine, and a positive general laxity test (>5/9 Beighton Score).20 The study was approved by the Human Subjects Ethics Sub-committee of the administrative institution, and all participants gave their written informed consent before the study. All procedures adhered to the Declaration of Helsinki.

Taping protocol

Three taping conditions were tested in random order: (1) no taping (control), (2) taping without tension on tape (hereafter referred to as the sham taping condition), and (3) taping with standardized tension on tape (hereafter referred to as the therapeutic taping condition). A 3.8 cm piece of I-shaped rigid Leukotape adhesive tape was applied for conditions (2) and (3). With the participants in the sitting position, they were asked to fully extend their thoracic spine, with the scapula in full retraction and depression position. 14 As proposed previously,14,22 tape was applied from the infero-medial 1/3 of the clavicle, then firmly across the fibres of the upper trapezius muscle with full stretching of the tape to the thoracic spine at T12 (Figure 1). The rationale of this taping procotol is to provide mechanical correction of scapular position,13,14 and to restore the proper balance between the scapular muscles to enhance earlier activation and force production.14,15,22 Noted that the shortage of supporting evidence of using elastic taping on musculoskeletal conditions,23,24 rigid tape was used for the present study. To standardize the tension of the tape and the cutaneous stimulation on all participants, the other end of the tape was connected to a strain gauge transducer (Ronso Electronic, Hong Kong) with a digital force display unit. The researcher pulled on the strain gauge transducer until a force of 1.5–2 kg was displayed and at the same time the tape was applied to the skin. 14,25 The sham tape was applied in the same way but without any tension applied. The same researcher, experienced in the procedure, performed all the taping procedure.

Subacromial space measurement

After each of the taping conditions, the SAS was measured using the same ultrasound scanning system. Each participant was asked to sit upright on a stool with their head in the neutral position. The SAS was measured with the arm at 0°, and during static holding at 60° of shoulder abduction.10 Due to the constraint of the imaging technique, SAS measurements beyond 60° of

shoulder abduction were not possible.10,18,19 At 0° of arm abduction, the participant was asked to relax their arm with their forearm in pronation and resting on their thigh. During static arm abduction at 60°, the participant actively maintained their shoulder at the required abduction angle without flexion, elbow flexed at 90° and forearm in pronation for 10 seconds.10 The angle of shoulder abduction was measured by a goniometer (Sammons Preston, Royan, Canada). The SAS was measured by placing the transducer on the lateral surface of the shoulder along the longitudinal axis of the humerus.6 The shoulder was scanned in the longitudinal view by using B-mode ultrasound. The SAS was defined as the tangential distance between the humeral head and the infero-lateral edge of the acromion.5,10 Three measurements were performed in each arm position and taping condition, and a 1-minute rest was allowed between each measurement to avoid muscle fatigue. The second researcher was blinded to the subacromial space measurement and taping conditions during image capture. To ensure the blinding of the second research to the taping conditions, the stored images were randomized and were retrieved for off-line analysis after each session of experiment.

Using the same methodology as in previous study, 10 the intra-rater reliability of the SAS measurement was assessed in a pilot study with 20 healthy individuals. Intraclass correlation coefficient (ICC (3,1), two-way mixed effect model, consistency) for absolute agreement was performed to calculate the standard error of measurement [SEM = SD × √( 1 – ICC)] and minimal detectable change (MDC = 1.96 × SEM × √2). 26 The ICC values of the SAS measurement showed excellent reliability during arm at 0° (ICC = 0.90, 95%CI = 0.75-0.96, SEM = 0.04, MDC = 1.1 mm) and 60° of abduction (ICC = 0.94, 95% CI = 0.86-0.98, SEM = 0.04, MDC = 1.2 mm).

