Kinesiotaping as an adjunct to exercise therapy for symptomatic and asymptomatic swimmers: A randomized controlled trial

Short Title: Kinesiotaping as an adjunct to exercise therapy for swimmers

Le kinesio-taping comme complément de la thérapie par l'exercice chez des nageurs symptomatiques et asymptomatiques : Un essai randomisé contrôlé.

Aynollah Naderi[1]*, PhD, Seyed Hamed Mousavi[2,3], MS, Wendy B. Katzman[4] DPTSc, Komeil Dashti Rostami[5] PhD, Shahrbanoo Goli[6] PhD, Mohammad Hossein Rezvani[1] PhD, & Hans Degens[7,8,9] PhD

1. Department of Health and Corrective Exercise, School of Sport Sciences, Shahrood University of Technology, Shahrood, Semnan, Iran.
2. Department of Sports and Exercise Medicine, University of Groningen, Groningen, Netherlands; University of Tehran.
3. Department of Sports Medicine and Health, Faculty of Physical Education and Sports Sciences, Tehran, Iran.
4. Department of Physical Therapy and Rehabilitation Science, University of California, San Francisco, San Francisco, CA,US.
5. Department of biomechanics, Faculty of Physical Education and Sports Sciences, University of Mazandaran, Mazandaran, Babolsar, Iran.
6. Department of Biostatistics, Shahroud University of Medical Sciences, Shahroud, Semnan, Iran.
7. School of Healthcare Science; Manchester Metropolitan University, UK.
8. Institute of Sport Science & Innovations, Lithuanian Sports University, Lithuania.
9. University of Medicine & Pharmacy of Targu Mures, Rumania

*, **Corresponding author**

Aynollah Naderi, PhD

School of Sport Sciences,

Shahrood University of Technology, Shahrood, Semnan, Iran

E-mail: ay.naderi@shahroodut.ac.ir.

Tel:+9832392204.

P.O.B: 3619995161.

Compliance with ethical standards

Declarations of interest The authors declare that they have no conflict of interest relating to the material presented in this article.

Ethical approval All procedures performed were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was reviewed and approved by the Research Ethics Committee of the Shahroud University of Medical Sciences and registered with the Iran Registry of Clinical Trials (IRCT20170114031942N3).

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Summary

Objectives: Kinesiotaping is widely used in sport injury prevention and treatment, and sports performance improvement; however, there is insufficient evidence of its effectiveness. The purpose of this randomized trial was to determine if short- and long-term treatment with exercise combined with kinesiotaping results in better outcomes on static and dynamic posture in symptomatic and asymptomatic swimmers with forward-head, forward-shoulder posture than exercise alone.

Material and Methods: Fifty-two 11- to 25-year-old competitive swimmers were randomly assigned to an exercise combined with kinesiotaping group (n=26) and exercise-only group (n=26). Both groups received a 10-week exercise intervention targeting shoulder and thoracic mobility, upper back and shoulder strength with or without kinesiotaping following each exercise session. Static and dynamic posture including pectoralis minor length, scapular anterior tilting index, scapular upward rotation, and glenohumeral internal and external rotation were measured at baseline, after one session (short-term), and after the 10-week intervention (long-term).

Results: Results from our study show that exercise combined with kinesiotaping resulted in immediate decrease forward-head angle (Cohen d=0.84) and forward-shoulder angle (Cohen d=1.37) and increase in dynamic posture including pectoralis minor length (Cohen d=0.63), glenohumeral internal rotation (Cohen d=0.91), total glenohumeral rotation (Cohen d=0.91), scapular anterior tilting index (Cohen d=0.48), scapular upward rotation 0-60° (Cohen d=0.56), and 60-120° (Cohen d=0.62). In addition, exercise combined with kinesiotaping relative to exercise-only did not have better effects after 10-week intervention for dynamic and static posture ($p>0.05$), but it may be a good choice to improve pain, dynamic and static posture in swimmers in the short-term ($p\leq0.05$).

Conclusion: Adding KT to exercise intervention may be a good choice to improve static and dynamic posture, and pain relief, in the short- but not in the long-term.

Keywords: swimming injury; swimmer’s shoulder; pectoralis minor length; Glenohumeral internal and external-rotation; scapular tilting

Résumé

Objectifs : Le kinesio-taping (KT) est largement utilisé pour la prévention et le traitement des blessures sportives et l'amélioration des performances ; cependant, les preuves de son efficacité demeurent insuffisantes. Le but de cet essai randomisé était de déterminer si un traitement à court et à long terme avec de l'exercice combiné au KT par rapport à l'exercice seul aboutissait à de meilleurs résultats sur la posture statique et dynamique chez les nageurs symptomatiques et asymptomatiques avec une posture en projection de la tête et enroulement des épaules.

Matériels et méthodes : Cinquante-deux nageurs de compétition âgés de 11 à 25 ans ont été assignés au hasard à un exercice combiné avec KT groupe (n = 26) et un seul d'exercice groupe (n = 26). Les deux groupes ont reçu une intervention d'exercice de 10 semaines ciblant la mobilité de l'épaule et du thorax, la force du haut du dos et des épaules avec ou sans KT avec chaque séance d'exercice. La posture statique et dynamique, y compris la longueur du petit pectoral, l'indice de la bascule antérieure de scapula, la rotation latérale de scapula et la rotation interne et externe de l'articulation gléno-humérale ont été mesurées au début, après une séance (à court terme) et après l'intervention de 10 semaines (à long terme).

Résultats: Les résultats de notre étude montrent que l'exercice combiné au KT a entraîné une diminution immédiate de l'angle de antéprojection de la tête (Cohen d = 0,84) et de l'angle de antéprojection de épaules (Cohen d = 1,37), et une amélioration de la posture dynamique, y compris la longueur du petit pectoral (Cohen d = 0,63), la rotation médiale de la gléno-humérale (Cohen d = 0,91), la rotation totale de la gléno-humérale (Cohen d = 0,91), l'indice de la bascule antérieure de la scapula (Cohen d = 0,48), la rotation latérale de la scapula 0-60◦ (Cohen d = 0,56) et 60 -120◦ (Cohen d = 0,62). L'exercice combiné au KT par rapport à l'exercice unique n'a pas eu de meilleurs effets après une intervention de 10 semaines pour la posture dynamique et statique ($p > 0,05$), mais il peut être un bon choix pour améliorer la douleur, la posture dynamique et statique chez les nageurs à court terme ($p \leq 0.05$).

