



# Kinesio taping of the deltoid does not reduce fatigue induced deficits in shoulder joint position sense



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## ABSTRACT

**Background:** Muscle fatigue is known to decrease shoulder proprioceptive acuity, potentially contributing to injuries. It has been suggested that Kinesio taping can improve proprioception. Therefore, the aim of this study was to investigate the effects of Kinesio taping on shoulder joint position sense after muscle fatigue.

**Methods:** Twenty-four healthy subjects were evaluated in a randomized, crossover, single-blind study design. Shoulder joint position sense was assessed during active repositioning tests at the target angles of 50°, 70° and 90° of arm elevation in scapular plane, in three sessions: control (no taping), Kinesio taping (Kinesio taping applied over the deltoid muscle with tension) and sham (Kinesio taping applied over deltoid without tension). Joint position sense was assessed three times: before taping; following taping application or rest, in the control session; and following a fatigue protocol. The constant error (repositioned angle–target angle) was considered for statistical analysis, using a 3-way repeated-measure ANOVA (within subject factors: taping, time and target angle).

**Findings:** There was no interaction or main effect involving taping. An interaction between time and angle was found and the simple effect showed that the constant error increased following fatigue at 70° and 90°, but not at 50°.

**Interpretation:** The results of this study does not support the use of Kinesio taping applied over the deltoid muscle for compensating or preventing shoulder joint position sense deficits caused by muscle fatigue of shoulder abductors.

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## 1. Introduction

The shoulder complex relies heavily on sensorimotor control for maintaining functional joint stability, due to its poor osseous and capsuloligamentous restraints (Myers et al., 2006). Proprioceptive signals arise from afferent neural input originating at the level of the mechanoreceptors (Riemann and Lephart, 2002), and has generally been described as having three submodalities: joint position sense (JPS), the appreciation and interpretation of information concerning joint position and orientation; kinesthesia, the ability to identify joint movement; and force sense, the ability to appreciate and interpret forces applied to or generated within a joint (Myers and Lephart, 2000).

Several studies have shown that shoulder JPS and kinesthesia are impaired by muscle fatigue (Carpenter et al., 1998; Iida et al., 2014; Lee et al., 2003; Myers et al., 1999; Voight et al., 1996). These deficits could predispose subjects who perform repetitive arm movement during work or sports activities to shoulder injuries. Therefore, interventions

aimed at reducing these proprioceptive deficits may help to prevent shoulder injury.

Skin stretch has been shown to cause illusory movement, demonstrating that cutaneous afferents play a role in proprioception (Collins et al., 2005). Kinesio taping (KT) is a technique that consists of applying an elastic adhesive tape over a target muscle, providing continual skin traction (Kase et al., 2003). Kinesio taping has been widely and increasingly used in clinical and sports practice, although its effects are still not clear (Morris et al., 2013; Williams et al., 2012). Similar to conventional taping, proprioception improvement due to cutaneous mechanoreceptors stimulation is one of the effects attributed to KT (Kase et al., 2003). Few studies have evaluated the effects of KT on proprioception (Chang et al., 2010; Chang et al., 2012; Chang et al., 2013; Halseth et al., 2004; Lin et al., 2011) and an improvement in grip force sense accuracy (Chang et al., 2010) and shoulder JPS (Lin et al., 2011) have been found after the application of KT in healthy subjects.

Given the potential of KT to directly affect proprioception, it could serve as a possible modality for mitigating the negative consequences of fatigue at the shoulder. Consequently, the purpose of this study was to investigate the effects of KT applied on the deltoid muscle on shoulder JPS after muscle fatigue. It was hypothesized that the application

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of KT would partially compensate for the proprioceptive deficits caused by muscle fatigue. The confirmation of this hypothesis would support the use of KT to reduce the effect of proprioceptive deficits caused by muscle fatigue and potentially contribute to shoulder injury prevention in populations that perform repetitive arm movement, such as overhead athletes and workers.

