

Acute Effects of Kinesio Taping on Knee Extensor Peak Torque and Stretch Reflex in Healthy Adults

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Abstract: Kinesio Tex tape (KT) is used to prevent and treat sports-related injuries and to enhance muscle performance. It has been proposed that the direction of taping may either facilitate or inhibit the muscle by having different effects on cutaneous receptors that modulate excitability of the motor neurons. This study had 2 goals. First, we wished to determine if KT application affects muscle performance and if the method of application facilitates or inhibits muscle performance. This was assessed by measuring isokinetic knee extension peak torque in the knee extensor. Second, we assessed neurological effects of taping on the excitability of the motor neurons by measuring the reflex latency and action potential by electromyography (EMG) in the patellar reflex. The study was a single-blind, placebo-controlled crossover trial with 28 healthy volunteers with no history of knee injuries. Participants received facilitative KT treatment, inhibitory KT treatment, or Hypafix taping of the knee extensor. There were significant differences in the peak torque between 3 treatments ($F_{(2,54)} = 4.873$, $P < 0.01$). Post hoc analysis revealed that facilitative KT treatment resulted in higher knee extensor peak torque performance than inhibitory KT treatment ($P = 0.036$, effect size 0.26). There were, however, no significant differences in the reflex latency ($F_{(2,54)} = 2.84$, $P = 0.067$) nor in the EMG values ($F_{(2,54)} = 0.18$, $P = 0.837$) in the patellar reflex between the 3 taping applications. The findings suggest that the direction of KT application over the muscle has specific effects on muscle performance. Given the magnitude of effect is small, interpretation of clinical significance should be considered with caution. The underlying mechanism warrants further investigation.

(*Medicine* 95(4):e2615)

Abbreviations: EMG = electromyography, KT = Kinesio Tex tape, KTM = Kinesio Taping method, RF = rectus femoris.

INTRODUCTION

Kinesio Tex tape (KT) and the Kinesio Taping method (together referred to here as the KTM) have recently gained popularity among sports and healthcare professionals as a

means to prevent and treat sports-related injuries, as well as to enhance performance.^{1,2} According to its developer, Kenso Kase, KT was designed to mimic some of the qualities of the skin. KT is a thin elastic tape that can be stretched up to 55% to 60% of its resting length.³ It has approximately the same thickness as the epidermis and its degree of stretch approximates the elastic qualities of human skin. When applied as specified by its developer, it has been claimed to have beneficial effects on the skin, fascia, circulation, lymphatic system, muscles, and skeletal system, and to provide pain relief, resolve edema, improve muscle performance, and increased joint stability.³ The research evaluating these claims has recently been summarized in several reviews addressing the effectiveness of the KTM on muscle strength,^{2,4} the treatment and management of sports-related injuries,^{1,5} and musculoskeletal pain and injury.^{6–9} The authors of these reviews concluded that the information available was inadequate and stress the need for more rigorous investigation of the KTM before its effectiveness can be assessed.

A common goal in the application of the KTM is to enhance muscle performance. The elastic recoil of KT has been proposed to alter the length–tension relationships of muscles.³ When KT is applied at the insertion of the muscle and extended to its origin, it is proposed that the recoil effect may inhibit motor neurons by stretching the Golgi tendon organs at the distal end of the muscle. In the reverse scenario, the application of KT from the origin to the insertion of the muscle may enhance the muscle spindle reflex contraction and facilitate contraction of the muscle.³ This concept is based on early neurological studies which demonstrate that cutaneous afferent signals, presumably associated with these proprioceptors, modify the excitability of slow and fast motor units differently^{10,11} and modulate the activity of the proprioceptive reflex loops.^{12,13} It has also been suggested that application of KT activates cutaneous mechanoreceptors, thereby alleviating pain (as predicted by the gate-control theory).³ Thus, if the application of KT affects afferent input, then motor neuron excitability should either be enhanced or inhibited, depending on the direction of application. No studies have specifically investigated the effect of KT on muscle strength via the monosynaptic reflex of the muscle concerned, but there are several studies which evaluated the effects of taping on cutaneous sensation and the associated changes in the muscle activity. For instance, Macgregor et al¹⁴ showed that when stretch was applied to the skin via taping over the vastus medialis obliquus muscle, which stimulates the cutaneous afferent receptors, this led to an increase in the muscle activity and the motor unit firing rate. Alexander et al¹⁵ evaluated the effect of taping on the monosynaptic reflex of the muscle concerned. Rigid sports tape was applied to the lower trapezius muscle on healthy individuals and the effect of the taping was assessed by H-reflex. The results indicated that the taping inhibited the electromyography (EMG) activity of the muscle by ~22%. Another study conducted by the same group of investigators evaluated the effects of rigid