Conclusion : Ajout de KT à l'intervention d'exercice peut être un bon choix pour améliorer la posture statique et dynamique, et le soulagement de la douleur à court terme mais pas à long terme.

Mots-clés: Blessure en natation; épaule du nageur; longueur du petit pectoral; rotation médiale de l'articulation gléno-humérale; bascule antérieure de la scapula

1. Introduction

Competitive swimmers swim up to 12,000 meters per day, 6 to 7 days per week, and sometimes twice per day during the competition preparation period [1]. They have approximately 16,000 shoulder revolutions per week or 2500 shoulder strokes in a day's practice [1,2]. Many of these shoulder movements are performed without any rest for muscle recovery. This high volume of exercise can cause upper body postural adaptations and lead to "swimmer's shoulder ", a general term for overuse injuries in swimmer athletes [3].

The prevalence of swimmer's shoulder can be as high as 55% in competitive swimmers [4] and causes a reduction or cessation of sports activities in 35% of cases[1]. Given the high prevalence of swimmer's shoulder, it is not surprising that 85% of young competitive swimmers consider mild shoulder pain as normal, and 72% of swimmers use analgesic drugs to continue swimming [3]. While pain may be alleviated, these injuries can cause long periods of compulsory rest when not properly cared for [5].

Swimmers often have a forward-head, forward-shoulder posture (FH-FSP) [3] that can affect glenohumeral range of motion (ROM), scapular kinematics and result in dynamic narrowing of the subacromial-space, a common characteristic of swimmer's shoulder [3,6]. As these postural and kinematic changes may initially be asymptomatic [6], they can cause pain and overuse injury making early detection an important priority in preventing injuries.

Although kinesiotaping (KT) is widely used in sport injury prevention and treatment for FH-FSP, [7-9], there is insufficient evidence of its effectiveness [10]. Most studies on KT suffer from a high risk of bias, considered KT as an isolated treatment method and/or investigated the immediate or short-term effects of KT only [9,11,12]. No studies to our knowledge have investigated the effectiveness of a combined KT and exercise program in swimmers with FH-FSP. Pain or fear of pain exacerbation (kinesiophobia) can cause participants to leave an exercise intervention [13] or incorrectly perform the exercise [14]. Therefore, early relief of pain by KT [15,16] may theoretically help to improve the efficacy of an exercise training program on static and dynamic posture.

The purpose of this study was to investigate short- and long-term effects of exercise training in combination with KT (E-KT) on static and dynamic posture in symptomatic and asymptomatic swimmers with FH-FSP. We hypothesized that E-KT results in greater improvements in static and dynamic posture and pain relief than exercise alone.

2. Methods

2.1. Study Design and Setting

This 10-week two-arm, parallel-group, randomized controlled trial stratified by presence of pain was conducted in a university-based exercise research lab.

2.2. Participants

Using effect sizes from previous studies on swimmers [6], we calculated (G*Power3.1.2: Heinrich Heine University, Düsseldorf, Germany) that 22 participants in each group were needed for an effect size of f=0.26, 2-tailed significance level (α) of 0.05 and desired power (1-β) of 0.85. With an anticipated drop-out rate of 20%, we enrolled 26 participants in each group.

Competitive male swimmers (11-25 years) with FH-FSP were recruited from January 2018 to March 2018 with flyers and posters at public and local university pools throughout **Blind**. Following the initial postural screening, 52 male swimmers with FH-FSP (26 with and 26 without shoulder pain) were included in the study.

Inclusion criteria for both pain-free swimmers and swimmers with pain were: FHP (≥46°) and FSP (≥52°) [17], and the ability to complete all procedures. Swimmers with either unilateral or bilateral shoulder pain were accepted with at least one-month self-reported shoulder pain ≥40 out of 100 on the visual analogue scale (VAS) during activity. Exclusion criteria were: fracture history; surgery and/or arthritis in upper extremity, shoulder girdle or/and spinal column; full thickness tear of the rotator cuff; cervical radiculopathy; shoulder instability; systemic musculoskeletal disease; structural chest deformity; hyper-kyphosis or scoliosis; severe pain during assessments; tape application contraindications based on tape comfort questionnaire [11].

This study was approved by the Institutional Review Board of **X** and performed in accordance with the Declaration of Helsinki. All participants provided written informed consent.

2.3. Randomization

An independent blinded colleague with no further involvement in the study used a computer-generated block randomization design (block size of 2, 4; Random Allocation Software 2.0) stratified by pain to ensure an equal number of swimmers with and without pain in each group. Group allocation was concealed in sealed envelopes that were opened after completion of baseline assessments. A sport science specialist providing exercise training, a physical therapist providing KT, and a laboratory specialist performing the measurements were not blinded to group allocation, but the investigator analyzing the data was blind to group allocation.

2.4. Interventions

All participants attended an exercise program led by the sport science specialist for 45-70 min, 3 sessions per week for 10 weeks. Participants in the E-KT group and exercise group received KT and sham KT, respectively, by the same physical therapist after each exercise session. The same sport science specialist conducted all exercise classes to ensure consistent instructions and supervision of the exercises.

Exercise intervention protocol: The exercise intervention was based on interventions for FH-FSP postural malalignments in previous studies [6,8] including stretching (4 exercises) and strengthening (4 exercises) exercises. The strengthening exercises targeted the scapular stabilizers, thoracic spine extensor and shoulder external rotators, and the stretching exercises aimed to increase the flexibility of the pectoral and shoulder internal rotator muscles, and glenohumeral capsule and underlying soft tissues.