Statistical analysis

Distributions consistently passed the Shapiro-Wilk normality test (all $p>0.05$), and all values are reported as mean ± SD. Independent t test was conducted to compare the age, body weight, height, BMI, the number of years in volleyball training and training hours per week between the two groups (asymptomatic athletes and athletes with RC tendinopathy). Mixed-model ANOVAs were used to compare the effects of taping on the SAS at 0° and 60° of shoulder abduction, and the change in subacromial space during SAS0°-60° (within subject factors: taping condition; between-subject factor: group). Bonferroni post hoc tests were used for pairwise comparisons when significant main effects were observed. The statistical analyses were performed using SPSS Version 23 for Windows (SPSS Inc, Chicago, IL.) The level of significance for all tests was set at 0.05.

## 3. Results

There were a total of 43 volleyball players participated in this study. Twenty-six athletes (mean age = 23.6 ± 3.3 years, weight = 70.0 ± 9.0 kg, height = 178.6 ± 6.9 cm, BMI = 21.9 ± 2.1 kg/m2) reported pain or discomfort on the shoulder during training (mean VAS = 5.7/10 ± 1.2, duration of symptoms = 21.9 ± 17.1 months, training experience = 10.3 ± 3.3 years, training hours per week = 7.1 ± 2.9), and physical examination and ultrasound imaging confirmed the presence of RC tendinopathy. Seventeen asymptomatic athletes (mean age = 21.7 ± 3.5 years, weight = 69.6 ± 5.1 kg, height = 179.4 ± 6.0 cm, BMI = 21.7 ± 1.9 kg/m2) reported no pain or discomfort on the shoulder during training (training experience = 8.7 ± 3.7 years, training hours per week = 6.9 ± 2.2). They demonstrated negative clinical tests during physical examination as well as normal homogeneity on the supraspinatus tendon. No between-group difference was found for any of the tested parameters (all p values >0.08).

Table 1 showed the effects of tape on the SAS at different arm positions in athletes with and without RC tendinopathy. Significant main effect of tape on the SAS was found (F=7.149, df=1, p=0.011), but no significant taping condition x arm position interaction (F=2.188, df=1, p=0.147) and between-group difference on the SAS (F=0.005, df=1, p=0.942).

In athletes with RC tendinopathy, post hoc analysis showed the SAS was significantly larger with therapeutic taping at 60° of shoulder abduction when compared to the no taping condition (6.9±1.9 mm vs. 5.8±1.7 mm, mean difference = 1.1 mm, 95% CI = -1.80 – -0.39, p=0.002), and the change was greater than the MDC (Table 2). There was no significant difference in the SAS with sham taping condition at 60° of shoulder abduction when compared to therapeutic taping condition (p=0.070) and no taping condition (p=0.153) (Table 2). No significant effect of tape on the SAS at 0° of shoulder abduction was found (all p>0.085). When considering the change in subacromial space during SAS0-°60°, athletes with RC tendinopathy showed less reduction of the SAS with therapeutic taping when compared to the no taping condition (2.0±1.4 mm vs. 2.8±1.4 mm, mean difference = 0.8 mm, 95% CI = 0.09 – 1.50, p=0.023). No significant difference was found between therapeutic taping and sham taping (p=0.276) and between sham taping no taping condition (p=0.261) (Table 2).

In the asymptomatic athletes, the SAS was significantly larger with therapeutic taping at 0° of shoulder abduction (8.7±0.9 mm vs. 8.3±0.8 mm, mean difference = 0.4 mm, 95% CI = - 0.71 – -0.11, p=0.008) when compared to the no taping conditions, and the change was smaller than the MDC (Table 2). No significant difference was found between therapeutic taping and sham taping (p=1.0) and between sham taping and no taping condition (p=0.151). No significant effect of tape on the SAS at 60° of shoulder abduction and the change in subacromial space during SAS0°- 60° was found (all p>0.096).

## 4. Discussion

Therapeutic taping applied to the scapula showed no effect on the SAS during arm resting at 0° of shoulder abduction in athletes with rotator cuff tendinopathy. Our findings showed less reduction of the SAS with therapeutic taping during active shoulder abduction from 0° to 60° in athletes with RC tendinopathy.