Editor: Kazuo Hanaoka.

Received: May 21, 2015; revised: December 30, 2015; accepted: January 5, 2016.

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All relevant data are available upon request.

The authors have declared that no competing interests exist.

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ISSN: 0025-7974

DOI: 10.1097/MD.0000000000002615

tape to the medial gastrocnemius muscle on healthy individuals, and the results indicated a decrease in the amplitude of the H-reflex, indicating a reduction in the excitability of the gastrocnemius muscle.¹⁶ However, it has to be noted that these 2 studies utilize traditional rigid sports tapes in which the material properties are very different from KT. Of importance, there are organizational differences between the H-reflex and the stretch reflex. The H-reflex is evoked by direct electrical stimulation of Ia afferent fibers. However, stretch reflex is elicited through activation of the muscle spindle primary endings, whose sensitivity is controlled by the activity of the γ -efferent fibers. We hypothesize that the sensitivity of this reflex can be influenced by KT application to the skin.

We have addressed these questions by measuring the reflex latency and the motor unit action potential with EMG in the patellar tendon reflex, and the peak torque in 1 of the quadriceps muscles. The first goal of this study was to determine if the KTM alters muscle performance and to evaluate the effect of the direction of taping. The second goal was to determine if motor neuron excitability is a contributing mechanism to the KTM effect through the activation of cutaneous receptors. The latter question should be evaluated in reflexive muscle action rather than voluntary actions and would be reflected in enhancement or inhibition of the reflex. The patellar reflex or knee-jerk reflex is a typical monosynaptic stretch reflex that is frequently used for neurophysiological examinations.¹⁷ Stretch reflexes are elicited through the activation of the primary endings of muscle spindles. The sensitivity of the muscle spindles is controlled by γ -efferent neurons, which should be sensitive to the KT applied to the skin.

METHODS

Sample Size Calculation

The sample size was calculated according to a previous study in which the effect of the KTM on the knee extensor isokinetic peak torque performance was measured in osteoarthritic patients.¹⁸ Values for the experimental and control group were 0.20 ± 0.11 and 0.10 ± 0.04 , respectively (mean \pm standard deviation [SD]). The calculated effect size (ES) was 0.52 and we opted for a conservative ES of 0.42. With a power of 95% and an alpha value of 5%, a priori compute required a sample size of 27 subjects (G*Power 3.1.7 software).

Subjects

Twenty-eight healthy volunteers, 13 males and 15 females, ages 20 to 24 years, participated in this study. Subjects were excluded if they were older than 40 years or had any of the following: current or past knee pathology or injury, skin conditions, allergy to tapes, or any medical condition that would interfere with participation in a sub-maximal sustained isometric exercise program, such as hypertension or diabetes mellitus. Prior written consent was obtained from each subject. The study was approved by the ethics committee of the administering institute and was in accordance with the ethical standards established in the 1964 Declaration of Helsinki.

Study Design

We performed a single-blind (subject) study with repeated measure design to evaluate the acute effects of the KTM on motor neuron excitability and performance of the dominant quadriceps muscle. Each subject received 3 types of taping: KT to facilitate the quadriceps muscle, KT to inhibit the quadriceps

muscle, and Hypafix taping. Hypafix is an adhesive, nonwoven tape commonly used as an underlay for rigid sports taping. This tape is stretchable across its width but rigid along the length. Hypafix taping was selected as control for 2 reasons: the tape does not limit range of movement like rigid tape; and the tape was applied instead of “no taping” to rule out any expected effect of intervention (taping). The tape application treatment was randomized with a web-based program (<http://www.randomization.com>) and the treatment was concealed from the participants and data collectors with opaque, sealed envelopes.