The intensity of exercise progressed through increased load (increasingly stiff TheraBand, and from 40% to 85% 1RM of free weight), sets (from 3 to 4) and reps (from 6 to 12 repetitions) in the isotonic strengthening exercises, and hold time (from 20 s to 30 s) and reps (from 4 to 10 repetitions) in the stretching exercises as long as participants were able to demonstrate good-quality movement. Participants advanced level of resistance with TheraBand once they could complete 4 sets of 12 repetitions for 1 week without increasing symptoms. The intensity of the exercise program was prescribed on an individual basis and progressed from moderate (12 to 14 score) to high (14 to 16 score) using the rate of perceived exertion of the Borg scale. [18]

Insert table 1 here

Kinesiotape (Kinesio Tex Tape; Kinesio Holding Corporation, Albuquerque, NM) has a stress of 0.53 MPa at 25% elongation [19], is waterproof, porous, adhesive, and with a width of 5 cm and thickness of 0.5 mm. First, two KT strips were used for mechanical correction with 50-100% stress, according to comfort. Subjects retracted and depressed their scapula and tape was applied from the anterior aspect of the acromioclavicular joint to the T_{12} spinous process in a diagonal fashion [20]. Y-shaped, light (15–25%) tension KT strip was applied to the deltoid muscle from insertion (3 cm below the deltoid tuberosity) to origin [15]. Another Y-shaped, light (15–25%) tension KT strip was applied to the supraspinatus muscle following the borders of the muscle belly. Participants adducted the shoulder with lateral neck flexion to the opposite side, and tape was applied from its insertion (below the greater tuberosity of the humerus) to the origin (spinous process of the scapula). KT strips were removed prior to, and new strips reapplied after, each session. The sham tape (an untensioned tape) was applied in the same way but without any tension for exercise group participants. Participants kept the KT in place until the next session or a minimum of 72 hours.

2.5.Measurements

Measurements were performed at first day before receiving intervention and without taping, after the first session as a short-term effect, and after the last session of the 10-week intervention as a long-term effect. During the baseline visit, while participants wore light clothing, height and body mass were measured and body mass index (kg/m^2) was calculated. The symptomatic shoulder in participants with unilateral shoulder pain and the dominant side in participants with bilateral shoulder pain was evaluated. The dominant side was identified using writing hand. Measurements were performed in random order for each outcome (mean of three trials was recorded) following a warm-up to prevent injury. The short- term measurement was performed 45 minutes after taping to ensure tape adhesion. Furthermore, 10 week measures were performed with the tape on.

Forward-head, forward-shoulder posture (FH-FSP) was assessed using a digitized, side-view photograph taken in a relaxed-standing posture. First, tragus and acromion anterior tip were marked with an adhesive dot, and a spherical pointer was taped to the skin overlying the C7 vertebra. Following a warm-up of 3 overhead squats, a side-view photograph was obtained and Adobe AutoCAD 2010 used to calculate forward head angle (FHA) and forward shoulder angle (FSA).

Resting pectoralis minor length (PML) was measured with 1-mm resolution in a relaxed-standing posture. First, the caudal edge of the fourth rib at the sternum and the medial-inferior aspect of the coracoid process were marked. Next, the distance between these landmarks was measured upon complete exhalation. PML index, a measure of the relative length of pectoralis minor was calculated from the average of three trials as: PML = 100* PM length (cm)/subject height (cm), where PM is the pectoralis minor.

Glenohumeral internal- (GHIR) and external-rotation (GHER) ROM were measured at end range with an ACUMAR™ digital inclinometer (Model ACU 360), placed on the distal forearm, with the participant supine and shoulder abducted to 90°, elbow flexed to 90°[21], and the wrist in neutral. A towel was used as needed to align the upper arm in the frontal plane; which required the humerus to be level to the acromion process based on visual inspection. Scapular stabilization was provided by the examiner. The limb was actively rotated by participant to end range, the point at which the scapula began to move on the stabilizing hand, while a research assistant recorded the rotation angles as a 3-trial mean.

Scapular upward-rotation (SAR) was measured with an ACUMAR™ digital inclinometer according to the method described by Johnson et al [22]. Measurements were taken at rest position and at 60°, and 120° arm elevation. Subjects elevated their arm in the scapular plane (using the wall as guide against the dorsal side of the hand) with the thumb pointed toward the ceiling throughout the testing procedure. The order of angle measurements was randomized before each test session. Upon arm elevation, the subject was instructed to hold the position while the inclinometer locator rods were positioned over the scapular spine (posterior-lateral acromion and the root of the scapular spine), and scapular upward rotation was measured as the angle between the scapular spine and the horizontal reference. After each trial of arm elevation, a rest period of approximately 30 to 50s was given to minimize fatigue. Three trials were taken at each angle, and the mean was recorded for analysis.

Scapular anterior tilting index (SATI) was 100 times the distance between the posterior border of the acromion and the table in the relaxed supine position divided by height [23].

Pain intensity at rest, during activity and at night were measured on a VAS ranging from 0 (no pain) to 100 (worst possible pain) [24].

2.6.Adverse events

Adverse events were recorded weekly by someone not otherwise involved in the study. An adverse event was defined as short-to-long-term, and manifested as serious, distressing, uncomfortable, and/or an unacceptable symptom.

2.7.Statistical analysis

SPSS statistical software (version 18.0, SPSS Inc., Chicago, IL, USA) was used for statistical analyses. The Shapiro-Wilk test showed that all data were normally distributed. A repeated-measures ANOVA with time as within factor (baseline, short- term, and long-term after interventions), group (EG vs. E-KTG) and pain (with pain vs. without pain) as between factors was used to evaluate the main effects and interactions between variables. Three-way interactions were excluded from the analysis. To locate significant differences ($p \leq 0.05$), paired t tests for multiple comparisons were conducted where appropriate. The effect size of the training gains was given by Cohen's *d* (≤0.19, 0.20-0.49, 0.50-0.79, and ≥0.80 representing trivial, small, medium, and large effects).

3. Results

In the text below, main effects and interactions are discussed only when significant. Participant characteristics data were presented in Table 2. Two-way ANOVA showed a significant main effect of pain for weight ($F_{1,46}$=10.0; p=0.002; n_p^2=0.19), height ($F_{1,46}$=9.1; p=0.003; n_p^2=0.17), age ($F_{1,46}$=5.4; p=0.03; n_p^2=0.10), sports history ($F_{1,46}$=12.2; p=0.001; n_p^2=0.20) and practice session per week ($F_{1,46}$=9.0; p=0.01; n_p^2=0.16). There were no significant main effects of group and group × pain interactions for any of the parameters (p>0.05) (Table 2 and Figure 1).

