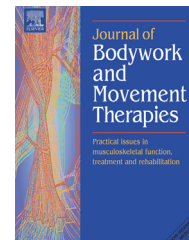


Available online at [www.sciencedirect.com](http://www.sciencedirect.com)

ScienceDirect

journal homepage: [www.elsevier.com/jbmt](http://www.elsevier.com/jbmt)

## OBSERVATIONAL LABORATORY STUDY

# Does 'Kinesio tape' alter thoracolumbar fascia movement during lumbar flexion? An observational laboratory study

Shihfan Jack Tu, MSc<sup>a</sup>, Roger C. Woledge, PhD<sup>a</sup>,  
Dylan Morrissey, PT PhD<sup>a,b,\*</sup>

<sup>a</sup> Sport and Exercise Medicine, Queen Mary University of London, Mile End Hospital, Bancroft Road, London, E1 4DG, UK

<sup>b</sup> Physiotherapy Department, Bart's Health NHS Trust, London, UK

Received 13 January 2016; received in revised form 16 March 2016; accepted 21 March 2016

## KEYWORDS

Kinesio tape;  
Thoracolumbar  
fascia;  
Ultrasound;  
Range of motion

**Summary** *Background:* Changes in thoracolumbar fascial thickness, structure and shear strain are associated with lower back pain (LBP). Therapeutic taping techniques such as Kinesio-Taping (KT) are increasingly used to treat LBP, albeit with variable effects and unclear mechanisms. However, evidence for quantifying how treatment effects in vivo fascia properties is inadequate. We therefore aimed to explore taping mechanisms using an in vivo ultrasound measurement.

*Methods:* Thoracolumbar ultrasound videos of known orientations and positions were taken from 12 asymptomatic participants (8 males and 4 females, aged  $22.9 \pm 3.59$ ) while performing velocity-guided lumbar flexion with and without KT applied. An automated algorithm using cross-correlation to track contiguous tissue layers across sequential frames in the sagittal plane, was developed and applied to two movements of each subject in each taping condition. Differences of inter-tissue movements and paracutaneous translation at tissue boundaries were compared.

*Results:* Significant reduction in the mean movement of subcutaneous tissue during lumbar flexion before and after taping was found. There was no difference in other observed tissue layers. Tissue paracutaneous translations at three boundaries were significantly reduced during lumbar flexion when KT was applied (skin-subcutaneous: 0.25 mm,  $p < 0.01$ ; subcutaneous-perimuscular tissue: 0.5 mm,  $p = 0.02$ ; and perimuscular-muscle: 0.46,  $p = 0.05$ ). No overall reduction in lumbar flexion was found ( $p = 0.10$ ).

*Conclusions:* KT reduced subcutaneous inter-tissue movement and paracutaneous translation in the superficial thoracolumbar fascia during lumbar flexion, and the relationship of such difference to symptomatic change merits exploration. Combining ultrasound data with muscle

\* Corresponding author. Sport and Exercise Medicine, Mile End Hospital, 275 Bancroft Road, London, E1 4DG, UK. Tel.: +44 7882 5010. E-mail address: [d.morrissey@qmul.ac.uk](mailto:d.morrissey@qmul.ac.uk) (D. Morrissey).

activation information may be useful to reveal potential mechanisms of therapeutic taping in patients with LBP.

© 2016 Elsevier Ltd. All rights reserved.

## Introduction

Kinesio-Taping (KT), developed by Kase et al. in the 1970s, is a popular taping technique (Kase et al., 2003a). Despite a poor understanding of its true effect or mechanism of action, widespread use of the technique has become an interesting and relatively new modality in treating musculoskeletal conditions, including rotator cuff tendonitis (Thelen et al., 2008), shoulder impingement syndrome (Kaya et al., 2011), acute whiplash (Gonzalez-Iglesias et al., 2009), patellofemoral pain (Akbas et al., 2011), and chronic lower back pain (Castro-Sanchez et al., 2012; Paoloni et al., 2011). This popularity may be due to the structure of the tape, which can be stretched along the longitudinal axis yet allows free movement of the taped body area. Other features of KT, such as its being thin, latex free and anti-allergenic or able to feature fashionable colours and patterns, may also be a marketing strength which has augmented the propensity to use KT. A common use is in flexion related lower back pain (AlBahel et al., 2013; Paoloni et al., 2011).

Lower back pain is a common disorder with a high recurrence and lifetime prevalence (Hoy et al., 2010). The condition represents a large socioeconomic burden to the healthcare system and society more generally due to the costs of treatment and time lost from work (Manchikanti et al., 2008; Martin et al., 2008). The cause of back pain remains unclear in over 80% of cases, even though some common spinal disorders related to LBP have been defined (Videman and Battié, 2012). Although current clinical practice guidelines recommend several treatments for LBP, most randomised controlled trials have shown that these treatments provide only mild to moderate clinical improvement in LBP patients (Van Tulder et al., 2006). The same guidelines also state that no difference has been proved between the various modalities of exercise-based therapy as well as manual therapy techniques. We therefore need better treatments. KT has been evaluated as a possible adjunct treatment. By adjunct, we mean a facilitator of treatments with longer term effect.