Treatments

Treatments were imposed in this study following the KTM as developed by Kase et al.³ The subject lay supine with the thigh hanging off from the bench so that the knee was in flexion and the hip in neutral position. For the facilitation treatment, 5-cm wide KT was applied with an I-shaped pattern (Kinesio Tex tape; Kinesio Holding Corporation, Albuquerque, NM). It was first anchored at the anterior superior iliac spine without tension and then applied along the border of the belly of the rectus femoris (RF) muscle, with 50% of available length tension. The tape was extended to the tibial tuberosity by wrapping it along the border of the patella. For the inhibition treatment, the tape applied in the opposite direction of the facilitation treatment, with tension of 15% of the available length tension. To ensure that consistent tension was applied to each subject, tape was applied to all subjects by the same investigator. To ensure that the same length of tape was applied, it was first stretched to 100% of its available tension and measured by a ruler. It was then stretched to the tension for facilitation or inhibition. Figure 1A shows the KT application. Hypafix tape (Kino white: Nitto Denko Corp., Osaka, Japan) was applied in the same manner as Kinesio tape inhibition application.

Measurement of Motoneuron Excitability in the Knee-Jerk Reflex

The knee-jerk reflex was elicited by a reflex hammer attached to a vertically aligned custom-built jig (Figure 2). The hammer was positioned at 60° from vertical to allow free swinging motion for a consistent tapping force. By adjusting the height of the jig, the hammer would strike onto the subject's middle third of the patella tendon. To ensure repeatability in subsequent trials, the skin area in which the hammer strikes the patellar tendon was marked. A pressure sensor was attached to the marked area to record the time of impact. Throughout the experiment, the subject was seated upright with legs dangling, blindfolded and headphones with music (the same music was played for all subjects in all trials). The patella tendon was tapped 3 times with 15 s relaxation in between. This maneuver was performed before and immediately after the taping application. The onset of knee movement and excursion were measured via an electrogoniometer (PennyGile, Biometrics Ltd, Gwent, UK) aligned with the femur and fibula on the lateral aspect of the knee.

The neuromuscular responses to the tapping stimulus were evaluated by EMG measurement. A double differential surface EMG with inter-electrode distance of 10 mm (DE-3.1, Delsys Inc., Boston, MA, USA) was used to record signals from the RF muscle. Prior to electrode placement, the skin was shaved, abraded with fine sandpaper and cleaned with alcohol to ensure that the skin resistance was $<<<5000$ ohms. As described

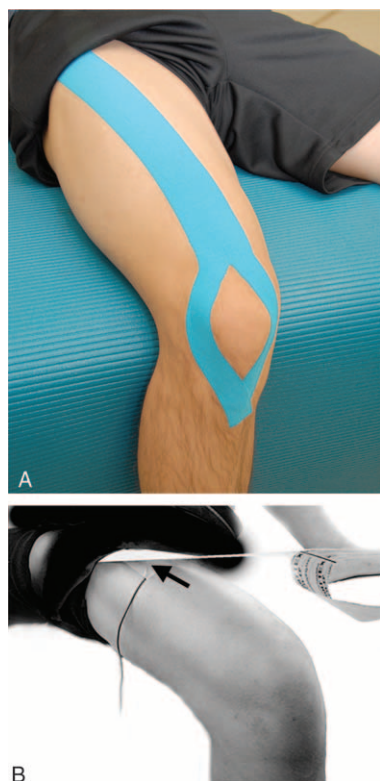


FIGURE 1. (A) Application of Kinesio tape to the rectus femoris muscle. (B) Electromyographic electrode fixed under the Kinesio tape. The arrow shows the position of the electrode.

