Clinical Biomechanics 61 (2019) 16–21

Contents lists available at ScienceDirect

Clinical Biomechanics

journal homepage: www.elsevier.com/locate/clinbiomech

Immediate effects of kinesiotaping on acromiohumeral distance and shoulder proprioception in individuals with symptomatic rotator cuff tendinopathy

Fábio Carlos Lucas de Oliveira, Benoit Pairot de Fontenay, Laurent J. Bouyer, Jean-Sébastien Roy*

Center for Interdisciplinary Research in Rehabilitation and Social Integration, CIUSSS-CN, Quebec City, Quebec, G1M 2S8, Canada
Department of Rehabilitation, Faculty of Medicine, Laval University, Quebec, G1V 0A6, Canada

A B S T R A C T

Background: Kinesiotaping is widely used for the rehabilitation of rotator cuff tendinopathy. It has been argued to reduce symptoms and functional limitations through improvement of proprioceptive feedback. In addition, kinesiotaping has been reported to increase the subacromial space in healthy subjects. However, its effects on the acromiohumeral distance and shoulder proprioception of individuals with rotator cuff tendinopathy have not been ascertained. This study investigated the immediate effects of kinesiotaping on the acromiohumeral distance and shoulder proprioception in individuals with rotator cuff tendinopathy.

Methods: Twenty-two individuals with chronic rotator cuff tendinopathy were included. The acromiohumeral distance was measured using an ultrasound scanner at rest and 60° shoulder abduction. Proprioception was measured through active joint repositioning in low- (45°–65°) and mid-amplitude (80°–100°) of shoulder flexion and abduction. A wireless inertial measurement unit system was used to quantify shoulder angles. First, measurements were taken without kinesiotaping. Thereafter, kinesiotaping was applied on the symptomatic shoulder, and the same measurements were retaken. Repeated measures ANOVAs were used for statistical analyses.

Findings: Kinesiotaping induced a significant increase in acromiohumeral distance at 60° abduction (ΔAHD = 0.94 mm; 95%CI: 0.50–1.38, $p < 0.001$), exceeding the minimal detectable change (0.70 mm). No significant difference was observed in acromiohumeral distance at rest or in proprioception during active joint repositioning in both low- and mid-amplitude ($p > 0.05$).

Interpretation: Kinesiotaping led to an immediate increase in acromiohumeral distance at 60° of abduction that, although it seems a minor change (↑10.5%), it may be significant for symptomatic patients, whereas it had no immediate effect on active joint repositioning.

1. Introduction

Rotator cuff tendinopathy (RCTe) is a very common musculoskeletal disorder that affects a large portion of the population (Bjelle, 1989; Urwin et al., 1998). Despite a multifactorial etiology (Desmeules et al., 2004), narrowing of the subacromial space is considered a common characteristic of RCTe (Seitz et al., 2011). Shoulder neuromuscular control deficits, such as the altered performance of rotator cuff (RC) and scapular muscles, are likely involved in this mechanical alteration of the subacromial space (de Oliveira et al., 2017a).

The subacromial space is estimated by measuring the acromiohumeral distance (AHD), which is defined as the tangential distance between the bony landmarks of the humeral head and inferior edge of the acromion (Desmeules et al., 2004; McCreesh et al., 2015). The AHD

Abbreviations: AE, absolute error; AHD, acromiohumeral distance; CI, confidence interval; CIRRIS, Centre for Interdisciplinary Research in Rehabilitation and Social Integration; ES, effect size; ICC, intraclass correlation coefficient; IRDPQ, l'Institut de réadaptation en déficience physique de Québec; KT, kinesiotaping; MDC, minimal detectable change; RC, rotator cuff; RCTe, rotator cuff tendinopathy; SEM, standard error of measurement

* Corresponding author at: Centre for Interdisciplinary Research in Rehabilitation and Social Integration, 525 Boulevard Wilfrid-Hamel, Quebec City, QC G1M 2S8, Canada.

E-mail addresses: fabio-carlos.lucas-de-oliveira.1@ulaval.ca (F.C.L. de Oliveira), benoit.pdf@fmed.ulaval.ca (B. Pairot de Fontenay), laurent.bouyer@rea.ulaval.ca (L.J. Bouyer), jean-sebastien.roy@rea.ulaval.ca (J.-S. Roy).

https://doi.org/10.1016/j.clinbiomech.2018.11.005
Received 6 July 2018; Accepted 8 November 2018

ranges between 9 and 12 mm in asymptomatic individuals (McCreesh et al., 2015; Pijls et al., 2010) varying according to age, gender, pathology, shoulder position, and measurement technique (Bey et al., 2007).

The AHD has been shown to be smaller in symptomatic individuals with RCTe in elevated arm positions when compared to healthy control (Bey et al., 2007; McCreesh et al., 2015). As a normal subacromial space is essential for proper shoulder function, these studies suggest that alterations in shoulder neuromuscular control, leading to the narrowing of the subacromial space, could be an important generating factor of RCTe.

Proprioceptive feedback mechanisms also play an important role in proper joint control (Aydin et al., 2001; Furmanek et al., 2014). Proprioception can be divided into three components: joint position sense (interpretation of information concerning orientation in space), kinesthesia (interpretation of joint motions) and sensation of effort (interpretation of force generated within a joint) (Ager et al., 2017; Furmanek et al., 2014; Myers and Lephart, 2000; Proske and Gandevia, 2012). Several tests have been developed to estimate the shoulder joint position sense using active joint repositioning (AJR) tasks. The AJR tasks measure the ability to actively reproduce a previously presented joint angle. Because integration between the central nervous system and peripheral receptors is believed to be a contributing factor for an adequate joint stability (Roy et al., 2017; Suprak, 2011), proprioception emerges as a crucial element of shoulder stability and control (Furmanek et al., 2014; Lubiatowski et al., 2013; Myers and Lephart, 2000).