A particular problem in understanding the role of KT in lower back pain treatment is that there are many ways of applying KT, with different suggested underlying mechanisms yet the literature has focussed on effects possibly to the detriment of our understanding and application. Five systematic reviews (Kalron and Bar-Sela, 2013; Morris et al., 2013; Mostafavifar et al., 2012; Parreira et al., 2014a; Williams et al., 2012) examining the clinical effects of KT application in musculoskeletal and sports related injuries concluded that KT may only have a small beneficial effect. However, the reports are somewhat confused by the diversity of taping approaches combined in evidence synthesis. All reviews are discussing similar materials that

include some low quality trials or small sample sizes. The most recent review (Parreira et al., 2014a) even directly concluded that current evidence does not support the clinical importance of KT, because the benefit effect founded in the current studies were either too small to be clinically worthwhile or not significant. To summarise, current evidence may not be enough to support the efficacy of KT application. However, judging effects without clarity about the underlying mechanism of KT may confound clinical studies. A few of these have evaluated this therapeutic tool and were either looking at different conditions or investigating with a diversity of approaches. To date, there is no robust evidence to link pathophysiological effects and actual body reactions triggered by KT, thus no clear direction has emerged to suggest these considerations translate into clinical practice.

Due to a poor understanding of the mechanism of chronic non-specific lower back pain, treatment techniques applied to this condition tend to have an unconfirmed mechanism of action. A hypothesized pathophysiology of lower back pain indicated to the thoracolumbar fascia, although this currently remains unclear (Langevin and Sherman, 2007; Malanga and Colon, 2010). In a similar fashion, patients with chronic lower back pain for longer than 12 months have been found to increase the thickness of their thoracolumbar fascia (Langevin et al., 2009); and the fascia shear strain has been reduced when compared with those without LBP (Langevin et al., 2011). However, neither the causative mechanisms underlying these changes nor the relationship to the symptoms are clear. This pathophysiological difference could therefore potentially suggest a reason for further investigation on the mechanism of action when KT is applied.

The aim of the present study was therefore to explore the effect of KT application on the thoracolumbar fascia using a newly developed ultrasound tool. This exploration could provide a better understanding on how the thoracolumbar soft tissue responds to therapeutic taping, which could become a useful guideline for treatment selection. The objectives were to measure soft tissue movement in the thoracolumbar area; and lumbar range of motion when performing the lumbar flexion task with and without KT.

## Methods

### Study design

A snap shot observational study was carried out to develop the methodology and to explore potential taping mechanisms. Asymptomatic participants were recruited to develop empirical and analytical methodology, and the

preliminary results were analysed to ensure the method could be applied to symptomatic cohort.

Twelve subjects (8 males; Age  $22.9 \pm 3.59$ ; BMI  $21.22 \pm 2.65$ ), who had no history of lower back pain or any other chronic pain that had limited their work or daily activities, were invited to participate in the study.

## General procedure

Subjects were asked to perform speed-guided lumbar flexion-extension tasks in two states (without taping and with KT) in the data collection session; the collection procedure is shown in Fig. 1. A metronome set at 90 beats per minute was used to provide a time guide. Subjects were advised to finish their forward bending in a period of four beats and return to a natural position at the same speed. Subjects were allowed to have several practice runs to get familiar with this experimental movement in order to perform the action smoothly and avoid unnatural action or pauses while the exercise was taking place. The same procedure was done twice on initial subjects on different days to test its reliability. The speed and range of motion (ROM) might be slightly different between subjects, however kinematic data were recorded using a motion capture system for later normalisation. Relative movement and trunk angle registration were used in data analysis.

## Taping procedure

Several application techniques are currently used in treating patients with LBP. To minimise the effect of individual therapists, in this study taping was applied using I-shape strips taped over one erector spinae muscle, parallel to the spinous process of the lumbar vertebrae (Fig. 2). Before taping, subjects' skin was checked to make sure that there was no pre-existing skin lesion over the taping area. A small piece of KT was then applied to the arm for 20 min before the trial to ensure the subject was not allergic to the tape. KT was applied to a single side of the muscle, a computerised random number being used to decide which side to tape. Tapes were applied with 10% of tension (paper-off tension) from the top of the first sacrum up to the bottom edge of the T12 vertebrae (treatment area). Two anchors with 0% tension were then applied above and below the treatment area. To control taping tension, the length of the taping area was measured before taping, and the tape was cut accordingly. As recommended by the KT application guidelines (Kase et al., 2003b), while applying taping the patients were asked to flex their lumbar spine to their natural end (they were asked to touch the toes) to stretch the erector spinae muscle. Consequently, the tape created convolutions when the subject stood in neutral. In order to perform ultrasound scanning, a  $5 \times 1$  cm window beside the L2 and L3 vertebrae was cut on the tape strip (Fig. 2).