Insert table 2 and figure 1 here

The data for the static and dynamic variables in each group and time point are given in Table 3 and the statistical analysis is summarized in Table 4. Regarding static and dynamic variables, the absence of a significant group × pain and time × pain interactions for all parameters (p>0.05) indicates that the interventions had similar effects in swimmers with and without shoulder pain.

Insert table 3 and table 4 here

3.1. Forward Head -Forward Shoulder Posture

A significant time × group interaction was found for FHP angle ($F_{2,96}$ =10.5; p=0.001) (Table 4). A post-hoc t test revealed a decrease in the FHP angle from baseline to short term for E-KTG, but not for EG. A significant main effect of time for FHP ($F_{2,96}$ =91; p=0.001) was reflected by a similar decrease in FHP angle at the end of the interventions in EG and E-KTG.

A significant time × group interaction was found for FSP angle ($F_{2,96}$ =15.1; p=0.001) (Table 4). A post-hoc t test revealed a decrease in the FSP angle from baseline to short-term for E-KTG, but not for EG. A significant main effect of time for FSP ($F_{2,96}$ =95; p=0.001) was reflected by a similar decrease in FSP at the end of the interventions in EG and E-KTG.

3.2.Resting pectoralis minor length

A significant time × group interaction was found for PML ($F_{2,96}$ =5.9; p=0.004) (Table 4). A post-hoc t test revealed an increase in the PMI from baseline to short term for E-KTG, but not for EG. A significant main effect of time for the PML ($F_{2,96}$ =74.2; p=0.001) was reflected by a similar increase in PML at the end of the interventions in EG and E-KTG.

3.3.Glenohumeral internal, external, and total ROM

A significant time × group interaction was found for GHIR ($F_{2,96}$ =4.2; p=0.02) but not for GHER and TGHR ($F_{2,96}$ =0.1; p=0.9 and $F_{2,96}$ =2.0; p=0.1; respectively) (Table 4). Post-hoc analyses revealed an increase in the GHIR ROM from baseline to short term for E-KTG, but not for the EG. The absence of interactions for GHER and TGHR indicates that the improvement over time for EG and E-KTG were similar at the baseline, short- term, and at the end of the interventions.

3.4. Scapular Anterior Tilt

A significant time × group interaction was found for SATI ($F_{2,96}$ =13.2; p=0.001) (Table 4). A post-hoc t test revealed an increase in the SATI from baseline to short term for the E-KTG, but not for the EG. A significant main effect of time for SATI ($F_{2,96}$ =52.9; p=0.001) was reflected by a similar increase in SATI at the end of the interventions in EG and E-KTG.

3.5.Scapular Upward Rotation

A significant time × group interaction was found for 0° to 60° and 60° to 120° SUR ($F_{2,96}$ =6.3; p=0.01 and $F_{2,96}$ =3.4; p=0.03; respectively) (Table 4). Post-hoc t test analyses revealed a significant increase in the 0° to 60° and 60° to 120° SUR from baseline to short term for E-KTG, but not for the EG. A significant main effect of time for 0° to 60° and 60° to 120° SUR ($F_{2,96}$ =48.4; p=0.001 and $F_{2,96}$ =42.8; p=0.001; respectively) was reflected by similar increases in SUR at the end of the intervention in the EG and E-KTG.

3.6.Pain intensity

A significant time × group interaction was found for pain at rest ($F_{2,48}$ =10.4; p=0.001), during activity ($F_{2,48}$ =13.8; p=0.001) and at night ($F_{2,48}$ =16.1; p=0.001). Post-hoc t tests revealed a significant decrease in the pain from baseline to short term for E-KTG, but not for the EG, indicating a decrease in the pain immediately after the E-KT intervention. A significant main effect of time for pain at rest ($F_{2,48}$ =25.2; p=0.001), during activity ($F_{2,48}$ =21.2; p=0.001), and at night ($F_{2,48}$ =14.1; p=0.001) reflected a similar decrease in pain at the end of the intervention in EG and E-KTG.

3.7.Adverse events

Four swimmers reported minor side effects (short-term, mild, non-serious, transient and reversible consequences of the interventions); two participants in the EG and one in the E-KTG experienced an increase in shoulder pain or soreness following exercise and one person in the E-KTG reported skin irritation related to tape application. These symptoms resolved within 24 hours.

4. Discussion

The main observation of the present study was that exercise combined with KT improved static and dynamic posture and reduced shoulder pain immediately for FH-FSP swimmers compared to exercise alone. However, adding KT to the exercise did not enhance the benefits of a 10-week exercise intervention for static and dynamic posture of swimmers.

Several factors were associated with shoulder pain including swimmer height and body mass, and volume of swim sessions. It is possible that greater torque is applied by the rotator cuff muscles during each stroke in taller participants because of a longer lever arm and larger weight that in turn may accelerate the development of muscle fatigue and subsequent pathological processes such as rotator cuff impingement from repetitive upper extremity movement above shoulder level, a risk factor for shoulder pain [25,26], it is not surprising that those with a greater number of swim sessions per week have pain, as reported in previous studies [25]. It is plausible that with higher volume of swimming, the supraspinatus tendon may become thicker, increasing the risk of impingement and in turn shoulder pain [26].

We found decreased FHP and FSP and increased length of the pectoralis minor muscle immediately after applying E-KT, demonstrating that KT improved static posture. Previous studies showed that KT can decrease FHP and FSP in computer users[27] and sedentary workers [20,28]. The KT-induced improvement of posture may be due to its passive mechanical effects and/or the active support of muscles maintaining posture. Although we cannot confirm active support, previous studies confirmed such an effect of KT [9] via enhancing postural awareness, motor control and thereby improved posture [29,30]. In addition, a previous study provide evidence that it is association between FHP and RSP, and thoracic kyphosis [31], accordingly these postural changes that were observed immediately following the KT can be caused by the kinetic chain effects of KT strips were used for mechanical.