## 2. Methods

### 2.1. Subjects

Twenty-four healthy subjects (12 males and 12 females), with a mean age of 21.5 years (SD 2.7), mean height of 158 cm (SD 10) and mean body mass of 70.5 kg (SD 13.1) participated in this study. Prior to participation, all subjects signed an informed consent form approved by the Institutional Review Board of the University of Oregon. Subjects were included if they were healthy, between the ages of 18 and 50 years and had no history of shoulder injuries that required rehabilitation or surgery. Exclusion criteria were current participation in overhead sports training, history of shoulder dislocation and generalized ligamentous laxity, assessed using the Beighton and Horan Joint Mobility Index (Boyle et al., 2003). This study was registered prospectively with [ClinicalTrials.gov](http://ClinicalTrials.gov) (NCT02104570).

Power calculations were performed using G\*Power (version 3.1.9.2) (Faul et al., 2007). Data were from a previous study using the same JPS protocol on 79 healthy subjects (Gillespie et al., 2013). Given an overall standard deviation of  $3.2^\circ$  and a correlation among repeated measures of 0.5, 24 subjects would result in a power of 0.8 to detect an effect size as small as 0.27 (or approximately  $0.9^\circ$  in this case).

### 2.2. Experimental design

A crossover, randomized, sham-controlled, single-blind (subject) design was used in this investigation. The dominant shoulder of the participants was evaluated in three sessions: control (no intervention), KT application and sham application, in a randomized order. Subjects performed the three sessions on the same day of the week and time of the day. Additionally, there was a one-week interval between sessions in order to avoid accumulation of taping effects (Hsu et al., 2009) or muscle fatigue (Myers et al., 1999). Participants were instructed not to perform upper-body exercises for the 24 h prior to each session. The experimental protocol was the same for all sessions, except for the taping application (Fig. 1).

### 2.3. Procedures

For all sessions, participants were seated on an ergonomically designed kneeling chair (Better Posture Kneeling Chairs, Jobri, Konawa, OK, USA). Initially, a maximal isometric voluntary contraction (MVIC) of shoulder abduction was performed, with the arm at  $90^\circ$  of elevation in the scapular plane. Subjects performed three MVIC trials, 5 s each, with 1 min of rest between them. Data were collected at 12 Hz with a hand held dynamometer (MicroFET 2, Hoggan Health Industries, Draper, UT, USA) attached to a rigid support. The mean force generated between the second and third seconds was calculated and then averaged over the 3 MVIC trials.

Following MVIC testing, shoulder JPS was assessed with an active joint repositioning task, using an app developed for Apple's 4th generation iPod Touch (Gillespie et al., 2013). This app uses the internal sensors of the device (accelerometers and gyroscopes) to record the orientation of a segment with respect to gravity, and enables an evaluation protocol similar to that performed using an electromagnetic tracking device (Suprak et al., 2006; Suprak et al., 2007). Instead of visual cues, the app provides auditory commands to the subject through Bluetooth noise canceling headphones, while subjects keep their eyes closed.