To our knowledge, this was the first study to investigate the effectiveness of therapeutic taping on the SAS using rigid tape applied to the scapula in athletes with RC tendinopathy. Our findings showed no taping effect on the SAS during arm resting position at 0° of abduction in the presence of therapeutic tape in athletes with RC tendinopathy. Previous studies showed a negative relationship between the SAS and scapular protraction27 and an association between increased SAS and manual upward rotation and posterior tilting of the scapula.28 In contradiction to our hypothesis, a piece of rigid tape applied to the scapula may not provide adequate mechanical correction of the scapula position and result in no change in the SAS during arm resting at 0° of abduction.

Interestingly, our findings showed an increase in the SAS at 60° of shoulder abduction after therapeutic taping in athletes with RC tendinopathy. During active arm abduction, the rotator cuff and scapular muscles play important role in the control of the SAS. 6,7,10,20 Scapular muscles deficit has been reported in people with RC tendinopathy,10,20,29,30 and was associated with alterations in scapular kinematics20,29,30 and reduction of SAS during arm elevation. 10,31,32 In addition, significant reduction of the SAS was found in elite tennis players with scapular dyskinesis when compared to players without dyskinesis.33 Thus, we calculated the change in the SAS between 0° and 60° of shoulder abduction to indicate the control of the

SAS during active arm abduction. 10 Our findings showed less reduction in the SAS during arm abduction from 0° to 60°after therapeutic taping in athletes with RC tendinopathy, which may indicate a better control in the SAS during active arm abduction in athletes with RC tendinopathy. The possible mechanism for the observed changes in SAS after therapeutic taping could be via cutaneous stimulation.12,34,35 To support this assumption, Leong et al.,14 reported an earlier activation of the scapular muscles during arm abduction in athletes with rotator cuff tendinopathy after scapular taping, and Selkowitz et al.15 also showed an increase in the activities of lower trapezius during arm elevation in people with RC tendinopathy after scapular taping. In this way, therapeutic taping may enhance the neuromotor control of the scapular muscles for better control of the scapula and preserving the SAS during arm abduction. Nevertheless, there was no significant difference in the SAS during arm abduction after sham taping, suggesting that taping with no tension may not provide adequate mechanical support and proprioceptive input for the control of the scapula to preserve the SAS during arm elevation in athletes with RC tendinopathy.

When tape was applied to the scapula in asymptomatic athletes, our results showed a relatively small increase in the SAS during arm resting at 0° and 60° of abduction after therapeutic taping. These changes were smaller than the MDC which may due to measurement error. One possible reason may be that a piece of rigid tape applied to the scapula in healthy athletes could not provide additional mechanical support for the scapula and resulted in no change in the SAS during arm resting at 0° of abduction. Our results were similar with a previous study showing a small increase in subacromial space in asymptomatic shoulders with a piece of rigid tape applied to the scapula at 60° of passive shoulder abduction. 17 In addition, our results showed no difference in the change in the SAS between 0° and 60° of abduction among the three taping

conditions. This may be due to healthy athletes having no pre-existing muscles deficit in the control of the SAS, resulting in no change in the SAS between 0° and 60° of abduction after scapular taping. This is in line with previous studies showing no added benefit of taping in asymptomatic individuals.22,36 Whether taping applied to the scapula in asymptomatic athletes is worthwhile for the prevention of RC tendinopathy is unknown and warrants further investigation in the form of a longitudinal study.

There were limitations in the present study that need to be considered. (1) The SAS was measured with the shoulder abducted at 0° and 60° because recent work showed that athletes with rotator cuff tendinopathy exhibit more reduction of the SAS during early phase of shoulder abduction than healthy athletes, and that this reduction in the SAS is associated with weakness of the scapular muscle.10 (2) In the present study, most of the athletes with shoulder pathology suffered mild tendinopathy with pain occurred after their practice and they did not have pain at all tested positions, and half of the study sample were control athletes with no pathology. Whether taping can reduce pain in athletes with RC tendinopathy during practice and those with severe tendinopathy warrants further investigation. (3) This study only investigated the immediate effects of scapular taping on SAS; the long-term effects of taping or after exercise were not investigated and this warrants future studies to reflect the functional need of taping during training and competition.