Taping techniques could be an interesting option to improve shoulder neuromuscular control. Kinesiotaping is widely used in clinics (de Oliveira et al., 2017b), and several types of application, such correction techniques are believed to improve shoulder neuromuscular control (Kase et al., 1996) by repositioning the humeral head in the glenoid fossa (Kim et al., 2014), and thus favoring an increase of AHD. While patients with RCTe have been shown to have prprioceptive deficits (Sahin et al., 2017), kinesiotaping has been argued to stimulate muscle activity adaptation, *via* proprioceptive feedback, allowing to recognize the position of a limb in space and perceive a limb motion (Aydin et al., 2001). Therefore, kinesiotaping could improve both shoulder proprioception and AHD in this population.

Previous studies have reported that elastic taping may improve the AHD (Harput et al., 2017; Luque-Suarez et al., 2013; Lyman et al., 2017) and shoulder proprioception (Burfeind and Chimera, 2015) in healthy individuals. Very few, however, have examined the effects of kinesiotaping on shoulder proprioception in individuals with RCTe, and none has investigated its effects on the AHD in this population. The current study, therefore, aims ***to investigate the immediate effects of kinesiotaping on AHD and active shoulder joint repositioning in individuals with RCTe.*** Based on the arguments presented above, we hypothesized that kinesiotaping would improve proprioception and increase AHD immediately after its application in individuals with RCTe.

2. Methods

2.1. Participants

Twenty-three individuals (14 men, 9 women) diagnosed with RCTe were recruited from a mailing list of employees and students at Laval University. To be eligible, participants had to present at least one positive finding in each of the following categories: a) painful arc of movement during shoulder flexion or abduction; b) Neer or Kennedy-Hawkins impingement sign (Alqunaee et al., 2012); and c) pain on resisted external rotation, abduction or empty can test (Alqunaee et al., 2012). Exclusion criteria were: a) open wound that compromised kinesiotaping application and ultrasound recording; b) previous shoulder surgery; c) allergy or intolerance to kinesiotaping; d) adhesive capsulitis (Siegel et al., 1999); e) history of glenohumeral luxation in the last 12 months or of fracture of the shoulder girdle; f) shoulder pain reproduced by cervical movements; g) clinical sign of RC full-thickness tears (lag signs) (Hertel et al., 1996; Miller et al., 2008).

All participants signed a detailed informed consent. The sectorial rehabilitation and social integration research ethics committee of the CIUSSS-CN approved this study, which complies with the ethical standards set out in the Declaration of Helsinki for human research.

2.2. Study design

All participants took part in a single evaluation session (cross-sectional design). After providing written informed consent, eligibility criteria were confirmed. Thereafter, participants filled out symptomatology and comorbidity questionnaires. Then, study outcomes were assessed. The AJR was evaluated first, followed by AHD.

Before collecting AJR data, two practice trials were performed in each tested position to familiarize the participants with the testing procedures. Thereafter, AJR of the painful shoulder was evaluated without kinesiotaping in the following order: 1) flexion, low-amplitude; 2) flexion, mid-amplitude; 3) abduction, low-amplitude; 4) abduction, mid-amplitude. Subsequently, measures of AHD with the arm at rest (0°) and 60° of shoulder abduction, without kinesiotaping, were taken consecutively. Finally, 3-strips of therapeutic kinesiotaping for RCTe were applied on the symptomatic shoulder (Fig. 1) and, immediately after, the same measurements were retaken in the same order.

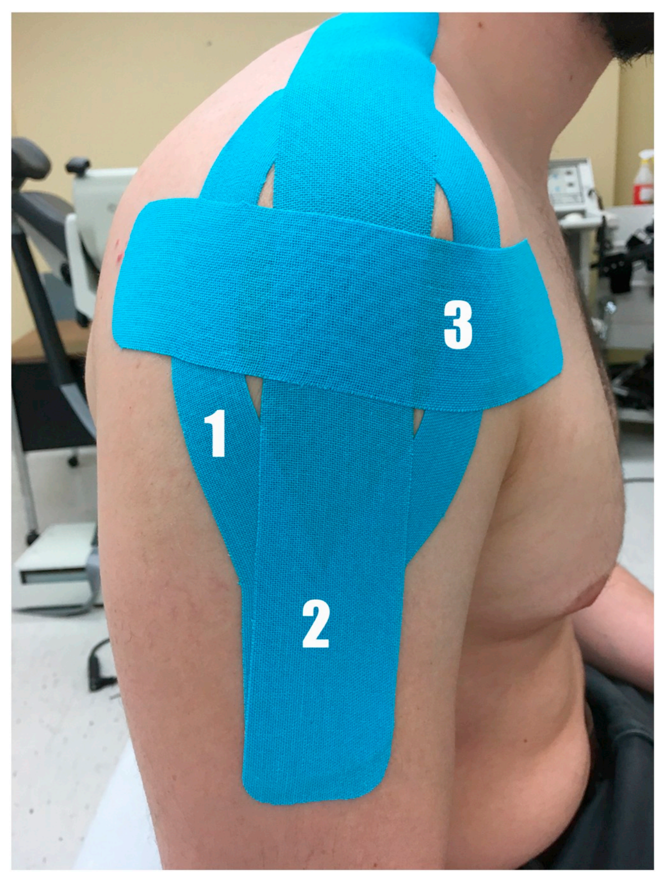

Fig. 1. Kinesiotaping application. First strip (1: Y-shape surrounding the three portions of the deltoid muscle for inhibition and relaxation), second strip (2: I-shape in functional correction for multiaxial shoulder instability over the glenohumeral joint, supraspinatus, trapezius, and middle deltoid muscles), and third strip (3: I-shape in mechanical correction for glenohumeral joint).