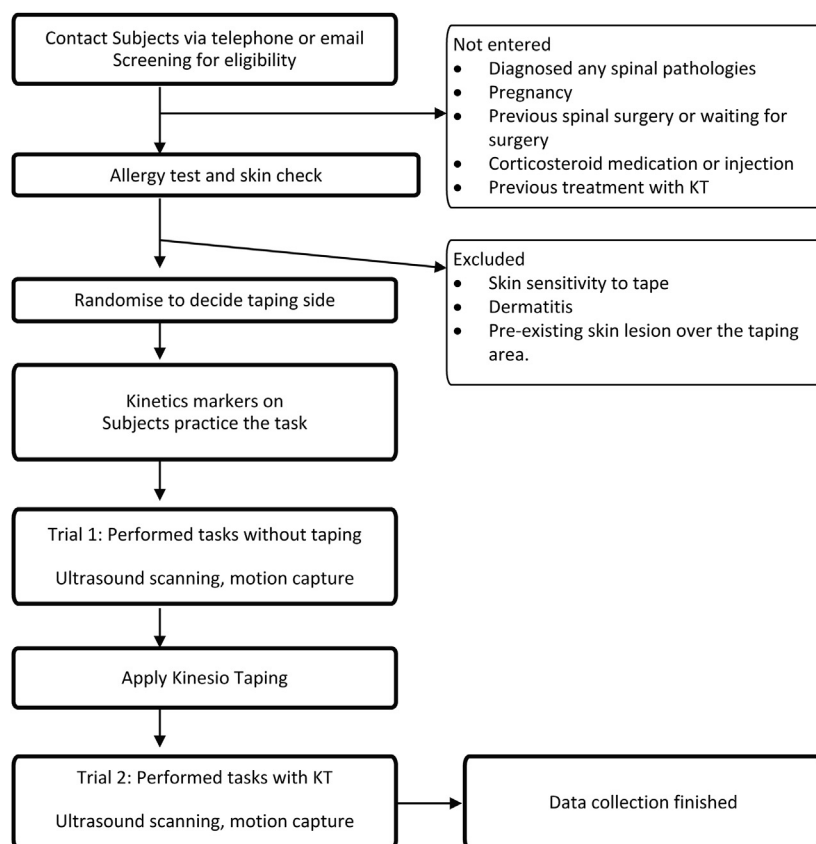
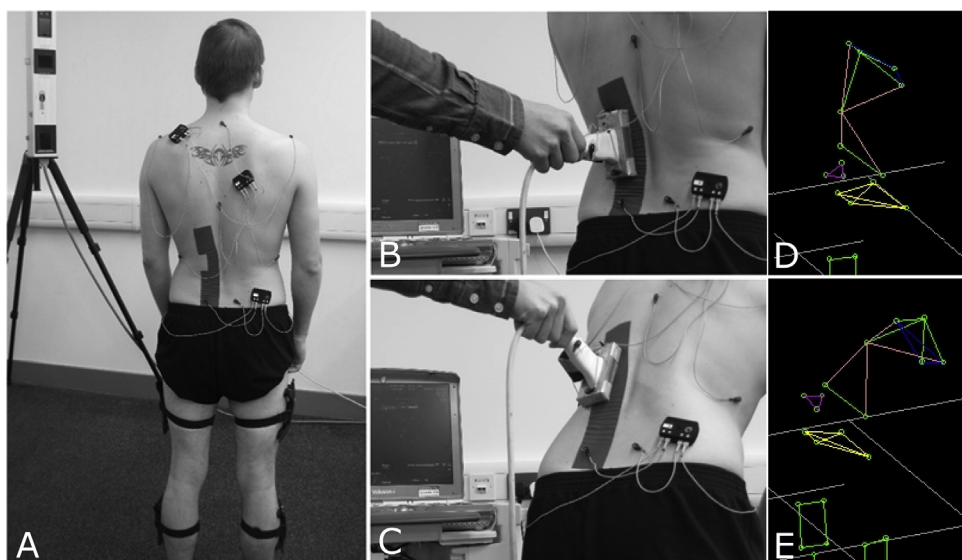


Figure 1 Flowchart of data collection procedure.



**Figure 2** Demonstration of KT application and data collection. A: KT application with cut-out, and motion capture marker positions. B&C: ultrasound scanning during movement; the probe head was attached with a frame and 3 motion markers. D&E: examples of stick figures in the motion capture system.