## 5. Conclusions

Therapeutic taping of the scapula can effectively increase the SAS in athletes with RC tendinopathy at 60° of shoulder abduction. Athletes with RC tendinopathy also demonstrated less reduction of the SAS with therapeutic taping during early arm abduction from 0° to 60°. Such

observation was not evidenced in asymptomatic athletes. Whether taping applied to the scapula in asymptomatic athletes is worthwhile for the prevention of RC tendinopathy is unknown and warrants further investigation.

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Table 1 Mean ± SD of the effects of tape on the subacromial space at 0° (SAS0°) and 60° of shoulder abduction (SAS60°), and the change in subacromial space during SAS0°-60° in athletes with and without rotator cuff (RC) tendinopathy.

| Variables (mm) | Athletes with RC tendinopathy | | | Asymptomatic athletes | | |
|---|---|---|---|---|---|---|
| | No taping | Therapeutic taping | Sham taping | No taping | Therapeutic taping | Sham taping |
| $SAS_{0°}$ | 8.7±1.1 | 9.0±1.2 | 8.8±1.2 | 8.3±0.8 | 8.7±0.9 | 8.6±0.9 |
| $SAS_{60°}$ | 5.8±1.7 | 6.9±1.9 | 6.3±1.5 | 6.2±1.4 | 7.2±2.1 | 7.2±1.5 |
| $SAS_{0-°60°}$ | 2.8±1.4 | 2.0±1.4 | 2.5±1.4 | 2.2±1.5 | 1.9±1.6 | 1.9±1.3 |

Table 1 Multiple comparison between taping protocol

| Variables | Taping protocol comparison | Athletes with RC tendinopathy | | | Asymptomatic athletes | | |
|---|---|---|---|---|---|---|---|
| | | Mean difference | 95% CI | *p* | Mean difference | 95% CI | *p* |
| $SAS_{0°}$ | No taping vs. therapeutic taping | -0.30 | -0.62 – 0.03 | 0.085 | -0.41 | -0.71 – -0.11 | 0.008* |
| | No taping vs. sham taping | -0.13 | -0.46 – 0.21 | 1.000 | -0.30 | -0.68 – 0.08 | 0.151 |
| | Therapeutic taping vs. sham taping | 0.17 | -0.15 – 0.49 | 0.570 | 0.11 | -0.27- 0.49 | 1.000 |
| $SAS_{60°}$ | No taping vs. therapeutic taping | -1.09 | -1.80 – -0.39 | 0.002* | -0.68 | -1.44 – 0.09 | 0.096 |
| | No taping vs. sham taping | -0.44 | -0.99 – 0.11 | 0.153 | -0.77 | -1.74 – 0.20 | 0.149 |
| | Therapeutic taping vs. sham taping | 0.65 | -0.04 – 1.35 | 0.070 | -0.09 | -0.92 – 0.73 | 1.000 |
| $SAS_{0°-60°}$ | No taping vs. therapeutic taping | 0.80 | 0.09 – 1.50 | 0.023* | 0.19 | -0.63 – 1.02 | 1.000 |
| | No taping vs. sham taping | 0.31 | -0.14 – 0.76 | 0.261 | 0.21 | -0.78 – 1.21 | 1.000 |
| | Therapeutic taping vs. sham taping | -0.48 | -1.19 – 0.23 | 0.276 | 0.02 | -1.00 – 1.04 | 1.000 |

