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Do kinaesthetic tapes affect plantarflexor muscle performance?

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Abstract
This study aimed to examine the effects of application of kinaesthetic tapes on plantarflexor muscle performance. We hypothesised that taping of the triceps surae muscle would improve plantarflexor muscle strength and endurance with no significant effect on drop jump performance. Using a repeated-measures design, all performance measures were obtained in 24 volunteers on two separate occasions: without tapes and after application of kinaesthetic tapes. Performance tests included measurements of isometric plantarflexor muscle strength and the associated electromyographic activity of the gastrocnemius muscle, an isokinetic fatigue resistance test (30 contractions at 180°·s⁻¹) and assessments of drop jump performance. The taping-intervention was associated with an increase in gastrocnemius electromyographic activity. However, significant increases in isometric strength were only found at fully dorsiflexed ankle positions (+12% at −20°). Strength gains were negatively correlated to baseline strength (r = −.58). The intervention did not affect the results of the isokinetic fatigue and drop jump tests. The application of kinaesthetic tapes over the triceps surae muscle promotes an increase in isometric strength and gastrocnemius muscle activity. Our data suggest that these effects are joint-angle dependent and more prominent in weaker individuals. By contrast, the taping-intervention improves neither drop jump performance nor muscular endurance.

Keywords: isometric strength, drop jump, reactive strength, fatigue resistance

Introduction
The application of kinaesthetic tapes, best known by the brand name Kinesio® Tex Tapes, has become an increasingly popular method in physiotherapy and sports medicine. The cotton-acrylic structure of this specific kind of tapes may be stretched longitudinally to up to 120–140%. Its characteristic tendency to recoil back to its original length following application is used to apply tensile forces onto the skin which reportedly affects the somatosensory system by microscopically lifting the fascia and soft tissues under the areas where the tapes are applied (Kase, Wallis, & Kase, 2003). According to their inventor, the Japanese chiropractor Kenzo Kase, these mechanisms may promote different therapeutic objectives, including improved circulation of blood and lymph flow, pain relief through neurological suppression, and enhanced proprioception by cutaneous stimulation of peripheral afferent nerves. The scientific literature examining the efficacy of these therapeutic applications of kinaesthetic tapes has recently been reviewed by Bassett and colleagues (Bassett, Lingman, & Ellis, 2010).

A central claim of Kase’s doctrine is that kinaesthetic tapes can also be used to modulate muscle tone (Kase et al., 2003). Certain application techniques are believed to enhance motoneuron activity, purportedly facilitating contraction and increasing muscle strength (Hammer, 2006). The early case reports by Murray (2000), who observed an increase in thigh muscle activity during knee extension exercise, bolstered this assertion and nurtured the hope of many athletes that kinaesthetic tapes might indeed not only be used in a therapeutic setting but also to improve sports performance. However, the following surveys performed to validate the proposed performance-enhancing effects have yielded controversial results. While the application of the tapes was associated with an increase in the isometric strength...
of the lower trapezius muscle (Hsu, Chen, Lin, Wang, & Shih, 2009) and eccentric quadriceps strength (Vithoulka et al., 2010), grip strength (Chang, Chou, Lin, Lin, & Wang, 2010) and concentric quadriceps strength (Fu et al., 2008) were reportedly unaffected by the taping-interventions. The application of tapes also failed to improve countermovement jump performance (Huang, Hsieh, Lu, & Su, 2011).

These discrepant findings indicate that the performance-enhancing potential of kinaesthetic tapes may be muscle- or task-dependent. Considering their functional importance, it is surprising that there are scant data available on their effects on plantarflexors’ contractile properties. Therefore, the main purpose of the present study was to test whether kinaesthetic taping would enhance isometric plantarflexor muscle strength. Moreover, as most tasks in sports and everyday life do not necessitate maximum efforts but rather the explosive or persistent generation of a certain level of muscular force, we aimed to evaluate the effects of the application of kinaesthetic tapes on reactive strength and muscular endurance. Ultimately, we wished to determine whether and to what extent kinaesthetic taping affects plantarflexor muscle performance. In the absence of more specific empirical data, we drew on the work of Huang and colleagues (2011) hypothesising that the taping intervention would not improve drop-jump performance. By contrast, we assumed that the taping-application would increase isometric plantarflexor strength (Hsu et al., 2009) and isokinetic fatigue resistance.