### Ultrasound collection

An ultrasound machine (Voluson i, GE Healthcare; WI, USA) with a frequency 4–12 MHz linear probe (GE 12L – RS, GE Healthcare; WI, USA) was used to collect data in the present study. Parasagittal b-mode cine ultrasound images of the lumbar tissue movements were collected synchronously with body kinematic data. Although the taping effect may appear in all areas where KT was applied, we have to choose a small window to observe due to the probe size. The transducer was placed at a point 3 cm lateral to the middle of the L2 and L3 spinous processes (Fig. 2), because the fascia planes are the most parallel to the skin in the higher level of the lumbar area (Langevin et al., 2009) which provided better accuracy of image processing. When performing trunk flexion, the caudal end of the transducer was stabilised on the subject's skin, and the skin was allowed to slide at the rostral end. The overall lateral and rostral translation of the ultrasound transducer was prevented during flexion movement. To ensure image quality, an ultrasound probe holder was made to avoid lateral translation and swing (Fig. 2).

### Motion capture

Active light emitting diodes (LEDs) were attached to the following body landmarks: acromion, spinal process of 7th cervical and 7th thoracic vertebrae, 10th rib angles, sternal angle, anterior superior iliac spine, posterior superior iliac spine. LED clusters were attached to thighs and shanks (Fig. 2). Three extra LEDs were used to monitor the motion of the ultrasound probe and record its orientation (Fig. 2). The three dimensional position of these LEDs was determined with an accuracy of  $\pm 1$  mm by using a CODA motion analysis system (v 6.79. Charnwood Dynamics; Leicester, UK) at a sampling rate of 200 Hz. The range of motion was

calculated by processing the marker position retrieved from segment orientations (sum of trunk and pelvis orientation).

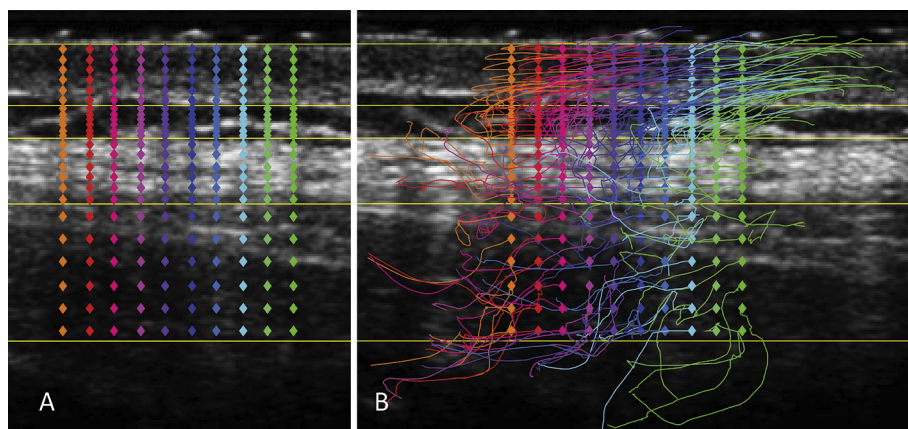
### Ultrasound tracking algorithm

A customised MATLAB (R2015a, Mathwork; MA, USA) based algorithm was used in the present study. The programme is designed to track fascia movements in 3D ultrasound images using a cross-correlation feature tracking method which is common in tendon research (Chernak and Thelen, 2012).

B-mode ultrasound videos were converted into an echogenicity matrix frame-by-frame. An investigator identified boundaries between skin, fascia and muscles according to echogenicity; the intra-investigator reliability of boundary identification was high (ICC = 0.98). The movements of tissue were then tracked by the programme. The centre area of each layer was defined as an area of interest. The programme automatically searched the contiguous area, and detected the movements within every layer. The positions were recorded and the routes of tissue movement were mapped (Fig. 3). Further movement calculations, including moving distance and boundary gliding, were carried out according to the map.

### paracutaneous tissue translation

This term was used to describe one of the main outcome measures which is the relative movements of two layers on either side of a tissue boundary, approximately parallel to the skin surface. Several terms were considered by the author before submitting. 'Shear strain', the ratio of deformation to original dimensions, was used in previous studies, because shape changes of the thoracolumbar fascial images were analysed and discussed (Langevin et al., 2011). However, the thoracolumbar tissue movements were monitored and the difference on the either



**Figure 3** Demonstration of ultrasound tracking algorithm. A: an example of layer recognition with 60 points of interest. B: an example of results of 60 tissue movement routes during the lumbar flexion task.

side of tissue boundaries were computed in the present study and do not accurately fit the definition of shear strain. 'Gliding', which is a common term to describe movement at joint surfaces, was also considered. Although boundaries on the sub-cutaneous lumbar tissue can be seen, they are not clear interface unlike joint surfaces. Connective tissues are connecting one layer to another and there are movement translations through layers. Therefore, we decided to use 'paracutaneous tissue translation' to describe the observed phenomenon.

### Statistics

Statistical analysis was performed using MATLAB Statistical toolbox (R2015a, Mathwork; MA, USA). Descriptive statistics were used to characterize the study sample. The paired t-test was used to test differences of tissue movements and paracutaneous translation at boundaries between conditions of no KT application and with KT. Statistical analyses were conducted at a 95% confidence level. P value < 0.05 was considered significant.