Fig. 2. Placement of the IMU wireless sensor used in active joint repositioning task.

2.3. Outcome measure

2.3.1. Active joint repositioning (AJR)

The AJR was evaluated using a standardized procedure based on the methods described by Zanella et al. (2001) and Vafadar et al. (2016). Previous studies using similar protocols have reported excellent test-retest reliability (intraclass correlation coefficients [ICC] = 0.96–0.99) (Zanella et al., 2001) of this method for evaluating AJR. Inertial measurement unit (IMU) sensors (Delsys Inc., Boston, MA, USA) were used to determine the accuracy in actively reproducing a shoulder angle. IMU sensors are reliable and valid for measuring shoulder angles (Cuesta-Vargas et al., 2010).

To record arm position, one sensor was placed at the acromioclavicular joint as a reference point. A second sensor was placed on the anterolateral face of the humerus, 5 cm above the lateral epicondyle, and a third on the posterior aspect of the forearm, 5 cm above from the styloid process of the ulna. Finally, to monitor the trunk position during arm elevation, an IMU sensor was placed over the spinous process of the C7 vertebra (Fig. 2). All measurements were taken with participant standing.

For each arm position and specific range of movements, participants performed three trials. The first trial was performed with eyes opened, where each participant auto-selected an arm position within the specific range (low-amplitude: 45°–65°, mid-amplitude: 80°–100°) delimited by marks on the panel or wall. The second and third trials were performed blindfolded. A laser dot, emitted by a laser pointer attached over the distal humerus with a customized bracelet, was used to identify, during the first trial, whether the angle achieved by the participant was within the predefined ranges (low- or mid-amplitude). Instructions to keep the elbow fully extended and forearm and wrist in a neutral position (thumbs up, without any upper limb rotation) during the whole movement, were provided to all participants between each trial. Additionally, participants were instructed to elevate their arms at a comfortable speed, to maintain this position for a few seconds (2 to 3 s) and bring the arms back to the starting position. Immediately after, participants were asked to actively reposition the shoulder at the same position previously selected, but without any auditory or visual feedback, and to stop the arm when they felt that the position, previously auto-selected, was reached again. At least, 5 s rest between trials and 2 min between movement ranges were given to all participants. During this task, participants did not receive any real-time feedback about their performance, except during open-eyes trials, where they could look at their hand, arm position and laser dot on the panel or wall.

The angle reached during arm elevation was obtained from the IMU using Delsys EMGWorks® Analysis software (Delsys Inc., Boston, MA, USA). Absolute repositioning error, calculated from the difference between the average of the two blindfolded trials and the single opened eyes trial within each amplitude, was used for data analysis.

2.3.2. Ultrasound imaging

The AHD was measured using an ultrasound scanner (Logic *e*9, GE Healthcare, Milwaukee, WI, USA) with a 4–15 MHz linear array probe. Ultrasound imaging has been shown to be a reliable method to assess AHD (ICC = 0.98 [0.97–0.99], minimal detectable change [MDC] = 0.70 mm) (McCreesh et al., 2016). Two trials were taken in two arm positions (at rest and at 60° of active shoulder abduction). The probe was positioned on the anterior aspect of the lateral surface of acromion along the longitudinal axis of the humerus in a coronal plane, where both the acromion and humerus can be viewed (Fig. 3a and b). During recording at rest, participants were seated up with the arm in neutral position, forearm resting on a pillow on their lap, and elbow flexed at 90°. The same procedures were followed to record images at

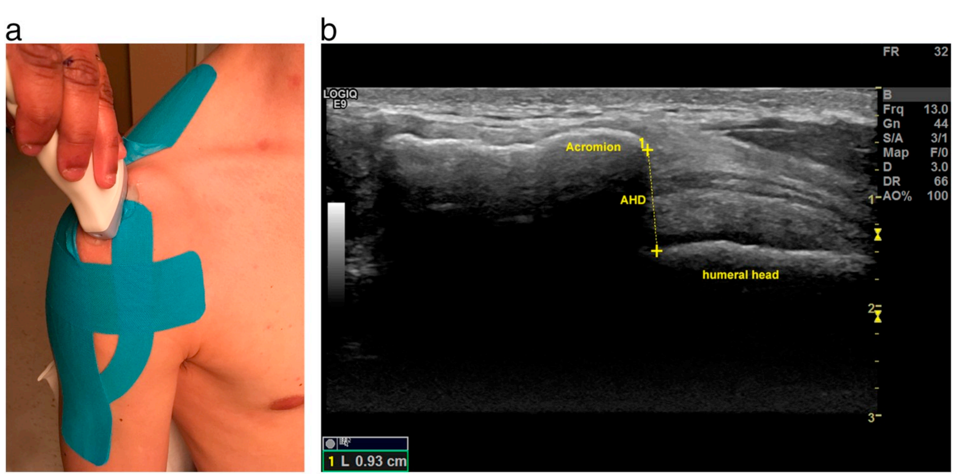

Fig. 3. Kinesiotaping technique for RCTe and ultrasonography illustrating the AHD measurements at rest (0°). The ultrasound transducer was placed and adjusted for viewing both the acromion and humeral head simultaneously.