*$p<0.05$

RC: rotator cuff; SAS: subacromial space; CI: confidence interval

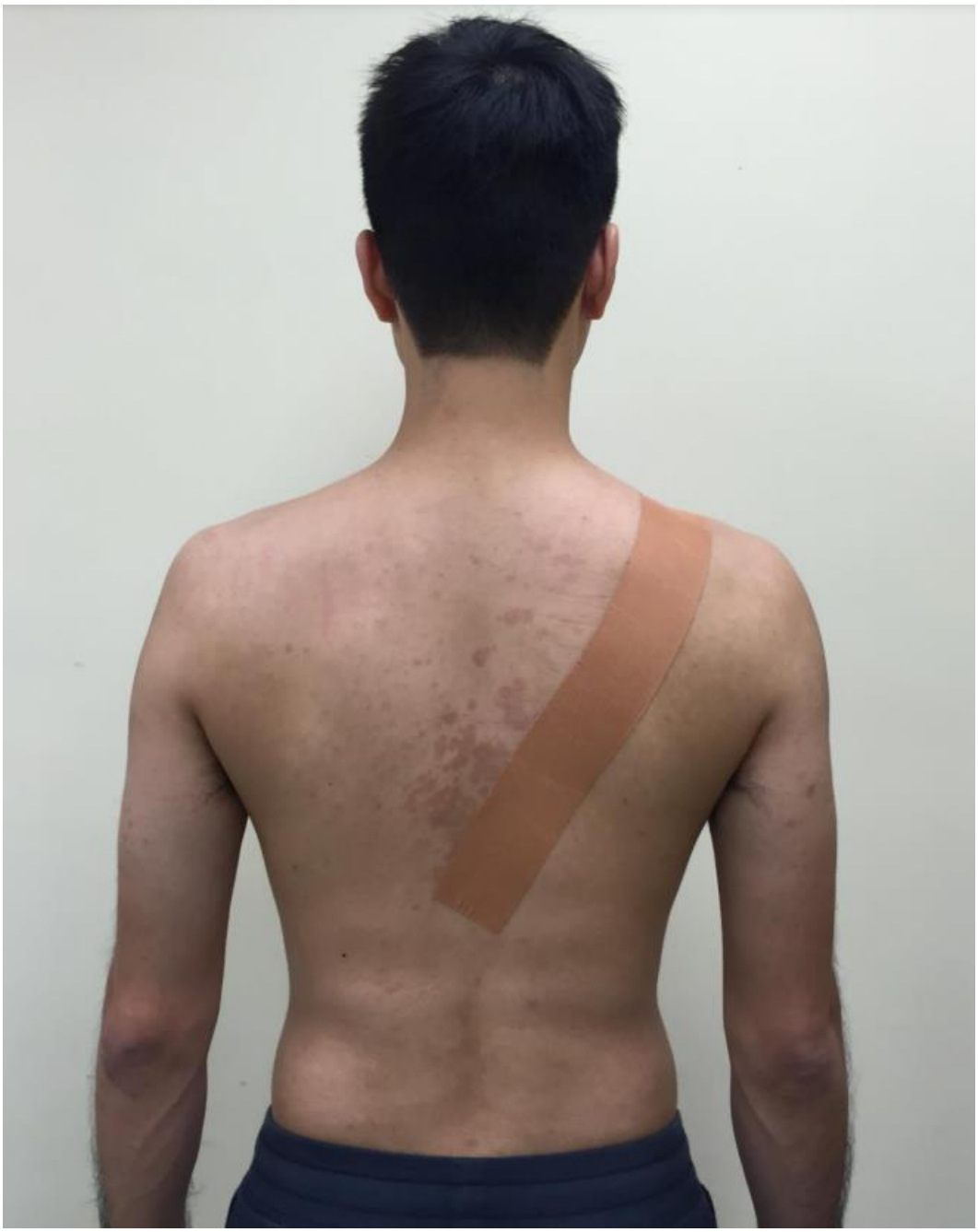

Figure 1. Scapular taping. A 3.8 cm piece of I-shaped rigid Leukotape tape was used. Tape was applied starting from the inferior margin of the medial 1/3 of the clavicle to thoracic spine at T12.