### Results

Movements of the subcutaneous zone (which contains fat and superficial fascia) were significantly reduced during the lumbar flexion (forward bending) task when KT was applied (Fig. 4A), though no difference was found in skin and muscle movements. Fig. 4B reveals the tissue movements when subjects were performing the lumbar extension (return to initial posture) task. There were no differences before and after KT was applied.

The inter-tissue paracutaneous translation in skin-subcutaneous and subcutaneous-perimuscular boundaries was significantly reduced during the lumbar flexion task when KT was applied (Table 1). Similarly, paracutaneous translation was also moderated in the fascia-muscle boundary; however, the difference was not statistically significant ( $p = 0.05$ ). No difference of paracutaneous inter-tissue translation was found when the subjects performed the return-to-stand task.

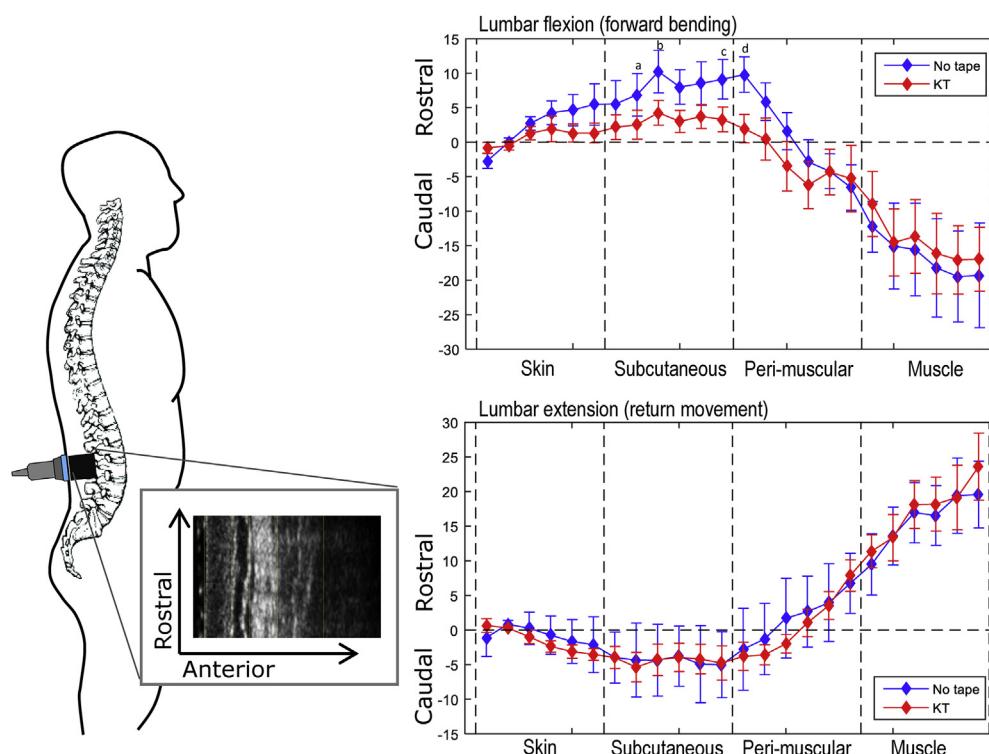
No significant differences in ROM was found after KT was applied. The mean lumbar flexion range was  $91.19 \pm 3.33^\circ$  before taping, and was  $92.47 \pm 1.80^\circ$  after ( $p = 0.10$ ,  $df = 11$ ).

### Discussion

The aim of the present study was to assess the impact of KT on the movements of the thoracolumbar tissue. Most studies concentrate on KT's effect on pain and symptoms (Williams et al., 2012), however, the evidence exploring its actual mechanisms is inadequate. It was therefore likely beneficial to understand the effect of KT on the skin and sub-cutaneous tissues in asymptomatic subjects during whole-body movements, in order to understand mechanisms and perhaps what kind of patients are most likely to benefit, myofascial related LBP for example. By understanding the KT mechanisms in those without pain, we will be able to compare any tissue movement observed in people with pain. Furthermore, comparison of symptomatic responders and non-responders may help us to understand pain mechanisms and response characteristics, therefore targeting treatment better.

The result of the present study shows that KT limited tissue movements in the subcutaneous zone, which is the area that contains fat tissue and superficial fascia, when the subjects were performing lumbar flexion tasks. However, KT did not repeat the alterations when the subjects were performing return-to-stand tasks. Interestingly, even though the tissue movements were moderated by KT, the mean angle of lumbar flexions was slightly increased after taping. The result of ROM change was not statistically significant ( $p > 0.05$ ), however. These results suggest that KT is likely to change actions of the subcutaneous tissue.