Contradictory results were reported regarding the rapid effects of KT on the scapula kinematics and shoulder joint ROM [11,15,30,12,7]. Our study indicated that E-KT increased scapular upward rotation and posterior tilt that helped normalizing scapular kinematics in swimmers' shoulders. One possible explanation for previous inconsistencies is different study populations, where we studied the KT benefit in swimmers. Another explanation may be different taping techniques and KT elasticity. For instance, Keenan et al. [12] showed no changes in scapula kinematics 45 min after applying KT, but they applied only two pieces of tape over the supraspinatus and deltoid muscles, which may not affect scapular kinematics. Consistent with our results, Shaheen et al. [30] showed that 60-90 min after applying KT, scapular upward rotation increased 5.9° in asymptomatic individuals. Repositioning the scapula following taping could optimize glenohumeral function and help effective upper extremity function during swimming.

Immediately after KT, glenohumeral internal rotation increased, whereas glenohumeral external rotation and total shoulder ROM were not changed, similar to previous studies for overhead athletes [11] and healthy individuals [9]. In people with FH-FSP, the glenohumeral joint is internally rotated, which likely limits further internal rotation ROM. KT could produce improvements in glenohumeral ROM by holding the scapular and glenohumeral joint backwards relative to the default position, thereby establishing a position that increases shoulder internal rotation. Improvement of scapular kinematics immediately following KT can result from a dynamic stabilizer effect on the scapula and/or a facilitating effect of KT for scapular stabilizing muscles. Fear of pain during movement in swimmers with shoulder pain may affect the scapular kinematics and glenohumeral joint ROM [15,7], and the reduced pain with KT can also improve scapular kinematics.

Short-term effect of KT was associated with pain relief, consistent with observations in a previous study [15]. The reduction in shoulder pain after E-KT can be due to improved scapular upward rotation and scapular anterior tilt, which has been associated with an increase in the subacromial space and relief of soft-tissue impingement [15]. Pain modulation via the gate control theory is another plausible explanation, because tension in the KT may provide afferent stimuli, stimulating pain inhibitory mechanisms. Further, it is believed that the wrinkles produced by KT increase the interstitial space, facilitating pressure release in underlying soft tissues, leading to an increase in blood and lymph flow under the skin that in turn reduce swelling and inflammation in injured tissues [32].

Participants may leave an intervention due to having pain or fearing from pain exacerbation [13]. Also, pain can cause an incorrect execution of the exercise task [14], which may hamper the effectiveness of an exercise training program. Therefore, an early relief of pain by KT [15,16] may theoretically help to improve the efficacy of the exercise training program on static and dynamic posture. However, in our study, the benefits of the E-KT and exercise alone were the same in swimmers with and without pain suggesting that immediate relief of pain by KT does not result in better outcomes following exercise therapy in the long term.

In the present study, we used two KT strips for mechanical correction. Those KT strips were applied from the anterior aspect of the acromioclavicular joint to the T_{12} spinous process in a diagonal fashion with 50-100% stress. Previous studies show that only used two KT strips can have a mechanical effect on spinal posture so that induced an immediate reduction in thoracic kyphosis in older women [29]and significantly increase in pectoralis minor length and decrease in rounded shoulder posture in seated male workers[28]. In addition, we used tow Y-shaped, light tension KT strips for deltoid muscle from insertion (3 cm below the deltoid tuberosity) to origin and supraspinatus muscle following the borders of the muscle belly. A previous study show that used those two KT strips can have immediate improvement pain-free active ROM immediately after tape application for patients with shoulder pain [7].

We included 11- to 25-year-old swimmers, which may limit the application to other age groups and overhead sports. However, shared shoulder girdle anatomy makes it likely applicable to any age and sport discipline. All participants in this study were male swimmers. Therefore, caution should be taken when generalizing our results to female swimmers. We did not control for leisure activities, but it is unlikely that differences in leisure activities would affect the conclusions of our study. The sport specialist providing exercise training, physical therapist providing KT, and laboratory specialist performing the measurements were not blinded to group allocation, which may have unintentionally affected the results.

5. Conclusions

E-KT resulted in short-term effects on pain, posture, scapular kinematics and glenohumeral joint ROM in swimmers with FH-FSP posture with shoulder pain. E-KT relative to exercise alone did not enhance the benefits of a 10-week therapeutic exercise intervention for swimmers' static and dynamic posture. These observations indicate that KT may be a good choice to improve static and dynamic posture, and pain relief, in the short- but not in the long-term.

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Table 1. Exercise Intervention Program

Exercise	Description	Target	Repetitions	Equipment
Chin tuck exercise	Participants stand and lengthen the neck by lifting the crown of head to the ceiling and pushing the chin and head straight back, simultaneously. The chin should be parallel to the floor and the ear in line with the tip of shoulder	Improve neck flexor strength and endurance and alignment of the head and neck	Active from 15 to 30 s holds final position/from 6 to 12 repetitions	Physioball
L to Y exercises	Participants supine with arms abducted to 90° and elbows flexed to 90° and retract the scapula and externally rotate the arms to 90° of shoulder abduction (L position). Maintaining retraction of the scapula, raise the arms above the head and fully extend the elbows so that the arms form the letter ‘Y with 120° with the torso.	Improve strength and endurance of scapular retractor muscles (lower and middle trapezius and rhomboid muscles) and spinal extensor muscles	Active from 15 to 30 s holds final position/from 6 to 12 repetitions	Physioball
TheraBand external rotator strengthening	Participants were instructed to sit or stand and hold middle of the band about shoulder width apart, with slight tension in the band. Keep the elbows by their side and forearms parallel to the ground. Pull the ends of the band outward, hold and slowly return.	Improve strength and endurance of shoulder external rotator muscles	3 to 4 sets / 6 to 12 repetitions	Yellow, red, green, blue and black TheraBand
Elbow push-up plus	Participants are lying prone, supported at forearm level. They lift their trunk upward and sustain it.	Improve strength and endurance of serratus anterior	Active from 15 to 30 s holds /from 6 to 12 repetitions	Body weight
Side-Lying dumbbell external rotation	Subjects lie on side on a firm, flat surface with lower arm cradling under head. Hold his upper arm against body side, with a 90° elbow angle. Keep elbow against side and slowly rotate at the shoulder, raising the weight to a vertical position. Slowly lower the weight to the starting position.	Improve strength and endurance of shoulder external rotator muscles	3 to 4 sets / 6 to 12 repetitions	Dumbbell
Doorway Pectoralis muscle stretching	Participants stand erect in a doorway or the corner of a room with arms raised shoulder height, elbows bent, and hands grasping doorjambs, feet in front-stride position. Lean forward on door frame, with hands on the wall to stretch the anterior chest.	Lengthen pectoralis major muscle, expand rib cage and anterior chest wall	Active from 20 to 30 s holds /from 4 to 10 repetitions	Doorway or room corner
Broomstick stretch	Subjects grasp the broomstick with left hand (thumb down) and place it behind back, keeping the elbow in line with shoulder. With his right hand, reach in front of the body and grasp the other end of the broomstick. To stretch the left subscapularis, pull forward on the broomstick with your right hand to externally rotate your left arm.	Lengthen subscapularis	Active from 20 to 30 s holds /from 4 to 10 repetitions	Broomstick
Cross-body stretch	Participants were instructed to sit or stand and hold the upper arm with the opposite hand in front of the body and slowly pull cross his chest as far as possible. Repeat with the other arm.	Posterior shoulder musculature stretch Posterior Shoulder Capsule	Active from 20 to 30 s holds /from 4 to 10 repetitions	Body part