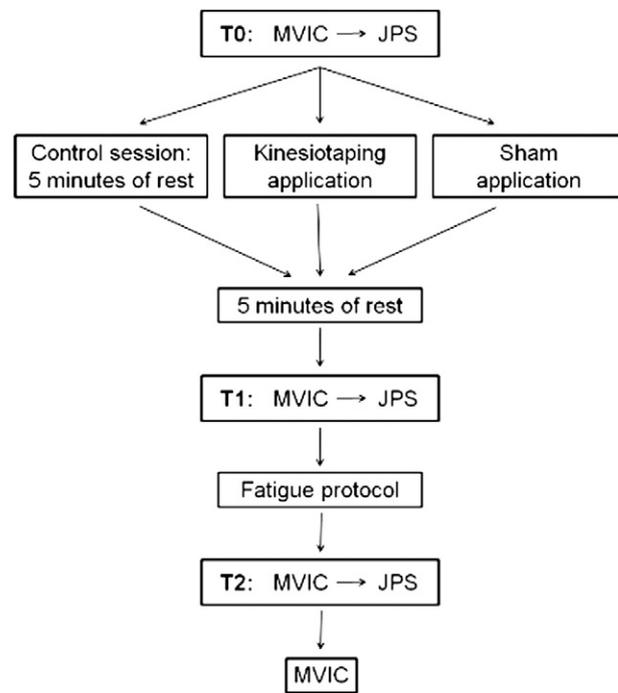


Fig. 1. Schematic representation of the procedures during the experiments. MVIC: Maximal voluntary isometric contractions; JPS: Joint position sense.

The iPod was attached to the distal arm of the subjects, between the deltoid insertion and lateral epicondyle, to minimize artifacts from muscle contraction. The initial position of each trial was with the arm vertical at the side of the body. Subjects were instructed to elevate the arm in the scapular plane (Fig. 2). There were two audible cues to help guide the subjects to the correct target angle. A low frequency



Fig. 2. Subject positioning during the joint position sense assessment.

tone was presented when the elevation angle was below the target angle and a high frequency tone when the angle was above the target angle. Subjects were instructed to stop arm movement when the tones were silenced, which occurred when the arm was within 2° of the target angle. They held this position for 3 s and subsequently returned the arm to the initial position. After 2 s, they were instructed to reproduce the target position, with no audio or verbal feedback of shoulder position. Three target angles of elevation (50°, 70° and 90°) were presented, two times each, in a randomized order. Two familiarization trials were performed before starting the tests. Data were stored on the device and subsequently exported and analyzed using a customized program written in LabView (version 2013, National Instruments Corporation, Austin, TX, USA). The differences between the actual angle reached with auditory cues and the repositioned angle, with no auditory cues, were calculated and the mean (constant error) was used for analysis (Schmidt and Lee, 1999).

Following baseline evaluations (T0), taping was applied (KT or sham) or subjects rested for 10 min (control session) (Fig. 1). In both taping sessions, two strips of the Kinesio Tex Gold Standard (Kinesio USA, LLC, Albuquerque, NM, USA), 5 cm width, were applied over the deltoid muscle, from origin to insertion (Fig. 3). In the KT session, the base of each strip was applied with no tension, over the acromioclavicular joint, with the arm at trunk side. Then, the shoulder was placed in abduction, external rotation and horizontal abduction, and the tape was applied along the anterior deltoid to the deltoid tuberosity. For the posterior strip application, the shoulder was moved into horizontal adduction with internal rotation while maintaining around 90° abduction. Both strips were applied using approximately 50% of the available tension, as recommended (Kase et al., 2003). For the sham condition, the tape was applied using the same configuration, but the arm remained at the side during all the application procedure and no tension was applied. The subjects were blinded to the intervention they were receiving. They were informed that there were two different



Fig. 3. Taping application over the deltoid muscle.

techniques, but were not given any further details about the taping procedure. After taping (or rest in the control session), MVIC and JPS were reassessed (T1).

During the fatigue protocol, a weight was attached to the subject's wrist. The weight was set at 20% of the baseline MVIC of the first evaluation session and maintained the same in the second and third sessions. The fatigue protocol consisted of repetitive shoulder elevation in the scapular plane, up to 90° of shoulder elevation, aiming at shoulder abductor muscles fatigue. The movement frequency was controlled using a metronome and consisted of 1 s for the concentric phase and 1 s for the eccentric phase. When the subject could not perform the movement at the preset frequency or through the complete range of motion, the MVIC was reassessed. If the force had fallen less than 50% of MVIC at T1, the exercise continued. When the drop in force was greater than 50% of MVIC at T1, they stopped the exercise and the JPS was immediately reassessed (T2).