Table 1
Demographic characteristics ($n = 22$).

	Mean (SD)
Demographic characteristics	
Age (years)	29.1 (6.7)
Height (m)	1.77 (0.12)
Weight (kg)	74.4 (14.2)
Duration of symptoms (months)	16.9 (20.9)
Dominance	
Right handed	90.9%, $n = 20$
Left handed	9.1%, $n = 2$
Dominant shoulder affected (72.7%, 16/22)	
Right shoulder	93.7%, 15/16
Left shoulder	6.3%, 1/16

SD: standard deviation.

60° shoulder abduction; however, a belt fixed to a custom-made chair and attached to the proximal forearm was used to restrain the abduction to 60°. Before each measurement, this angle (60°) was confirmed by an inclinometer, which is a valid and reliable tool for measuring shoulder angles (ICC flexion = 0.95 [0.90–0.98], ICC abduction = 0.97 [0.94–0.98], SEM = 2°) (Kolber et al., 2012). Participants were instructed to maintain the belt slightly stretched during data collection, to keep actively the angle of interest. To reduce the possibility of muscular fatigue, participants were instructed to bring their arm down between each trial or any time that fatigue was felt. An interval of, at least, 20 s were given between trials.

2.4. Kinesiotaping techniques

After a proper skin cleansing, the standard 5 cm wide blue Kinesio® Tex Classic was applied on the symptomatic shoulder using a combination of techniques designed for RCTe and symptoms (Fig. 1) (Kase et al., 2003). This technique involves the use of three tape strips, as follows: 1) Y-shape with light tension (15–25%), surrounding the deltoid muscles, from insertion to origin to provide inhibition and deltoid relaxation (de Oliveira et al., 2017b; Djordjevic et al., 2012; Kase et al., 2003); 2) I-shape with severe tension (50–75%), from 7 to 10 cm above the acromioclavicular joint to 7–10 cm below the deltoid tuberosity, passing over the supraspinatus, trapezius, glenohumeral joint, and middle deltoid (Kase et al., 2003), aiming functional correction of multiaxial shoulder instability; 3) I-shape with severe tension (50–75%), placed with inward pressure, from coracoid process to posterior deltoid, just slightly below the coracoacromial arch (Kase et al., 1996; Kase et al., 2003) for mechanical correction at the glenohumeral joint.

After application, adhesion of the kinesiotaping to the skin was stimulated by rubbing the surface of each strip vertically and horizontally. All applications followed the principles described by Kase et al. (2003) and were applied by the same physiotherapist, certified by Kinesio®Taping Association International (KTAI). During AHD measurement with kinesiotaping, part of the second strip was cut to allow the placement of the probe between the acromion and humerus (Fig. 3a).

2.5. Sample size

The sample size was determined based on expected change on the AHD at 60° abduction. Using similar AHD measurements, a previous study (Harput et al., 2017) reported that AHD at 60° abduction increased significantly (from 10.16 to 10.85 mm, $p < 0.05$) in healthy subjects. Considering the following parameters (G*Power 3.1.9.2, *t*-tests, difference between two dependent means [matched pairs]; $\alpha = 0.05$, power [1-β] = 0.95, effect size [ES] = 0.817) (Faul et al., 2007), at least 22 individuals with RCTe would be sufficient to ensure the robustness of the results.

2.6. Statistical and data analysis

All data analyses were performed using SPSS Statistics 20 for *Windows* (IBM Corp., Armonk, USA). The level of statistical significance was set at 5%. Descriptive statistics are expressed as mean and standard deviation (SD).

For the AHD, the Shapiro-Wilk's test was used to detect the normal distribution of the AHD data. A 2-way analysis of variance (ANOVA) for repeated measures (general linear model; SPSS 20, proc. GLM) was then used to evaluate the effects of the kinesiotaping application on AHD (2 angles [0°, 60°] × 2 conditions [no KT, with KT]). Intra-rater/intra-session reliability of AHD measurements was analysed by comparing the two measurements performed at each position using ICC (2-way mixed model and 95% confidence interval).

For AJR, a gamma distribution was detected. (Stacy, 1962) Therefore, a 3-way ANOVA for repeated measures using Generalized Estimating Equations (GEE; SPSS 20, proc. GENLIN; corrtype = unstructured, distribution = Gamma, link = log) was used to compare the effects of kinesiotaping on the AJR with movement (flexion, abduction), range (low-amplitude, mid-amplitude) and condition (no KT, with KT) as factors. GEE's posthoc tests were conducted in attempting to detail interactions among factors.

3. Results

Demographic characteristics are presented in Table 1. From the 23 participants included, one woman presented an AHD measure three times greater than the mean at baseline measurements. She was considered an outlier and was excluded from the statistical analyses. This resulted in 22 participants (63.6% men [$n = 14$] and 36.4% women [$n = 8$]) enrolled into the study.