Methods

Participants

Twelve male (age: 24.9 ± 4.0 yrs; height: 1.80 ± 0.06 m; mass: 74.0 ± 6.2 kg) and 12 female (age: 24.0 ± 3.6 yrs; height: 1.67 ± 0.04 m; mass: 61.1 ± 5.9 kg) volunteers were recruited among sports students at the University of Vienna and physiotherapists working at the Department of Physical Medicine and Rehabilitation (Medical University of Vienna). To be included, participants had to be free of internal or orthopaedic disease and give written informed consent. All of our volunteers were physically active but did not engage in competitive sports. The study was conducted in agreement with the declaration of Helsinki and approved by the ethics committee of the Medical University of Vienna (EK 028/2011).

Study design

All performance tests were carried out without tapes and after application of kinaesthetic tapes. The tests were conducted on two separate days, interspersed by a minimum of 48 hours, at a constant time of day. To minimise bias due to learning effects, equal numbers of participants started the test series with and without tapes, respectively. On each testing day, the measurements were carried out in a predetermined order. First, EMG electrodes and tapes (on the respective testing days only) were applied to the skin. Then, following a standardised warm-up program consisting of a 5-min treadmill run (average velocity 7–9 km·h⁻¹), drop-jump performance was assessed. Subsequently, isometric plantarflexor strength was measured. Finally, an isokinetic fatigue test was performed.

Treatment technique

Two specialists in Physical Medicine and Rehabilitation, experienced in the use of kinaesthetic tapes, applied the tapes over both legs while participants were lying in the prone position with their feet dangling over the edge of an examination bed. First a Y-shaped stripe of tapes (ktape®, bivias GmbH, Dortmund, Germany) was applied over both heads of the gastrocnemius muscle, starting approximately 10 cm proximal to the popliteal fossa, converging over the Achilles tendon and ultimately attaching to the sole of the foot (Huang et al., 2011). With the foot held in a dorsiflexed position, an additional stripe of tapes was attached over the soleus muscle (Figure 1), from the mid-shank region to the sole of the foot (Firth, Dingley, Davies, Lewis, & Alexander, 2010). The tapes were applied without added tension. Following Kase’s suggestions (Kase et al., 2003), the tapes were always applied in the direction from muscle origin to insertion (proximal-to-distal) and an activating colour of tapes (magenta) was used.

Performance tests

For assessments of drop-jump performance, a series of 3 × 3 reactive jumps was completed. Participants were instructed to rebound immediately as high as possible after dropping from an elevated stand while keeping their hands on their hips. Drop heights were 20, 40 and 60 cm, respectively. Ground reaction forces were acquired at a sampling frequency of 1 kHz using a force plate embedded into the ground (AMTI, Watertown, MA, USA), digitised using a 12-bit analogue-to-digital converter (AT-MIO-16, National Instruments, Austin, TX, USA) and stored to a personal computer. The instants of the initial foot contact, take-off, and landing were identified using the vertical components of the force records and used to determine flight times and ground contact times.
Jump heights (Jump height = 1/8 × Flight time² × 9.81) and reactive strength indices (Reactive strength index = Jump height / Ground contact time) were then calculated following standard procedures (Flanagan, Ebben, & Jensen, 2008). Reliability analyses showed high consistency in both outcome measures on single testing days (Jump height: ICC = 0.96–0.98; Reactive strength index: ICC = 0.96–0.99).

Dynamometric measurements were only performed in the dominant leg, defined as the leg preferentially used to kick a ball (de Ruiter, de Korte, Schreven, & de Haan, 2010). Following the manufacturer’s setup recommendations for seated measurements of plantarflexor strength, participants were seated on an isokinetic dynamometer (Biodex System 3, Shirley, NY, USA). The knee of the tested leg was flexed at approximately 25° (0° representing the anatomical position), the foot firmly strapped to a foot pedal and the axis of rotation of the ankle, defined as an imaginary line connecting the two malleoli, was carefully aligned with the axis of rotation of the dynamometer. Seat and dynamometer position were recorded to ensure identical testing conditions on both testing days. During all dynamometric measurements, torque, velocity and position data were acquired at a sampling frequency of 100 Hz. To determine angle-specific isometric plantarflexor strength, participants performed maximum voluntary contractions at five ankle positions from −20° to +20°, in steps of 10° (0° representing a right angle between the axes of the foot and shank). The sequence of the joint angles was predetermined and sufficient recovery times were allowed between trials to minimise fatigue-related bias. For each contraction, peak torques over a 5-s contraction were recorded and the best of three trials at each joint position was used for further analyses.