The ROM results of the present study do not corroborate the results of the study of Yoshida et al. Yoshida and Kahanov (2007), which reported a significant increase in the ROM upon application of KT, instead they support the findings of another KT study (Lemos et al., 2014) which reported no significant immediate improvement of ROM after applying KT. However, evidence on ROM improvement is currently conflicting. This may be due to two reasons:



**Figure 4** Comparison of tissue movements before and after KT applied. Red lines represent mean movements when KT was applied, while blue represents data without KT application. Error bars are standard error across 12 subjects. Scale unit: pixels (1 pixel = 0.12 mm). Statistics: a.  $p < 0.05$ ,  $T = 1.83$ ,  $df = 11$ ; b.  $p < 0.05$ ,  $T = 1.82$ ,  $df = 11$ ; c.  $p = 0.03$ ,  $T = 0.63$ ,  $df = 11$ ; d.  $p = 0.03$ ,  $T = 1.01$ ,  $df = 11$ .

**Table 1** paracutaneous tissue translation comparisons (t-test; unit: pixels).

	Interface	NT		KT		p-value
		Mean	Std.	Mean	Std.	
Lumbar Flexion	Skin/Sub	0.52	0.34	0.27	0.27	<0.01*
	Sub/Fascia	0.88	0.74	0.38	0.29	0.02*
	Fascia/Muscle	0.94	0.60	0.48	0.42	0.05
Return	Skin/Sub	0.35	0.38	0.33	0.49	0.43
	Sub/Fascia	0.52	0.72	0.31	0.20	0.20
	Fascia/Muscle	0.49	0.35	0.60	0.33	0.19

firstly, results were produced by different assessment methods; for example, Yoshida measured the distance between the finger and the toes and Lemos measured distance changes on lower back skin markers (Schober's test), although they both asked subjects bend to touch their toes. While in the present study, ROM were calculated by kinematic data (trunk and pelvis orientation). Second, the taping techniques were slightly different in each study. It is therefore difficult to compare results from the different studies.

Apart from ROM, the study's result provides unexpected findings that the method of KT used reduces overall movements and tissue paracutaneous translation between tissue layers. This may conflict with the findings published by Langevin et al. [Langevin et al., \(2011\)](#). which suggested

a 20% decrease in shear strain in the thoracolumbar fascia was predominant in chronic lower back pain patients, therefore challenging the theory that decreased shear predisposes individuals to developing chronic lower back pain, and that KT could be used to treat this. However, the findings from this previous paper don't imply causality, due to a lack of established causal relationships between LBP and altered fascia characteristics. It could be that the reduction of shear strain is an adaptive change to reduce LBP during movement. Further research to help identify these factors is needed.

There were a few limitations in the present study. Firstly, we did not compare the effect with a sham taping or different application methods - for example using different direction of tape tension, however, keeping the study procedure as simple as the standard taping method, which was introduced in KT books and prior studies ([Added et al., 2013](#); [Kase et al., 2003b](#); [Parreira et al., 2014b](#)), provides a clearer and focused view in research findings. Apart from KT, there are also other types of tapes are currently used in the clinical practice, McConnell tape and dynamic tape, for example. Only one particular methods of KT was applied in the present study, therefore it is uncertain if similar effect can be delivered using different tape or methods. More studies is required to answer this as no studies were looking at taping effect on tissue movement has been published.

Second, in order to capture the ultrasound videos of the taped area, a rectangular portion of the tape was removed to allow placement of the probe. This may have affected

the taping effect to the area from which results were retrieved and therefore may have had an impact upon overall movement and paracutaneous translation between layers. Unfortunately there was no obvious method that could be applied to avoid cutting a window in the tape, owing to the current limitation of ultrasonography techniques – ultrasonic waves do not penetrate KT. Another potential limitation was that the assessment could only be performed at the level of second and third lumbar spine due to the size of the ultrasound probe view. KT may affect movements of the whole thoracolumbar fascia. Nonetheless, the scanning position was chosen because of the flat surface in this level making the assessment and retrieval of higher quality images easier (Langevin et al., 2009). This may warrant further research in areas where mobility is more restricted. This would also offer a greater idea of the effects of KT on connective tissue and pathogenesis for lower back pain (Langevin and Sherman, 2007).

The present study did not monitor muscle activity during the tasks. Information about muscle activity should be considered for future research due to findings in other studies which note an altered muscle activity when KT was applied to other portions of the body (Gomez-Soriano et al., 2014; Martinez-Gramage et al., 2016). It has also been suggested that the reduction of paracutaneous boundary translation may be the result of impaired neuromuscular control and recruitment patterns of muscles during trunk movements. This has been shown to be associated with chronic lower back pain (Jacobs et al., 2009; MacDonald et al., 2009), and therefore analysis of this electromyography data could possibly reveal the neuromuscular mechanism of KT. There has been some previous research into the effect of KT on anticipatory control of the trunk, however evidence is currently conflicting (Bae et al., 2013; Voglar and Sarabon, 2014).