#### 2.4. Statistical analysis

Descriptive statistics were presented as mean and standard error of the mean at each condition analyzed. Statistical analysis was performed using SPSS version 22 (IBM, Chicago, IL, USA). Intraclass correlation coefficients (ICC) were calculated to determine reliability for the constant error at each target angle. For between-days reliability, ICC(3,3) was calculated for data at T0, from each evaluation session. For within-day reliability, ICC(3,2) was calculated for the constant errors at T0 and T1 in the control session. Mauchly's test of sphericity was performed for all measures, before analyses of variance, and Greenhouse–Geisser correction was used if the assumption was violated. In order to compare the fatigue protocol between sessions, the number of repetitions before reaching the fatigue criteria, the MVIC immediately after the fatigue protocol (T2) and at the end of the session (after JPS reassessment) were compared between sessions using one-way repeated-measures analyses of variance (ANOVA's). For the JPS assessment data (constant error), a three-way repeated-measures ANOVA was conducted, with the following within-subject factors: taping condition (control, KT and sham), time (T0, T1 and T2) and target angle (50°, 70° and 90°). Significance level was set as 5%. When a significant interaction was found, the simple effects were calculated using the Sidak correction for multiple comparisons (Cardinal and Aitken, 2006).

### 3. Results

All subjects completed the fatigue protocol with no complications. There were no significant differences between the sessions regarding the number of repetitions during the fatigue protocol, the MVIC at T2 and the MVIC after JPS reassessment (Table 1). Between-days and within-day reliability results are presented on Table 2.

Regarding JPS data, there was no significant three-way interaction ( $P = 0.18$ ). A two-way interaction between time and angle was found ( $P = 0.005$ ) (Fig. 4). This effect was further investigated using a simple effect analysis, which showed a significant higher constant error at T2 compared to T0 and T1 at the target angles of 70° and 90° ( $P < 0.001$ ), but not at 50° ( $P > 0.05$ ). Higher errors were found at the target angles

Table 1

Number of repetitions performed during the fatigue protocol and maximal voluntary isometric contraction (MVIC; expressed as a percentage of MVIC before fatigue protocol) at each evaluation session.

	Control session	Kinesio taping session	Sham session	P value
Number of repetitions during fatigue protocol	95 (6)	98 (6)	93 (6)	0.61
% MVIC after fatigue protocol	41.6 (1.2)	44.6 (0.9)	42.2 (1.1)	0.13
% MVIC after JPS reassessment	66.9 (2.4)	65.5 (2.4)	66.3 (2.6)	0.88

Data are mean (standard error).

**Table 2**

Within-day and between-days intraclass correlation coefficient for constant errors at each target angle.

	Within-day	Between-days
50°	0.75	0.64
70°	0.65	0.80
90°	0.79	0.67

of 70° and 90° compared to 50° at T0 and T1 ( $P < 0.05$ ), but not at T2 ( $P > 0.05$ ). There was no main effect of taping condition ( $P = 0.41$ ).

#### 4. Discussion

Kinesio taping has been widely used for musculoskeletal injury prevention and treatment, although there is still little evidence of its effectiveness (Morris et al., 2013; Williams et al., 2012). Few studies have evaluated the effects of KT on proprioception, with diverse findings (Chang et al., 2010; Chang et al., 2012; Chang et al., 2013; Halseth et al., 2004; Lin et al., 2011). The hypothesis of the present study, that KT would compensate for JPS deficits caused by muscle fatigue, was not confirmed. These results indicate that KT has no significant effects on shoulder proprioception of healthy individuals, even after muscle fatigue.

To our knowledge, only one study has previously tested the effects of KT on proprioception following muscle fatigue and has found smaller errors of knee repositioning with KT application compared to no taping (Han and Lee, 2014). However, that study did not have a sham group and KT was applied after the fatigue protocol, which may have allowed fatigue recovery. It is also possible that skin stimulation improves the afferent input for a limited time and, after a period, the receptors accommodate to the additional stimulus. In the present study, taping was applied before the fatigue protocol and removed only at the end of the session. This method is similar to the real application of KT, since athletes, for example, use it during game or training, not after. Our results demonstrate that when KT is used during the exercise practice, it does not compensate for fatigue induced deficits in shoulder JPS in healthy subjects.