Following the measurements of isometric strength, participants performed the isokinetic fatigue resistance test proposed by Trappe and colleagues (Trappe, Trappe, Lee, & Costill, 2001). The test consists of 30 maximum contractions over a 40° range of motion at an isokinetic velocity of 180°·s⁻¹. A fatigue index was calculated as the average of the two highest torque values divided by the average of the two lowest values, multiplied by 100. Isokinetic work, defined as the product of torque and angular displacement in the isovelocity phase of the movement, was determined for each contraction and summated to give the total work performed during the fatigue test. Mean torque over the 30 contractions was calculated as additional outcome measure.

During isometric measurements, the surface electromyographic (EMG) activity of the gastrocnemius medialis and gastrocnemius lateralis muscles was simultaneously acquired at a sampling frequency of 2 kHz (myon RFTD, myon AG, Baar, Switzerland), considering the SENIAM recommendations for skin preparation and electrode placement (Hermens, Freriks, Disselhorst-Klug, & Rau, 2000). Care was taken to ensure consistent electrode positioning across testing days. The EMG activity of the soleus muscle could not be assessed, as proper electrode placement was impossible after application of kinaesthetic tapes (Figure 1). The raw EMG data were preamplified (gain × 1000, CMRR > 100 dB), digitised, band-pass filtered between 50–500 Hz, RMS-rectified (time constant 250 ms) and integrated over 500 ms around the peak torque to give integrated EMG (iEMG). All measurement data were processed using custom-made MATLAB routines (MATLAB R2010b, Mathworks Inc., Natick, MA, USA).

**Statistical analyses**

Two-way repeated measures ANOVAs were used to assess the influence of the main factors ‘drop height’ and ‘taping condition’ on drop-jump results as well as ‘joint angle’ and ‘taping condition’ on the outcomes of dynamometric and EMG measurements. On occasions when the assumption of sphericity was violated (Mauchly’s test, p < 0.05), degrees of freedom were corrected using Greenhouse-Geisser (ε ≤ 0.75) or Huynh-Feldt.
Bonferroni-adjusted paired-samples t-tests were applied to follow up significant findings. Pearson’s coefficients were used for correlational analyses and interpreted as measures of effect size. The statistical level of significance was set at $p < 0.05$ and values are reported as means $\pm$ SD. All statistical analyses were performed using PASW Statistics 18.0 (SPSS Inc., Chicago, IL, USA).

**Results**

The results from drop jump tests (best attempt from all drop heights), isometric strength tests (highest torque over all joint positions) and the isokinetic fatigue test in dependency of the taping condition are summarised in Table I.

Drop jump heights ($F(2, 46) = 8.01, p = 0.001$) and reactive strength indices ($F(1.62, 37.20) = 7.92, p = 0.003$) were significantly affected by the factor ‘drop height’, with the best results (Jump height: $28.1 \pm 6.9$ cm; Reactive strength index: $1.39 \pm 0.10$) observed from a drop height of $40$ cm. By contrast, the factor ‘taping condition’ had no effect on drop-jump results. Confirming the ANOVA results (Jump height: $F(1, 23) = 1.75$, n.s.; Reactive strength index: $F(1, 23) = 0.00$, n.s.), paired-samples t-tests showed that neither maximum jump heights nor reactive strength indices differed significantly (Table I).

In dynamometric measurements, there was a significant main effect of ‘joint angle’ on isometric strength ($F(1.58, 36.29) = 134.12, p = 0.000$), with torques gradually increasing from a plantar- ($+20^\circ$) to a dorsiflexed ($-20^\circ$) joint position (Figure 2a). Although, after KT-application, torques were higher at all joint positions examined, the effect of the factor ‘taping condition’ just failed to reach statistical significance ($F(1, 23) = 3.42, p = 0.077$). However, there was a significant interaction effect ‘joint angle $\times$ taping condition’ ($F(2.65, 60.97) = 3.07, p = 0.040$), indicating that the kinaesthetic tapes had different effects on plantarflexor strength depending on the joint angles at which measurements were performed. It is evident from Figure 2a that more prominent increases in strength are to be expected at dorsiflexed ankle positions. Paired-samples t-tests performed for closer scrutiny of this presumption revealed that only the values of torque measured at $-20^\circ$ differed significantly. Here, participants achieved higher torques after tape-application: (with tapes: $154.8 \pm 42.1$ Nm; without tapes: $137.9 \pm 50.8$ Nm; $t(23) = -2.37$, $p = 0.000$, $F(1, 23) = 3.42, p = 0.077$).

