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QUANTIFICATION USING MRI ANALYSES SHOWS COMPLEX AND WIDESPREAD MECHANICAL EFFECTS OF KINESIO TAPING WITHIN A WHOLE LIMB

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SUMMARY
Using MRI we show that major local deformations occurring within the anterior crural muscles after application of Kinesio Tape (KT) over m. tibialis anterior are not confined to the direction and neighborhood of the tape. Moreover, considerably high deformations are observed within the remainder of the muscles of the human lower leg. These findings demonstrate that KT application may be therapeutic through a much more complex mechanism than previously expected and continuity of muscular and non-muscular connective tissues play a role in this mechanism.

INTRODUCTION
Kinesio taping (KT) [for a review see 1] is an increasingly popular technique that has been employed by physiotherapists in treatment of sports injuries as well as various neuro-musculoskeletal disorders. The proposed benefits depend on the particular application technique used e.g., assisting or “holding” fascia, creating space above area of pain, inflammation or edema by “lifting” the skin, assisting or limiting motion by the preloaded “spring” action of the tape [2]. Current studies focus on the outcomes of KT such as improvements in muscle strength, proprioception, range of motion, lymphatic drainage and pain [e.g., 1]. However, investigation of the aforementioned mechanical effects of KT *in vivo* is limited.
KT is applied for drop foot treatment typically by placing the ends of the tape at the dorsal surface of the metatarsus and tuberosity of tibia, stretching the tape over the plantar-flexed ankle and adhering it over the skin above m. tibialis anterior. The tension created along the tape acts like an extra layer of fascia as a physical aid to achieve the normal ankle posture. Also conceivable is that the mechanical effects caused may translate into proprioceptive stimuli and a preferable tonus of the target muscle.
Continuity of muscular and non-muscular connective tissues leads to major mechanical interaction between these tissues within a limb with several important functional implications [for a review see 3]. Using finite element modeling, such mechanical interaction has been shown to cause highly non-uniform muscle tissue deformation [4]. In a recent magnetic resonance imaging (MRI) study [5], upon changing knee joint angle, local high strain distributions have been observed in m. gastrocnemius in agreement with the imposed muscle-tendon complex length changes. However, (1) observed local length changes (much higher than global length change) include local lengthening occurring simultaneously with local shortening at different parts of the muscle. (2) Moreover, similar deformations were shown also for the globally isometric m. soleus.
Based on these issues we hypothesized that KT application for drop foot correction causes local complex tissue deformations (I) not confined to the direction and neighborhood of the tape within the targeted AC muscles, and (II) within also the remainder of the muscles of the human lower leg. Our aim is to test these hypotheses using MRI analyses.

METHODS
Healthy female subjects (n=4, age = 26 ± 2 years, height = 159 ± 6 cm and body mass = 49 ± 6 kg) participated. Each subject was positioned prone within the MRI scanner with the ankle angle fixed at 90° using an MRI compatible device. After acquiring sets of 3D high resolution MR images in this *undeformed state*, KT for drop foot correction was applied over m. tibialis anterior. After waiting for 30 minutes to allow tissue deformation to take place in this *deformed state*, a second MR image set was collected.
Demons algorithm [3], an intensity based non-rigid non-parametric image analysis technique, was applied to the MR image sets to align images of the deformed and undeformed states. Image differences calculated (based on voxel gray scale values) iteratively are used to characterize the displacement values for each original voxel. Using the displacement fields obtained, Green-Lagrange strain tensors were calculated for each voxel in order to assess local deformations in the lower leg muscles caused by KT application. Anatomical regions distinguished are AC, peroneal muscles, deep flexor muscles, m. soleus and m. gastrocnemius. First and third principal strains were analyzed, characterizing maximal tissue lengthening and shortening respectively.
Image sets of the undeformed state were also transformed by a “synthetic rigid body motion” imposed on the data. In this data set, deviation of any principal strains from zero was used as estimate of errors in strain calculations (*baseline strains*).

RESULTS AND DISCUSSION
After KT application, mean principle strains were significantly higher than baseline strains, which remained very small (Table 1). This indicates that KT causes tissue

deformations much larger than possible subject repositioning artifacts.

Table 1: Baseline strains and tissue strains

Local baseline strains (synthetic rigid body motion) (n=4). No Kinesio Tape					
Mean ± SE	**anterior crural**	**peronei**	**deep flexors**	**m. sol.**	**m. gastroc.**
1st principal strain	0,019 ±0,024	0,026 ±0,031	0,015 ±0,017	0,019 ±0,025	0,014 ±0,018
3rd principal strain	-0,020 ±0,026	-0,011 ±0,021	-0,014 ±0,016	-0,012 ±0,014	-0,020 ±0,025
Local principal strains in the deformed state (n=4). 30 minutes after Kinesio Tape application					
1st principal strain	0,199 ±0,157*	0,143 ±0,123*	0,068 ±0,060**	0,109 ±0,087**	0,098 ±0,085*
3rd principal strain	-0,145 ±0,104*	-0,077 ±0,062*	-0,071 ±0,048*	-0,086 ±0,057*	-0,106 ±0,074*
(*) indicate significant differences (p<0,05) with baseline strains. (**) indicate no significant differences (p=0,0571) with baseline strains.					