Table 2. Demographic characteristics of study participants

Characteristics	EG (n=25) Mean±SD		E-KTG (n=23) Mean±SD	
	Without pain (n=13)	With pain (n=12)	Without pain (n=12)	With pain (n=11)
Age (y)	17.6±3.9	19.3±1.7	17.1±3.5	19.2±1.8
Height (cm)	169±13	180±8	171±16	181±6
Body mass (kg)	61.6±13.5	73.2±5.5	62.5±14.7	71.7±5.1
BMI ($kg\cdot m^{-2}$)	21.4±2.3	22.7±1.1	21.5±2.3	21.9±0.9
Sports history (y)	7.5±2.6	9.15±2.3	6.9±2.2	9.8±2.1
Practice session (n/w)	5.4±1.2	6.5±1.1	5.3±1.0	6.1±1.2
Pain at rest (mm)	0.0	52.1±7.1	0.0	52.4±6.2
Pain on activity (mm)	0.0	48.8±5.6	0.0	49.5±4.9
Pain at night (mm)	0.0	56.3±7.1	0.0	56.2±5.9
Evaluated shoulder	Dominant (n=10) Non-dominant (n=3)	Dominant (n=8) Non-dominant (n=4)	Dominant (n=8) Non-dominant (n=4)	Dominant (n=9) Non-dominant (n=2)

Table 3. Static and dynamic posture measures before and after short- and long-term interventions

Variables	Time	EG (n=25) Mean ±SD		E-KTG (n=23) Mean ±SD	
		Without pain	With pain	Without pain	With pain
FHP (degree)	Baseline	51.2±3.1	51.8±3.7	51.7±3.5	52.0±3.8
	Short -term effects	51.1±3.2	50.5±2.5	48.5±3.3	49.1±3.6
	Long -term effects	44.9±3.4	45.7±2.2	44.2±3.8	45.5±3.9
FSP (degree)	Baseline	55.7±3.9	55.2±4.1	54.6±3.5	55.5±4.3
	Short -term effects	53.2±3.5	55.4±2.7	55.2±2.8	50.3±2.9
	Long -term effects	48.5±2.4	48.3±4.2	47.2±2.4	48.6±2.0
PMI (%height)	Baseline	7.9±0.4	7.8±0.4	7.8±0.4	7.7±0.4
	Short -term effects	7.9±0.4	7.8±0.4	8.1±0.4	7.9±0.3
	Long -term effects	8.3±0.3	8.1±0.4	8.3±0.4	8.1±0.3
GHIR (degree)	Baseline	59.7±2.6	57.9±2.5	58.7±2.71	58.2±2.7
	Short -term effects	59.2±4.1	57.8±2.9	62.0±3.1	60.6±3.0
	Long -term effects	63.3±1.0	61.5±2.8	63.2±3.5	63.2±3.2
GHER (degree)	Baseline	104.5±4.2	103.6±4.5	104.8±4.9	104.2±4.9
	Short -term effects	104.6±3.5	104.0±4.2	105.5±4.0	104.9±4.9
	Long -term effects	109.8±3.4	108.8±5.7	109.5±5.3	110.6±5.4
TGHR (degree)	Baseline	163.6±5.4	161.5±6.0	163.5±6.0	162.3±4.5
	Short -term effects	164.3±4.3	161.9±5.5	167.2±5.2	166.0±5.4
	Long -term effects	172.5±3.1	170.4±8.3	172.1±6.3	172.9±6.5
SATI (% height)	Baseline	4.4±0.7	4.8±0.4	4.3±0.7	4.5±0.7
	Short -term effects	4.5±0.7	4.7±0.4	4.0±0.5	4.2±0.5
	Long -term effects	4.2±0.7	4.3±0.3	3.9±0.5	4.2±0.4
0° to 60° SUR (degree)	Baseline	11.5±2.9	12.2±4.6	11.6±3.9	12.2±3.4
	Short -term effects	11.3±3.8	12.1±5.3	14.7±4.7	14.2±5.3
	Long -term effects	14.5±3.3	16.3±5.4	15.2±4.5	16.9±4.6
60° to 120° SUR (degree)	Baseline	16.2±4.2	14.7±3.7	15.5±3.9	14.2±4.4
	Short -term effects	16.5±4.2	14.6±3.2	17.9±3.1	16.3±2.9
	Long -term effects	19.7±2.7	17.3±2.8	19.7±2.9	18.9±2.4

Table 4. Repeated-measures ANOVA results (F (sig)) for static and dynamic posture measures of interest