Irrespective of these limitations, there is a clear effect of KT on tissue movement. Further observational studies, particularly case series work, are then required in this study area. The key future experiment is repetition of these measures in patients with LBP. What we would like to observe is what happens to the tissues when some patients benefit or don't benefit from KT based on clinical responses, for example, subjective pain scale assessments, total ROM assessments.

## Conclusion

In summary, thoracolumbar tissue dynamics were altered in subjects without LBP after receiving KT application. Results suggest that KT may reduce sub-cutaneous connective tissue movements and inter-tissue translation at boundaries during lumbar flexion movement, however whether the degree or direction of change in tissue movement may represent a beneficial result after the application of KT remains uncertain.

## Conflicts of interest

Dr Morrissey is part-funded by the NIHR/HEE Senior Clinical Lecturer scheme (CAT SCL-2013-04-003). This report presents independent research part-funded by the National

Institute for Health Research (NIHR). The views expressed are those of the authors and not necessarily those of the NHS, the NIHR or the Department of Health.

## References

- Added, M.A., Costa, L.O., Fukuda, T.Y., de Freitas, D.G., Salomao, E.C., Monteiro, R.L., Costa, L.D.A., 2013. Efficacy of adding the Kinesio taping method to guideline-endorsed conventional physiotherapy in patients with chronic nonspecific low back pain: a randomised controlled trial. *BMC Musculoskelet. Disord.* 14, 301.
- Akbas, E., Atay, A.O., Yuksel, I., 2011. The effects of additional Kinesio taping over exercise in the treatment of patellofemoral pain syndrome. *Acta Orthop. traumatologica turcica* 45, 335–341.
- AlBahel, F., Hafez, A.R., Zakaria, A.R., Al-Ahaideb, A., Buragadda, S., Melam, G.R., 2013. Kinesio taping for the treatment of mechanical low back pain. *World Appl. Sci. J.* 22, 78–84.
- Bae, S.H., Lee, J.H., Oh, K.A., Kim, K.Y., 2013. The effects of Kinesio taping on potential in chronic low back pain patients anticipatory postural control and cerebral cortex. *J. Phys. Ther. Sci. Jpn.* 1367–1371.
- Castro-Sanchez, A.M., Lara-Palomo, I.C., Mataran-Penarrocha, G.A., Fernandez-Sanchez, M., Sanchez-Labraca, N., Arroyo-Morales, M., 2012. Kinesio Taping reduces disability and pain slightly in chronic non-specific low back pain: a randomised trial. *J. Physiother.* 58, 89–95.
- Chernak, L.A., Thelen, D.G., 2012. Tendon motion and strain patterns evaluated with two-dimensional ultrasound elastography. *J. biomechanics* 45, 2618–2623.
- Gomez-Soriano, J., Abian-Vicen, J., Aparicio-Garcia, C., Ruiz-Lazaro, P., Simon-Martinez, C., Bravo-Esteban, E., Fernandez-Rodriguez, J.M., 2014. The effects of Kinesio taping on muscle tone in healthy subjects: a double-blind, placebo-controlled crossover trial. *Man. Ther.* 19, 131–136.
- Gonzalez-Iglesias, J., Fernandez-De-Las-Penas, C., Cleland, J., Huijbregts, P., Del Rosario, G.V.M., 2009. Short-term effects of cervical Kinesio taping on pain and cervical range of motion in patients with acute whiplash injury: a randomized clinical trial. *J. Orthop. sports Phys. Ther.* 39, 515.
- Hoy, D., Brooks, P., Blyth, F., Buchbinder, R., 2010. The epidemiology of low back pain. *Best Pract. Res. Clin. rheumatology* 24, 769–781.
- Jacobs, J.V., Henry, S.M., Nagle, K.J., 2009. People with chronic low back pain exhibit decreased variability in the timing of their anticipatory postural adjustments. *Behav. Neurosci.* 455–458, 2009 APA, all rights reserved., United States.
- Kalron, A., Bar-Sela, S., 2013. A systematic review, of the effectiveness of Kinesio Taping (R) – fact or fashion? *Eur. J. Phys. Rehabilitation Med.* 49, 699–709.
- Kase, K., Wallis, J., Kase, T., 2003a. *Clinical Therapeutic Applications of the Kinesio Taping Method*, second ed. Kinesio Taping Association.
- Kase, K., Wallis, J., Kase, T., Association, K.T., 2003b. *Clinical Therapeutic Applications of the Kinesio Taping Methods*. Kinesio Taping Assoc.
- Kaya, E., Zinnuroglu, M., Tugcu, I., 2011. Kinesio taping compared to physical therapy modalities for the treatment of shoulder impingement syndrome. *Clin. Rheumatol.* 30, 201–207.
- Langevin, H.M., Fox, J.R., Koptiuch, C., Badger, G.J., Greenan-Naumann, A.C., Bouffard, N.A., Konofagou, E.E., Lee, W.-N., Triano, J.J., Henry, S.M., 2011. Reduced thoracolumbar fascia shear strain in human chronic low back pain. *BMC Musculoskelet. Disord.* 12, 203.