For AHD, a significant 2-way interaction between condition and angle was found ($p = 0.013$). Post-hoc analysis showed a significant increase of AHD at 60° abduction with kinesiotaping compared to without kinesiotaping ($\Delta AHD = 0.94$ mm, $p < 0.001$, observed power = 0.987) (Table 2). There was no significant difference at rest ($p = 0.299$). The intra-rater reliability of AHD measurements was excellent (at rest: $ICC_{nokt} = 0.93[0.83–0.97]$, $ICC_{kt} = 0.96[0.91–0.98]$; at 60° of abduction, $ICC_{kt} = 0.97[0.93–0.99]$ and $ICC_{nokt} = 0.92[0.83–0.97]$.

For AJR, the ANOVA GEE model revealed no significant 3-way interaction ($p = 0.773$) among the factors (movement, range, intervention). In addition, there were no significant 2-way interactions. Details can be viewed in Table 3.

4. Discussion

This study demonstrated an immediate increase in the AHD at 60° shoulder abduction with kinesiotaping, whereas no significant changes in the absolute error (AE) were observed for the AJR in both low- and mid-amplitude movements.

Table 2
Descriptive statistics of the acromiohumeral distance (AHD) in two conditions (with and without kinesiotaping) ($n = 22$).

	AHD_{nokt}	AHD_{kt}	ΔAHD (95% CI)	*p*-value
0° (at rest)	11.19 (1.47)	11.46 (1.85)	0.27 (−0.26 to 0.79)	0.299
60° abduction	8.94 (1.94)	9.88 (1.91)	0.94 (0.50 to 1.38)	< 0.001*

Values expressed as mean (standard deviation). AHD is expressed as width in millimeters.
AHD_{nokt}: acromiohumeral distance without kinesiotaping. AHD_{kt}: acromiohumeral distance with kinesiotaping. ΔAHD: difference between conditions (AHD_{nokt} and AHD_{kt}), while positive values mean increase and negative values mean reduction. CI: confidence interval.
* Difference statistically significant ($p < 0.05$).

Table 3
Mean absolute error scores during the joint repositioning task for testing proprioception in two conditions (without [NoKT] and with kinesiotaping [KT]) (n = 22).

	NoKT	KT	Mean difference (95% CI)	*p*-value
Low-amplitude (45°–65°)				
Flexion	3.48 (2.22)	3.01(2.61)	−0.46 (−1.61 to 0.68)	0.427
Abduction	2.69 (2.44)	3.15 (3.22)	0.47 (−0.88 to 1.82)	0.497
Mid-amplitude (80°–100°)				
Flexion	2.90 (2.20)	3.33 (2.07)	0.42 (−0.68 to 1.54)	0.448
Abduction	1.95 (1.30)	2.75 (1.84)	0.80 (−0.26 to 1.86)	0.140

Values are expressed as mean (standard deviation). Proprioception is expressed as mean of absolute error in degrees (°).
NoKT: absolute error without kinesiotaping. KT: absolute error with kinesiotaping. Mean difference: difference between conditions (NoKT and KT), while positive values mean increase and negative values mean reduction in the absolute error. CI: confidence interval.

Current evidence showed that kinesiotaping does not enhance proprioception in healthy subjects (Aarseth et al., 2015; Zanca et al., 2016). For example, Aarseth et al. (2015) investigated shoulder proprioception in healthy subjects with kinesiotaping at 50°, 90° and 110° in the scapular plane, whereas Zanca et al. (2016) examined shoulder proprioception with kinesiotaping at 50°, 70° and 90° in the scapular plane, but following a muscle fatigue protocol. Both studies did not find any significant effects in the joint position sense with kinesiotaping. Because healthy individuals are less likely to have proprioceptive deficits (Lephart et al., 1994), we hypothesized that individuals with symptomatic RCTe, in whom proprioceptive deficits are more common (Anderson and Wee, 2011), could benefit from the kinesiotaping for improving their proprioception. Notwithstanding, our results indicate that kinesiotaping did not improve AJR ability in individuals with RCTe, which does not support our *a priori* hypotheses.

Our findings corroborate Keenan et al. (2017) who did not find significant differences in shoulder threshold to detect passive motion (TTDPM) when comparing individuals with RCTe (n = 10) with (AE = 2.17°) and without kinesiotaping (AE = 2.85°). In our study, the mean AE measured without kinesiotaping were inferior to 3.5°, while the mean difference between conditions (without and with kinesiotaping) were < 1° (Table 3). A possible explanation for the results of Keenan et al. (2017) and also ours, is the possibility that the performance during the AJR task was influenced by individual proprioceptive ability. It is likely that individuals with good proprioception or with baseline values near optimal ability may be good enough not to need any improvements in their level of proprioception, whereas individuals with poor proprioceptive ability may be more susceptible to the kinesiotaping effects. A previous study (Callaghan et al., 2008) has demonstrated that participants with poor proprioception (AE > 5°) improved their abilities to detect passive motion with kinesiotaping. In our study, the number of participants presenting an AE ≥ 5° was not large enough to provide robust results (n = 5), but we observed that all of them improved, especially in mid-range movements, with mean improvements between 3 and 5°. Thus, the improvements in proprioceptive ability provided by kinesiotaping could be more significant in participants with initially poor proprioception. Therefore, further studies should focus on individuals identified with poor proprioceptive ability at baseline to determine whether the level of proprioceptive ability impacts the kinesiotaping effects.