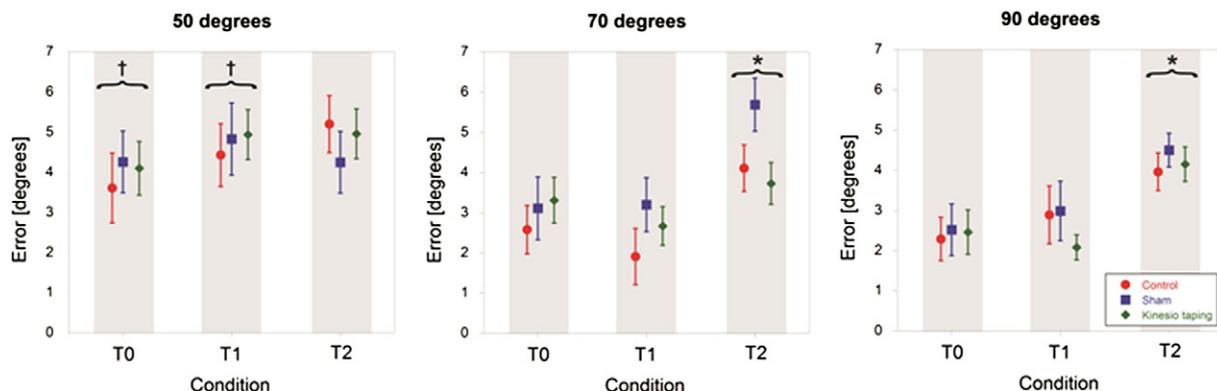
Contrasting with previous studies that have reported improvement in proprioceptive acuity of healthy individuals with KT application, no significant effect was found in the present study in the baseline condition (T1 compared to T0). An improvement in the grip force sense was found with KT applied over the wrist flexor muscles of healthy subjects compared to no taping and sham conditions (Chang et al., 2010). The authors attributed this effect to the tension applied to the taping, which would have stimulated skin and underlying superficial fascia. However, the sham application was a small piece of KT applied across the belly of wrist flexors, providing different skin stimulation and

making it difficult to attribute the alterations found to the tension applied to the tape. In the present study, the sham was applied using the same taping configuration, removing only the principal characteristic of the KT method, i.e., the tension. This ensured the same skin contact stimulation, and then any possible difference found between the taping conditions could be attributed to the tension applied. Furthermore, using the same material for the sham application avoids any movement restriction potentially caused by rigid tape, as previously reported (Hsu et al., 2009).

Other studies investigated the effects of KT on proprioception, but have not compared to a sham technique. Lin et al. (2011) found a decrease in shoulder repositioning errors in healthy subjects when using KT applied with full tension, aiming to maintain scapular retraction and depression. Since the subjects were tested before and after the taping application in a single session, a learning effect cannot be discarded. Halseth et al. (2004), also using a pretest-posttest design, found no effect of a KT technique for lateral ankle sprain on ankle JPS of healthy subjects, similar to our findings. Our results are also in accordance with another study (Bradley et al., 2009) that has found no improvement in shoulder JPS with a rigid taping technique for shoulder stabilization in healthy football players. It is possible that an intact sensorimotor system, as is the case of subjects with no shoulder injuries, would not benefit from any extra stimulus potentially provided by taping.