- Langevin, H.M., Sherman, K.J., 2007. Pathophysiological model for chronic low back pain integrating connective tissue and nervous system mechanisms. *Med. hypotheses* 68, 74–80.
- Langevin, H.M., Stevens-Tuttle, D., Fox, J.R., Badger, G.J., Bouffard, N.A., Krag, M.H., Wu, J., Henry, S.M., 2009. Ultrasound evidence of altered lumbar connective tissue structure in human subjects with chronic low back pain. *BMC Musculoskelet. Disord.* 10.
- Lemos, T.V., Albino, A.C.G., Matheus, J.P.C., Barbosa, AdM., 2014. The effect of Kinesio taping in forward bending of the lumbar spine. *J. Phys. Ther. Sci.* 26, 1371–1375.
- MacDonald, D., Moseley, G.L., Hodges, P.W., 2009. Why Do Some Patients Keep Hurting Their Back? Evidence of Ongoing Back Muscle Dysfunction during Remission from Recurrent Back Pain. *Pain, Netherlands*, pp. 183–188.
- Malanga, G.A., Colon, E.J.C., 2010. Myofascial low back pain: a review. *Phys. Med. rehabilitation Clin. N. Am.* 21, 711–724.
- Manchikanti, L., Singh, V., Datta, S., Cohen, S.P., Hirsch, J.A., 2008. Comprehensive review of epidemiology, scope, and impact of spinal pain. *Pain physician* 12, E35–E70.
- Martin, B.I., Deyo, R.A., Mirza, S.K., Turner, J.A., Comstock, B.A., Hollingworth, W., Sullivan, S.D., 2008. Expenditures and health status among adults with back and neck problems. *Jama* 299, 656–664.
- Martinez-Gramage, J., Merino-Ramirez, M.A., Amer-Cuenca, J.J., Lison, J.F., 2016. Effect of Kinesio Taping on gastrocnemius activity and ankle range of movement during gait in healthy adults: a randomized controlled trial. *Phys. Ther. Sport* 18, 56–61.
- Morris, D., Jones, D., Ryan, H., Ryan, C., 2013. The clinical effects of Kinesio<sup>®</sup> Tex taping: a systematic review. *Physiother. theory Pract.* 29, 259–270.
- Mostafavifar, M., Wertz, J., Borchers, J., 2012. A systematic review of the effectiveness of kinesio taping for musculoskeletal injury. *Phys. Sportsmed.* 40, 33–40.
- Paoloni, M., Bernetti, A., Fratocchi, G., Mangone, M., Parrinello, L., Cooper, M.D., Sesto, L., Di Sante, L., Santilli, V., 2011. Kinesio Taping applied to lumbar muscles influences clinical and electromyographic characteristics in chronic low back pain patients. *Eur. J. Phys. Rehabilitation Med.* 47, 237–244.
- Parreira, PdCS., Costa, LdCM., Hespanhol Junior, L.C., Lopes, A.D., Costa, L.O.P., 2014a. Current evidence does not support the use of Kinesio Taping in clinical practice: a systematic review. *J. Physiother.* 60, 31–39.
- Parreira, PdCS., Costa, LdCM., Takahashi, R., Junior, L.C.H., da Luz Junior, M.A., da Silva, T.M., Costa, L.O.P., 2014b. Kinesio Taping to generate skin convolutions is not better than sham taping for people with chronic non-specific low back pain: a randomised trial. *J. Physiother.* 60, 90–96.
- Thelen, M.D., Dauber, J.A., Stoneman, P.D., 2008. The clinical efficacy of Kinesio tape for shoulder pain: a randomized, double-blinded, clinical trial. *J. Orthop. Sports Phys. Ther.* 38, 389.
- Van Tulder, M., Becker, A., Bekkering, T., Breen, A., Gil del Real, M.T., Hutchinson, A., Koes, B., Laerum, E., Malmivaara, A., 2006. Chapter 3 European guidelines for the management of acute nonspecific low back pain in primary care. *Eur. Spine J.* 15, s169–s191.
- Videman, T., Battié, M.C., 2012. Commentary: back pain epidemiology—the challenge of case definition and developing new ideas. *Spine J.* 12, 71–72.
- Voglar, M., Sarabon, N., 2014. Kinesio taping in young healthy subjects does not affect postural reflex reactions and anticipatory postural adjustments of the trunk: a pilot study. *J. Sports Sci. Med.* 13, 673–679.
- Williams, S., Whatman, C., Hume, P.A., Sheerin, K., 2012. Kinesio taping in treatment and prevention of sports injuries a meta-analysis of the evidence for its effectiveness. *Sports Med.* 42, 153–164.
- Yoshida, A., Kahanov, L., 2007. The effect of kinesio taping on lower trunk range of motions. *Res. sports Med.* 15, 103–112.