Variables	Group effect		Pain effect		Time effect		Group × Pain		Group × Time		Time × Pain	
	$F_{(1,46)}$	p	$F_{(1,46)}$	P	$F_{(1,46)}$	P	$F_{(1,46)}$	p	$F_{(1,46)}$	P	$F_{(1,46)}$	p
FHP (degree)	1.2	0.32	0.2	0.6	90	0.001	0.01	0.89	10.5	0.001	1.3	0.3
FSP (degree)	3.8	0.06	0.7	0.4	95	0.001	0.09	0.82	15.1	0.001	1.0	0.4
PMI (%height)	0.1	0.81	1.9	0.2	74.2	0.001	0.03	0.86	5.9	0.01	2.6	0.08
GHIR (degree)	2.5	0.11	3.1	0.09	50.1	0.001	0.5	0.52	4.2	0.02	0.5	0.6
GHER (degree)	0.4	0.53	0.2	0.7	62.4	0.001	0.1	0.73	0.1	0.9	0.3	0.7
TGHR (degree)	1.8	0.22	1.5	0.2	88.4	0.001	0.5	0.51	2.0	0.1	0.5	0.6
SATI (% height)	3.3	0.07	2.6	0.1	52.9	0.001	0.05	0.84	13.2	0.001	0.9	0.4
0°-60° SUR (degree)	1.1	0.31	0.6	0.4	48.4	0.001	0.05	0.83	6.3	0.01	2.3	0.09
60°-120° SUR (degree)	0.5	0.52	3.7	0.06	42.8	0.001	0.2	0.72	3.4	0.03	0.1	0.9

Abbreviations*: EG, Exercise group; E-KTG, Exercise-kinesiotaping group; FHP, Forward-head posture; FSP, Forward-shoulder posture; PMI, Pectoralis minor index; GHIR, Glenohumeral internal rotation; GHER, Glenohumeral external rotation; TGHR, Total glenohumeral rotation; SATI, Scapular anterior tilting Index; SUR, Scapular upward rotation.*

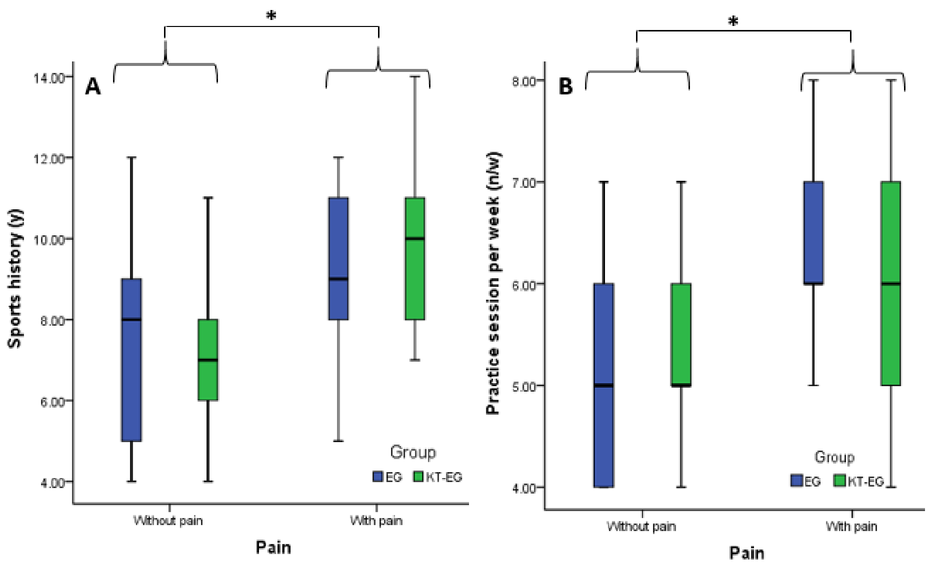

Figure 1. Box-Whisker Plot of a) sports history and b) practice session per week

* *Significant main effects p<0.05*

We thank the editors and the reviewers for their time evaluating our manuscript and their useful comments. The feedback has helped us strengthen the manuscript. All changes are indicated in red font. Below we give an itemized response to the comments raised.

Reviewers' comments:

Minor issues.

Abstract in French :

• « Le but de cet essai randomisé était de déterminer si un traitement à court et à long terme avec de l'exercice combiné au KT par rapport à l'exercice seul aboutissait à de meilleurs résultats sur la posture statique et dynamique chez les nageurs symptomatiques et asymptomatiques avec les postures de la tête en avant et les épaules en avant. »

 At my opinion, unclear sentence about aims of the study.

As suggested by the reviewer, we have amended this sentence as follows:

'Le but de cet essai randomisé était de déterminer si un traitement à court et à long terme avec de l'exercice combiné au KT par rapport à l'exercice seul aboutissait à de meilleurs résultats sur la posture statique et dynamique chez les nageurs symptomatiques et asymptomatiques avec une posture en projection de la tête et enroulement des épaules.'

• « ont été assignés au hasard à un exercice combiné avec un groupe de KT (n = 26) et un groupe d'exercice unique (n = 26). »

• Unclear. Bad translation of english sentence.

As suggested by the reviewer, we have amended this sentence as follows:

'*Cinquante-deux nageurs de compétition âgés de 11 à 25 ans ont été assignés au hasard à un exercice combiné avec KT groupe (n = 26) et un seul d'exercice groupe (n = 26)*.'

• Change « Poitrine » for « thorax »

As suggested by the reviewer, we have amended this sentence as follows:

'Les deux groupes ont reçu une intervention d'exercice de 10 semaines ciblant la mobilité de l'épaule et de la thorax, la force du haut du dos et des épaules avec ou sans KT avec chaque séance d'exercice.'

- Change « L’angle de la tête en avant » for « antéprojection de la tête »

  - « … a entraîné une augmentation de la posture en avant… »

As suggested by the reviewer, we have amended this sentence as follows:

‘*Les résultats de notre étude montrent que l'exercice combiné au KT a entraîné une diminution immédiate de l’angle de antéprojection de la tête (Cohen d = 0,84) et de l’angle de antéprojection de épaules (Cohen d = 1,37), et une amélioration de la posture dynamique, y compris la longueur du petit pectoral (Cohen d = 0,63), la rotation médiale de la gléno-humérale (Cohen d = 0,91), la rotation totale de la gléno-humérale (Cohen d = 0,91), l'indice de la bascule antérieure de la scapula (Cohen d = 0,48), la rotation latérale de la scapula 0-60◦ (Cohen d = 0,56) et 60 -120◦ (Cohen d = 0,62).*’

 Unclear sentence.