Narrowing of the subacromial space is a common deficit associated with RCTe (Seitz et al., 2011). It is often associated with other deficits such as altered muscle activation and loss of force-couple among RC muscles, resulting in shoulder muscle imbalance (de Oliveira et al., 2017a; Myers et al., 2009). Therefore, methods that could help avoiding excessive reduction in subacromial space during arm elevation may be important for individuals with RCTe. Previous studies have examined the effect of kinesiotaping on the AHD in healthy subjects (Harput et al., 2017; Luque-Suarez et al., 2013). Harput et al. (2017) investigated the immediate effects of kinesiotaping on AHD at 60° shoulder abduction in 41 asymptomatic volleyball players and found a significant increase in AHD with kinesiotaping (0.69 mm, $p < 0.001$) that were, according to the authors, attributed to a mechanical correction provided by kinesiotaping (Harput et al., 2017). Luque-Suarez et al. (2013) compared the effects of kinesiotaping to sham-kinesiotaping on AHD (n = 49) at rest and 60° in the scapular plane. The authors (Luque-Suarez et al., 2013) found that kinesiotaping increased significantly the AHD (1.16 mm) and argued that the increase was due to changes in the firing pattern of the RC muscles. Both studies addressed only asymptomatic participants.

To our knowledge, the current study is the first to examine the effects of kinesiotaping on AHD in individuals with symptomatic RCTe. Because previous studies have shown that kinesiotaping increased AHD in healthy subjects, we hypothesized that kinesiotaping could provide the same effect in individuals with RCTe. Our results showed that AHD increased significantly at 60° shoulder abduction with kinesiotaping (0.94 mm), supporting our main hypothesis. Although it seems a minor change, the AHD increased 10.5% with kinesiotaping compared to without, on average, which may be significant for symptomatic patients. This result is in line with a recent study (Navarro-Ledesma and Luque-Suarez, 2018) that demonstrated a reduction of 7.4% (0.51 mm) in the AHD of symptomatic shoulders at 60° in scapular plane compared to healthy contralateral shoulders. Given that a greater occupation ratio of the subacromial space in individuals with RCTe compared to healthy controls may be associated with this AHD reduction due to thickness of supraspinatus tendon (Michener et al., 2015), it is likely that the increase observed in our study might contribute to reduction of compression of the subacromial structures during arm elevation. Therefore, the AHD increase observed in our study has potential to be important for pain relief. Notwithstanding, our results should be interpreted with caution as the effects of kinesiotaping on symptoms and functional limitations were not investigated in this study. In addition, no significant correlation between the AHD and shoulder functional limitations in individuals with RCTe have been reported (Navarro-Ledesma et al., 2017). Therefore, our data do not allow us to state whether this increase is sufficient to provide clinically meaningful changes in symptoms and functional limitations caused by RCTe.

Our findings indicate that kinesiotaping may have contributed to restraining the humeral head superior translation during arm elevation, which could be interpreted as a mechanical correction in the glenohumeral joint; however, the physiological mechanism behind this effect is still unclear. Adjustments in the muscular activity emerge as a possible explanation for these results. A previous study (Alexander et al., 2003) reported that H-reflex amplitude decreased with taping on lower trapezius in healthy subjects, contributing to inhibition of this muscle. Therefore, it is plausible that the activation of deltoid muscle has been inhibited with kinesiotaping, as intended by the first strip surrounding the three deltoid portions (Fig. 1), favoring a reduction of the narrowing of the humeral head in the subacromial space during arm elevation, resulting in AHD increase. Nevertheless, as muscle activity was not investigated in our study, future work should verify whether kinesiotaping does reduce muscle activity.

4.1. Limitations

We recognize some limitations in this study. First, only the immediate effects of kinesiotaping were examined. A mid- and long-term examination should be conducted to identify prolonged effects of kinesiotaping. In addition, only one aspect of proprioception was explored in this study. Other aspects of proprioception such as kinesthesia and sensation of effort, could be more (or less) sensitive than the AJR sense to the changes in proprioception.

5. Conclusions

The application of kinesiotaping led to an immediate increase in AHD at 60° shoulder abduction, whereas it had no immediate effect on low- and mid-amplitude AJR in individuals with RCTe. Future studies are needed to determine how much these effects are clinically meaningful, in the long-term, for symptomatic individuals with RCTe.

Competing interest

The authors have no relevant conflict of interests to declare.

Ethics approval

The sectorial rehabilitation and social integration research ethics committee of the Center Integrated University Health and Social Services from Capitale Nationale (CIUSSS-CN) approved this study, which complies with the ethical standards set out in the Declaration of Helsinki for human research.

Funding

This work was supported by the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES). FCLO receives a doctoral scholarship from the Brazilian Government through the Science without Borders program in association with the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – CAPES. JSR is supported by salary awards from the Fonds de Recherche Québec-Santé (FRQS) and the Canadian Institutes of Health Research (CIHR).