Data from the present study also showed that KT had no effect on muscle fatigue, with subjects performing the same number of repetitions until fatigue criteria and having the same rate of recovery in all the sessions. Alvarez-Álvarez et al. (2014) found an improvement in the resistance to fatigue of trunk extensor musculature when using KT during the Biering-Sorensen test, an isometric task. During isometric contractions, one of the main causes of task failure is the occlusion of blood flow and, consequently, decrease in oxygen supply and increase in metabolite accumulation (Hunter, 2009). Therefore, the effect on fatigue resistance may have been related to one of the attributed effects of KT - an improvement in peripheral blood and lymphatic flow, due to the lifting effect on the skin (Aguilar-Ferrández et al., 2014). However, during dynamic contractions, blood flow is not a limiting factor (Hunter, 2009), which may help to explain why KT had no effect on fatigue development in the present study. This is consistent with a previous study that evaluated the effects of KT on plantarflexor muscle endurance during dynamic contractions (Csapo et al., 2012).

The present study found a significant increase in the repositioning errors after muscle fatigue at the higher target angles of elevation. The general decrease in proprioceptive acuity after fatigue is in accordance with previous studies that have evaluated internal and external rotations of the shoulder, using repositioning and threshold movement detection tests (Carpenter et al., 1998; Iida et al., 2014; Lee et al., 2003; Voight et al., 1996). In the baseline tests, the subjects presented



**Fig. 4.** Mean constant errors and standard error at each target angle in T0 (baseline), T1 (immediately after taping application or rest, in the control session) and T2 (following the fatigue protocol). \*Significant difference ( $P < 0.05$ ) compared to T0 and T1. †Significant difference ( $P < 0.05$ ) compared to 70° and 90°.

a pattern of smaller errors at higher target angles, which is in accordance with previous studies that have evaluated JPS during arm elevation in healthy subjects (King et al., 2013; Suprak et al., 2006). Following muscle fatigue, the relationship between target angle and repositioning error was altered, with no significant effects of fatigue on JPS at 50°, but an increase in errors at 70° and 90°. The pattern of smaller errors at greater elevation found by previous studies was initially attributed to the muscle activation level, since at higher angles the moment arm of the limb increases, increasing the torque applied to the shoulder due to gravity (Suprak et al., 2006). However, more recent studies showed that external load causes only a small improvement in JPS (Suprak et al., 2007) and body orientation does not change this pattern (Chapman et al., 2009), suggesting that the angular position has a greater role in the repositioning acuity than the generated torque.

There are limitations of the present study that need to be addressed. Although the participants were trained to perform the movements in the scapular plane, before the JPS evaluation, the plane of elevation was not controlled, only visually inspected by the examiner. However, since it was demonstrated that shoulder JPS is not significantly affected by the plane of movement (Suprak et al., 2006), it is unlikely that this would influence our results. Due to the small number of trials at each target angle during the repositioning task, the variable error was not calculated. Additionally, although the within and between-days ICC indicate moderate to good reliability for the constant errors, more trials at each target angle might improve it, by providing more representative error scores. However, the number of repetitions was determined in order to avoid fatigue recovery before the end of the reassessment. Furthermore, an inherent limitation of studies involving KT is the difficulty in determining the tension applied (Wong et al., 2012). In the present study, the same investigator applied KT in all the subjects and was trained to use the same tension, but there is no guarantee that exactly 50% of the tension was applied. However, this is similar to what occurs in clinical practice. Finally, these results are limited to arm elevation in scapular plane up to 90°, which corresponds to the range of motion of most part of daily living activities (Pearl et al., 1992). However, other ranges of movement could cause different mechanical stress in the shoulder structures and the taping and therefore present different results.

## 5. Conclusions

The hypothesis of this study, that KT could partially compensate for the proprioceptive deficits induced by muscle fatigue, was not supported. Although subjects presented an increase in the repositioning errors following muscle fatigue, the change was the same in all the sessions, independent of the intervention. Therefore, this study does not support the use of KT applied over the deltoid muscle for compensating or preventing shoulder joint position sense deficits caused by muscle fatigue of shoulder abductors.

## Conflict of interest statement

The authors declare no conflict of interest.

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