- « …. L'exercice combiné au KT par rapport à l'exercice unique n'a pas amélioré les effets de l'intervention d'exercice de 10 semaines ».

As suggested by the reviewer, we have amended this sentence as follows:

‘L'exercice combiné avec KT par rapport à un seul exercice n'a pas eu de meilleurs effets après une intervention de 10 semaines’

 Not well formulated.

- « la posture dynamique et statique chez les nageurs en court terme. »

 Change the « en » for an « à ».

As suggested by the reviewer, we have amended this sentence as follows:

‘la posture dynamique et statique chez les nageurs dans le à court terme ($p \leq 0.05$).’

- The conclusion isn’t clear at my opinion. It seems to say some contradictions on the results.

As suggested by the reviewer, we have amended this sentence as follows:

‘Ajout de KT à l'intervention d'exercice peut être un bon choix pour améliorer la posture statique et dynamique, et le soulagement de la douleur à court terme mais pas à long terme.’

Introduction

- § 4 : réf 7 not referred with sport injury prevention and treatment of FH FSP

As suggested by the reviewer, we have replaced this sentence as follows:

'Although kinesiotaping (KT) is widely used in sport injury prevention and treatment for FH-FSP, [1-3], there is insufficient evidence of its effectiveness [4].'

Methods

- Participants

o §3, line 8 : questionnaire about tape comfort. I didn't find the questionnaire in the cited reference. The referred article (18) used a subjective assessment.

As suggested by the reviewer, we have replaced this réf with a réf that used this questionnaire;

'Exclusion criteria were: fracture history; surgery and/or arthritis in upper extremity, shoulder girdle or/and spinal column; full thickness tear of the rotator cuff; cervical radiculopathy; shoulder instability; systemic musculoskeletal disease; structural chest deformity; hyper-kyphosis or scoliosis; severe pain during assessments; tape application contraindications based on tape comfort questionnaire [5].'

Major issues:

- If I understand the role of the KT applied on the scapula, I have some difficulties to understand how the 2 Y-shaped KT could improve FH-FSP?

In the present study, the effect of KT alone has not been investigated, but the effect of KT in combination with exercise has been investigated, which is quite clear in the title and purpose of the study. *'Kinesiotaping as an adjunct to exercise therapy for symptomatic and asymptomatic swimmers: A randomized controlled trial'.*

In addition, we have not only used 2 Y-shaped KT, but also, we used two KT strips that has a biomechanical effect on the FSP and FHP. Please see this sentence in our paper' *Two KT strips were used for mechanical correction with 50-100% stress, according to comfort. Subjects retracted and depressed their scapula and tape was applied from the anterior aspect of the acromioclavicular joint to the T_{12} spinous process in a diagonal fashion [6]."*

Furthermore, results from our study show that adding KT to the exercise

1. leading to immediately improvement static and dynamic posture and immediately relieve shoulder pain for swimmers compared to exercise alone

2. Did not enhance the benefits of a 10-week exercise intervention for static and dynamic posture of swimmers.

 It's a pity that the respective role of different KT were not part of the discussion.

"In the present study, we used two KT strips for mechanical correction. Those KT strips were applied from the anterior aspect of the acromioclavicular joint to the T_{12} spinous process in a diagonal fashion with 50-100% stress. Previous studies show that only used two KT strips can have a mechanical effect on spinal posture so that induced an immediate reduction in thoracic kyphosis in older women [7]and significantly increase in pectoralis minor length and decrease in rounded shoulder posture in seated male workers[8]. In addition, we used tow Y-shaped, light tension KT strips for deltoid muscle from insertion (3 cm below the deltoid tuberosity) to origin and supraspinatus muscle following the borders of the muscle belly. A previous study show that used those two KT strips can have immediate improvement pain-free active ROM immediately after tape application for patients with shoulder pain [1]."

1. Thelen MD, Dauber JA, Stoneman PD (2008) The clinical efficacy of kinesio tape for shoulder pain: a randomized, double-blinded, clinical trial. J Orthop Sports Phys Ther 38 (7):389-395. doi:10.2519/jospt.2008.2791
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3. Alam S, Malhotra D, Munjal J, Chachra A (2015) Immediate effect of Kinesio taping on shoulder muscle strength and range of motion in healthy individuals: A randomised trial. Hong Kong J Occup Ther 33 (2):80-88. doi:10.1016/j.hkpj.2014.10.004
4. Desjardins-Charbonneau A, Roy JS, Dionne CE, Desmeules F (2015) The efficacy of taping for rotator cuff tendinopathy: a systematic review and meta-analysis. Int J Sports Phys Ther 10 (4):420. doi:10.2519/jospt.2015.5455
5. Gulpinar D, Ozer ST, Yesilyaprak SS (2017) Effects of Rigid and Kinesio Taping on Shoulder Rotation Motions, Posterior Shoulder Tightness, and Posture in Asymptomatic Overhead Athletes: A Randomized Controlled Trial. J Sport Rehabil (in press):1-26. doi:10.1123/jsr.2017-0047
6. Gak H, Lee J-H, Kim H-D (2013) Efficacy of kinesiology taping for recovery of dominant upper back pain in female sedentary worker having a rounded shoulder posture. Technol health care 21 (6):607-612. doi:10.3233/THC-130753
7. Greig AM, Bennell KL, Briggs AM, Hodges PW (2008) Postural taping decreases thoracic kyphosis but does not influence trunk muscle electromyographic activity or balance in women with osteoporosis. Man Ther 13 (3):249-257. doi:10.1016/j.math.2007.01.011

8. Han J-T, Lee J-H, Yoon C-H (2015) The mechanical effect of kinesiology tape on rounded shoulder posture in seated male workers: a single-blinded randomized controlled pilot study. Physiother Theory Pract 31 (2):120-125