References

Aarseth, L.M., Suprak, D.N., Chalmers, G.R., Lyon, L., Dahlquist, D.T., 2015. Kinesio tape and shoulder-joint position sense. J. Athl. Train. 50, 785–791.
Ager, A.L., Roy, J.S., Roos, M., Belley, A.F., Cools, A., Hebert, L.J., 2017. Shoulder proprioception: how is it measured and is it reliable? A systematic review. J. Hand Ther. 30, 221–231.
Alexander, C.M., Stynes, S., Thomas, A., Lewis, J., Harrison, P.J., 2003. Does tape facilitate or inhibit the lower fibres of trapezius? Man. Ther. 8, 37–41.
Alqunaee, M., Galvin, R., Fahey, T., 2012. Diagnostic accuracy of clinical tests for subacromial impingement syndrome: a systematic review and meta-analysis. Arch. Phys. Med. Rehabil. 93, 229–236.
Anderson, V.B., Wee, E., 2011. Impaired joint proprioception at higher shoulder elevations in chronic rotator cuff pathology. Arch. Phys. Med. Rehabil. 92, 1146–1151.
Aydin, T., Yildiz, Y., Yanmis, I., Yildiz, C., Kalyon, T.A., 2001. Shoulder proprioception: a comparison between the shoulder joint in healthy and surgically repaired shoulders. Arch. Orthop. Trauma Surg. 121, 422–425.
Bey, M.J., Brock, S.K., Beierwaltes, W.N., Zauel, R., Kolowich, P.A., Lock, T.R., 2007. In vivo measurement of subacromial space width during shoulder elevation: technique and preliminary results in patients following unilateral rotator cuff repair. Clin. Biomech. 22, 767–773.
Bjelle, A., 1989. Epidemiology of shoulder problems. Baillieres Clin. Rheumatol. 3, 437–451.
Burfeind, S.M., Chimera, N., 2015. Randomized control trial investigating the effects of kinesiology tape on shoulder proprioception. J. Sport Rehabil. 24, 405–412.
Callaghan, M.J., Selfe, J., McHenry, A., Oldham, J.A., 2008. Effects of patellar taping on knee joint proprioception in patients with patellofemoral pain syndrome. Man. Ther. 13, 192–199.
Cuesta-Vargas, A.I., Galan-Mercant, A., Williams, J.M., 2010. The use of inertial sensors system for human motion analysis. Phys. Ther. Rev. 15, 462–473.
de Oliveira, F.C.L., Bouyer, L.J., Ager, A.L., Roy, J.S., 2017a. Electromyographic analysis of rotator cuff muscles in patients with rotator cuff tendinopathy: a systematic review. J. Electromyogr. Kinesiol. 35, 100–114.
de Oliveira, F.C.L., de Fontenay, B.P., Bouyer, L.J., Desmeules, F., Roy, J.S., 2017b. Effects of kinesiotaping added to a rehabilitation programme for patients with rotator cuff tendinopathy: protocol for a single-blind, randomised controlled trial addressing symptoms, functional limitations and underlying deficits. BMJ Open 7, e017951.
Desmeules, F., Minville, L., Riederer, B., Cote, C.H., Fremont, P., 2004. Acromio-humeral distance variation measured by ultrasonography and its association with the outcome of rehabilitation for shoulder impingement syndrome. Clin. J. Sport Med. 14, 197–205.
Djordjevic, O.C., Vukicevic, D., Katunac, L., Jovic, S., 2012. Mobilization with movement and kinesiotaping compared with a supervised exercise program for painful shoulder: results of a clinical trial. J. Manipulative Physiol. Ther. 35, 454–463.
Faul, F., Erdfelder, E., Lang, A.-G., Buchner, A., 2007. G* power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav. Res. Methods 39, 175–191.
Furmanek, M.P., Slomka, K., Juras, G., 2014. The effects of cryotherapy on proprioception system. Biomed. Res. Int. 61, 39–51.
Harput, G., Guney, H., Toprak, U., Colakoglu, F., Baltaci, G., 2017. Acute effects of scapular Kinesio Taping(R) on shoulder rotator strength, ROM and acromiohumeral distance in asymptomatic overhead athletes. J. Sports Med. Phys. Fitness 57, 1479–1485.
Hertel, R., Ballmer, F.T., Lombert, S.M., Gerber, C., 1996. Lag signs in the diagnosis of rotator cuff rupture. J. Shoulder Elb. Surg. 5, 307–313.
Kase, K., Tatyusuki, H., Tomoki, O., 1996. KinesioTM Taping Perfect Manual, 2nd ed. Ken Ikai Co Ltd., Tokyo, Japan.
Kase, K., Wallis, J., Kase, T., 2003. Clinical Therapeutic Applications of the Kinesio Taping Method, 1st ed. Ken Ikai Co Ltd., Tokyo, Japan.
Keenan, K.A., Akins, J.S., Varnell, M., Abt, J., Lovalekar, M., Lephart, S., Sell, T.C., 2017. Kinesiology taping does not alter shoulder strength, shoulder proprioception, or scapular kinematics in healthy, physically active subjects and subjects with Subacromial Impingement Syndrome. Phys. Ther. Sport 24, 60–66.
Kim, S.Y., Kang, M.H., Kim, E.R., Oh, J.S., 2014. Kinesio Taping improves shoulder internal rotation and the external/internal rotator strength ratio in patients with rotator cuff tendinitis. Isokinet. Exerc. Sci. 22, 259–263.
Kolber, M.J., Fuller, C., Marshall, J., Wright, A., Hanney, W.J., 2012. The reliability and concurrent validity of scapular plane shoulder elevation measurements using a digital inclinometer and goniometer. Physiother. Theory Pract. 28, 161–168.