Figure 1 shows local deformations calculated for the anatomical regions studied. (1) AC muscles' peak local lengthening and shortening amounts to 82.5% and 41.4%, respectively. Inter-quartile range (IQR) values of pooled data from all subjects equaled 0.218 and 0.162 for the first and third principal strains, respectively. Therefore, above all tissue deformation due to KT application is not limited to a shallow region below the dermis as also within the deeper lying tissue, a considerable strain distribution is observed. Assessment of the eigenvectors shows that for less than only 14% of the voxels within AC muscles are the peak deformations along the KT direction whereas, those in the anterior-posterior and medio-lateral directions amount to 24% and 28%, respectively. This shows that, in agreement with our first hypothesis that local deformation due to KT is not necessarily in the direction of the tape application.

Moreover, highly pronounced and heterogeneous local deformations were not limited to the AC muscles: (2) Peroneal muscles peak lengthening and shortening amounts to 81.0% and 38.2%, respectively. IQR values equaled 0.109 and 0.070 for the first and third principal strains, respectively. (3) Deep flexor muscles Peak local lengthening and shortening attained values of 38.9% and 34.1%, respectively. IQR values equaled 0.068 and 0.057 for the first and third principal strains, respectively. (4) m. soleus peak lengthening and shortening amounts to 72.7% and 35.0%, respectively. IQR values for the first and third principal strains equaled 0.104 and 0.079, respectively. (5) m. gastrocnemius Peak local lengthening and shortening attained values of 72.7% and 40.9% respectively. IQR values equaled 0.079 and 0.085 for the first and third principal strains, respectively. Wide range of lengthening and shortening strains observed within muscles away from the site of KT application suggests that continuity of connective tissue within the lower limb plays a major and potentially so far neglected role as mechanical effects of KT application. This confirms our second hypothesis.

Remarkably, the mechanical effects demonstrated here for the target muscle appear to contrast possible expectations from the presently employed technique. Therefore, KT application for drop foot correction may be therapeutic through a much more complex mechanism than just providing an external fascial support. Aspects of such mechanism may involve (i) changed force production characteristics of individual sarcomeres and (ii) modulated response of mechanoreceptors. Our results indicate that such effects are to be expected for muscles of the entire limb. On the other hand, KT effects such as "lifting" appear to occur. Our present study shows that using MRI analyses, mechanical effects of KT can be quantified. Detailed analyses for therapeutic mechanisms are indicated.

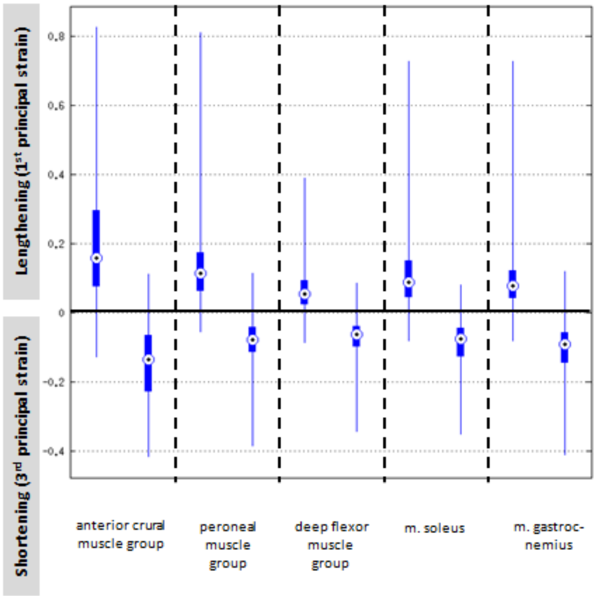

Figure 1: Local lengthening and shortening effects of KT application with box & whisker plots. Median and peak values are indicated by dotted circle inside a box and lines extending from each end of the box (whiskers), respectively. Absolute value of the difference between the upper and lower quartiles (indicated by the edges of a box) i.e., inter-quartile ranges (IQR) quantify strain heterogeneity.

CONCLUSIONS

The results show that (1) KT application causes local strains not necessarily aligned with the tape and also deep within the target muscle. (2) Such local strains are not limited to the specific muscle on which KT is applied, but also occur within synergistic, as well as antagonistic muscles far from the KT application site. (3) Variable magnitudes of local lengthening occur simultaneously with local shortening at other locations. Our developed methods can allow for an improved understanding of mechanisms of KT effects, which may fill an important gap in the literature for this treatment technique.

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