### Table I. Differences between untaped (NT) and taped (KT) conditions in terms of maximum isometric strength, isokinetic fatigue resistance and drop jump performance.

<table>
<thead>
<tr>
<th></th>
<th>NT</th>
<th>KT</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$T_{max}$ (Nm)</td>
<td>$140.5 \pm 51.5$</td>
<td>$155.2 \pm 42.0$</td>
<td>0.037</td>
</tr>
<tr>
<td>FI (%)</td>
<td>$51.9 \pm 19.9$</td>
<td>$53.0 \pm 16.0$</td>
<td>0.842</td>
</tr>
<tr>
<td>FT work (J)</td>
<td>$13.6 \pm 4.4$</td>
<td>$15.1 \pm 7.6$</td>
<td>0.244</td>
</tr>
<tr>
<td>FT $T_{mean}$ (Nm)</td>
<td>$43.2 \pm 10.2$</td>
<td>$43.9 \pm 12.9$</td>
<td>0.761</td>
</tr>
<tr>
<td>JH (cm)</td>
<td>$28.7 \pm 6.6$</td>
<td>$28.4 \pm 6.5$</td>
<td>0.801</td>
</tr>
<tr>
<td>RSI</td>
<td>$1.42 \pm 0.45$</td>
<td>$1.45 \pm 0.45$</td>
<td>0.435</td>
</tr>
</tbody>
</table>

Note: FI: Fatigue Index. FT $T_{mean}$: Average torque achieved during the isokinetic fatigue test. FT work: Work performed during the isokinetic fatigue test. JH: Highest jump height achieved in drop jump tests. RSI: Highest reactive strength index achieved in drop jump tests. $T_{max}$: Maximum isometric torque. Data are presented as means $\pm$ SD.

![Figure 2](image-url)
The degree of the performance-enhancing effect, calculated as the difference between the highest torques achieved under both taping conditions, was negatively correlated to baseline strength, defined as the highest torque achieved without tapes (r = −0.58, p = 0.003).

In agreement with the higher torques observed after application of kinaesthetic tapes, the factor ‘taping condition’ was also found to have a significant effect on both the gastrocnemius medialis (F(1, 23) = 8.37, p = 0.008) and gastrocnemius lateralis (F(1, 23) = 4.79, p = 0.039) iEMG activity (Figures 2b and 2c). Paired-samples t-tests used for posthoc analyses showed that, following the taping intervention, the gastrocnemius medialis iEMG activity was significantly higher at the joint angle of −20° (without tapes: 67.6 ± 42.6 μVs; with tapes: 83.4 ± 40.0 μVs; t(23) = −2.93; p = 0.008, r = 0.52) with a further trend towards higher activities at −10°, 0° and 20°. Similarly, the iEMG activity of the gastrocnemius lateralis muscle was significantly higher at −20° (Without tapes: 50.6 ± 53.2 μVs; With tapes: 67.8 ± 55.0 μVs; t(23) = −2.89; p = 0.008, r = 0.42) and tended to be higher at 0°.

In the isokinetic fatigue resistance test, similar fatigue indices were observed under both taping conditions. Also, no statistical differences were found for the total work performed during the fatigue test and the mean torque over all contractions (Table I).

Discussion

The aim of the present study was to test whether the application of kinaesthetic tapes over the triceps surae muscle would affect muscular strength and the performance in further tasks involving plantarflexion contractions.

Following the application of tapes, we observed a significant increase in isometric muscle strength. Interestingly, this effect appeared to be joint-angle dependent. While the taping intervention resulted in marked and statistically significant strength gains at fully dorsiflexed joint positions (+12% at −20°), virtually no effect was evident at plantarflexed ankle position. These data suggest that the application of kinaesthetic tapes would primarily facilitate movements that require strong but slow contractions of the lengthened plantarflexor muscles. Theoretically, performance enhancements could therefore be seen in activities such as heel raises or sprint starts. However, further research is required to directly establish the functional relevance of the strength gains observed.