Lephart, S.M., Warner, J.J., Borsa, P.A., Fu, F.H., 1994. Proprioception of the shoulder joint in healthy, unstable, and surgically repaired shoulders. J. Shoulder Elb. Surg. 3, 371–380.
Lubiatowski, P., Ogrodowicz, P., Wojtaszek, M., Kaniewski, R., Stefaniak, J., Dudzinski, W., Romanowski, L., 2013. Measurement of active shoulder proprioception: dedicated system and device. Eur. J. Orthop. Surg. Traumatol. 23, 177–183.
Luque-Suarez, A., Navarro-Ledesma, S., Petocz, P., Hancock, M.J., Hush, J., 2013. Short term effects of kinesiotaping on acromiohumeral distance in asymptomatic subjects: a randomised controlled trial. Man. Ther. 18, 573–577.
Lyman, K.J., Gange, K.N., Hanson, T.A., Mellinger, C.D., 2017. Effects of 3 different elastic therapeutic taping methods on the subacromial joint space. J. Manipulative Physiol. Ther. 40, 494–500.
McCreesh, K.M., Crotty, J.M., Lewis, J.S., 2015. Acromiohumeral distance measurement in rotator cuff tendinopathy: is there a reliable, clinically applicable method? A systematic review. Br. J. Sports Med. 49, 298–305.
McCreesh, K.M., Anjum, S., Crotty, J.M., Lewis, J.S., 2016. Ultrasound measures of supraspinatus tendon thickness and acromiohumeral distance in rotator cuff tendinopathy are reliable. J. Clin. Ultrasound 44, 159–166.
Michener, L.A., Subasi Yesilyaprak, S.S., Seitz, A.L., Timmons, M.K., Walsworth, M.K., 2015. Supraspinatus tendon and subacromial space parameters measured on ultrasonographic imaging in subacromial impingement syndrome. Knee Surg. Sports Traumatol. Arthrosc. 23, 363–369.
Miller, C.A., Forrester, G.A., Lewis, J.S., 2008. The validity of the lag signs in diagnosing full-thickness tears of the rotator cuff: a preliminary investigation. Arch. Phys. Med. Rehabil. 89, 1162–1168.
Myers, J.B., Lephart, S.M., 2000. The role of the sensorimotor system in the athletic shoulder. J. Athl. Train. 35, 351–363.
Myers, J.B., Hwang, J.H., Pasquale, M.R., Blackburn, J.T., Lephart, S.M., 2009. Rotator cuff coactivation ratios in participants with subacromial impingement syndrome. J. Sci. Med. Sport 12, 603–608.
Navarro-Ledesma, S., Luque-Suarez, A., 2018. Comparison of acromiohumeral distance in symptomatic and asymptomatic patient shoulders and those of healthy controls. Clin. Biomech. 53, 101–106.
Navarro-Ledesma, S., Struyf, F., Labajos-Manzanares, M.T., Fernandez-Sanchez, M., Morales-Asencio, J.M., Luque-Suarez, A., 2017. Does the acromiohumeral distance matter in chronic rotator cuff related shoulder pain? Musculoskelet. Sci. Pract. 29, 38–42.
Pijls, B.G., Kok, F.P., Penning, L.I., Guldemond, N.A., Arens, H.J., 2010. Reliability study of the sonographic measurement of the acromiohumeral distance in symptomatic patients. J. Clin. Ultrasound 38, 128–134.
Proske, U., Gandevia, S.C., 2012. The proprioceptive senses: their roles in signaling body shape, body position and movement, and muscle force. Physiol. Rev. 92, 1651–1697.
Roy, J.S., Bouyer, L.J., Langevin, P., Mercier, C., 2017. Beyond the joint: the role of central nervous system reorganizations in chronic musculoskeletal disorders. J. Orthop. Sports Phys. Ther. 47, 817–821.
Sahin, E., Dilek, B., Baydar, M., Gundogdu, M., Ergin, B., Manisali, M., Akalin, E., Gulbahar, S., 2017. Shoulder proprioception in patients with subacromial impingement syndrome. J. Back Musculoskelet. Rehabil. 30, 857–862.
Seitz, A.L., McClure, P.W., Finucane, S., Boardman 3rd, N.D., Michener, L.A., 2011. Mechanisms of rotator cuff tendinopathy: intrinsic, extrinsic, or both? Clin. Biomech. 26, 1–12.
Siegel, L.B., Cohen, N.J., Gall, E.P., 1999. Adhesive capsulitis: a sticky issue. Am. Fam. Physician 59, 1843–1852.
Stacy, E.W., 1962. A generalization of the gamma distribution. Ann. Math. Stat. 33, 1187–1192.
Suprak, D.N., 2011. Shoulder joint position sense is not enhanced at end range in an unconstrained task. Hum. Mov. Sci. 30, 424–435.
Urwin, M., Symmons, D., Allison, T., Brammah, T., Busby, H., Roxby, M., Simmons, A., Williams, G., 1998. Estimating the burden of musculoskeletal disorders in the community: the comparative prevalence of symptoms at different anatomical sites, and the relation to social deprivation. Ann. Rheum. Dis. 57, 649–655.
Vafadar, A.K., Cote, J.N., Archambault, P.S., 2016. Interrater and intrarater reliability and validity of 3 measurement methods for shoulder-position sense. J. Sport Rehabil. 19 (2014–0309).
Zanca, G.G., Gruninger, B., Mattiello, S.M., 2016. Effects of Kinesio taping on scapular kinematics of overhead athletes following muscle fatigue. J. Electromyogr. Kinesiol. 29, 113–120.
Zanella, P.W., Willey, S.M., Seibel, S.L., Hughes, C.J., 2001. The effect of scapular taping on shoulder joint repositioning. J. Sport Rehabil. 10, 113–123.