While the quantitative comparison of EMG-recordings obtained on separate occasions is complicated and data must be interpreted cautiously, we found the taping intervention to be also associated with significantly increased iEMG activities (−20°: Gastrocnemius medialis muscle +20%, Gastrocnemius lateralis muscle +28%; Figures 2b and 2c). This suggests that the strength gains related to the taping intervention may, at least partly, be explained by increased muscular activity. However, the reasons why the effects of the taping intervention were most prominent at −20° remain a matter of speculation. The fact that the tapes are under greatest tension at this specific joint position suggests that the taping effects may be quantitatively related to the degree of cutaneous stimulation of mechanoreceptors. Stretch applied to the skin is known to activate the slowly adapting type 2 mechanoreceptors located deep in the dermis and has previously been shown to be associated with increased muscular activity (Christou, 2004; Macgregor, Gerlach, Mellor, & Hodges, 2005), although the precise mechanisms linking the afferent stimulation to augmented motor output are not yet clearly understood.

It is striking that, following the application of kinaesthetic tapes, iEMG activities also tended to be greater at +20° (GM +11%, GL +22%), whereas there was no notable increase in isometric strength at the corresponding joint position (torques +2%). A possible explanation for this observation appears to be offered by the length-tension relationship of the triceps surae muscle: it is common understanding that the gastrocnemius and soleus muscles occupy similar portions of the length-tension curve, functioning mostly on its ascending limb (Herzog, Read, & ter Keurs, 1991; Maganaris, 2003). Thus, each sarcomere’s potential to generate force decreases steadily as the muscles shorten. It may therefore be speculated that, in extensively shortened plantarflexors, even excessive recruitment of sarcomeres may fail to result in significantly increased plantarflexor strength.

Another interesting finding was that the potential to increase strength by application of kinaesthetic tapes was negatively associated with baseline strength (r = −0.58), suggesting that weaker individuals would benefit more from the taping intervention. Possibly, this phenomenon may be explained by individually different potentials for muscle recruitment. While untrained individuals are unable to fully activate their muscles during maximum voluntary contraction, it is generally accepted that strength training increases an individual’s ability of muscle activation (Folland & Williams, 2007). Although it is difficult to interpret the results from longitudinal training studies in terms of inter-individual differences, it is plausible to assume that stronger individuals have a greater potential to activate their muscles during maximal contractions. As, in our study, the stronger participants benefitted less from
the taping-intervention, it may be speculated that the ability to further increase muscular activity and strength by the application of tapes is limited in individuals whose potential for muscle recruitment is already high.

In addition to the recordings of maximum isometric strength, our study also involved measurements of drop-jump performance, which is indicative of a participant’s ability to explosively generate force and make effective use of the stretch-shortening cycle (Young, Wilson, & Byrne, 1999). These abilities are particularly important in sprinting and jumping activities. In our study, the taping intervention did neither affect jump heights nor reactive strength indices, reflecting both jump heights and ground contact times. In two similar studies, the application of kinaesthetic tapes over the triceps surae also failed to improve countermovement jump height, in spite of a trend towards greater ground reaction forces and gastrocnemius medialis EMG activity (Hsieh et al., 2007; Huang et al., 2011). Taken together these results and our data suggest that the higher plantarflexor muscle strength by the application of tapes is limited in individuals whose potential for muscle recruitment is already high.

Conclusions
To summarise, the outcomes of our study suggest that in isometric contractions the application of kinaesthetic tapes over the triceps surae muscle promotes greater muscular activity in both heads of the gastrocnemius muscle, resulting in increased plantarflexor strength. However, this effect was found to be joint-angle dependent, as significant differences in strength could only be observed when the plantarflexors were used in a lengthened position. Additionally, our data indicate that the degree of the performance-enhancing effect may depend on baseline strength. Weaker participants presumably benefit more from the taping intervention. In contrast to isometric strength, the taping intervention did not significantly affect the performance in drop-jump tests and an isokinetic fatigue test suggesting that kinaesthetic taping of the triceps surae does neither improve reactive strength nor muscular endurance.

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References