previously,^{19,20} the subject was asked to perform maximal isometric voluntary contraction and the electrode was placed at the most palpable portion of the muscle belly. The electrode was aligned along the longitudinal axis of the muscle fibers, and was placed at 1/2 on the line from the anterior spina iliaca superior to the superior part of the patella. The electrode was fixed under the KT application (Figure 1B). The reference electrode was placed over the head of the fibula. EMG signals were preamplified (1000×), differentially amplified with common mode rejection rate >80 dB, bandpass filtered between 20 and 450 Hz (Bagnoli-2 EMG system, Delsys Inc.), and collected at a sampling frequency of 2000 Hz. The pressure sensor signals, the electrogoniometer signals, and EMG signals were simultaneously acquired and digitized with an AD convertor (National Instruments USB-621, National Instruments Corporation, Austin, TX) and were visually displayed on the computer simultaneously.

Measurement of Knee Extensor Isokinetic Peak Torque

The knee extensor peak torque was evaluated using isokinetic dynamometer (Cybex Humac Norm, CSMI version 2.04, Stoughton, MA, USA). The subject was seated in the dynamometer chair with the hips in 85° flexion and the knees in 90° flexion. The knee joint was aligned with the axis of the dynamometer. The subject's torso and the thigh were firmly



FIGURE 2. Subject and the reflex jig positioned for testing.

strapped to the seat; the shank of the leg was strapped to arm of the dynamometer. The subject then performed 3 practice trials of concentric knee contraction, followed with 5 maximal concentric knee extensions at an angular velocity of 60° s^{-1} . The peak torque is functionally defined as the mean of maximum force output recorded by the isokinetic dynamometer in the 5 concentric contractions.

Data Analyses

A customized Labview software program (Labview version 8.6, National Instruments Corporation) was used to record and determine the onset of the reflex hammer contact, onset of EMG data, and the knee-jerk movement. The reflex hammer contact was defined as the point when a sharp peak signal was collected from the pressure sensor. Premotor time, or reflex latency, was defined as the time from the point of reflex hammer contact to the onset of muscle activation; that is, the onset of the EMG signals. The onset of muscle activation was defined as when the EMG signals exceed 3 SD of the mean of baseline activity.²⁰ The peak-to-peak EMG signals were normalized with the amount of knee angle movement.

Statistical Analyses

Repeated measures of 1-way analysis of variance (ANOVA) were performed to examine the effects of the taping on knee extensor peak torque, EMG signals, and reflex latency

of the RF. Post hoc comparisons with Bonferroni adjustment were conducted when appropriate. Cohen *d* ES were calculated to measure the size of the differences between 3 conditions. All analyses were conducted using the Statistical Package for the Social Sciences (SPSS) Software (version 11.1; SPSS, Inc., Chicago, IL). The level of significance was set at $P < 0.05$.

RESULTS

Table 1 shows the isokinetic peak torque, reflex latency, and EMG values of the RF under the 3 taping conditions that were measured. The EMG values are reported relative to the knee angle movement.

Isokinetic Peak Torque Performance

The peak torque, when the RF was taped to achieve facilitation, was the greatest of the 3 taping techniques and it was least when the muscle was taped to achieve inhibition. There was a significant difference in the peak torque between the 3 taping conditions ($F_{(2,54)} = 4.87$, $P = 0.01$). The ES explained by partial eta-squared is 0.15 and the observed power is 0.78. Post hoc multiple pair *t* test with Bonferroni adjustment revealed significant differences between the facilitation and the inhibition taping ($P = 0.036$), but not when the facilitation technique was compared with Hypafix taping ($P = 0.125$). The ESs of the 3 taping conditions were small ranging from 0.07 to 0.26 (Table 2).

Reflex Latency and EMG of RF Muscle

There were no significant differences between any of the taping treatments with respect to the patellar tendon reflex latency ($F_{(2,54)} = 2.84$, $P = 0.067$). The ES explained by partial eta-squared is 0.095 and the observed power is 0.53. However, it has to take note that post hoc multiple pair *t* test with Bonferroni adjustment revealed close to significance between facilitation taping versus Hypafix taping and the ES is large ($P = 0.052$, ES = 2.01). There were no significant differences between any of the treatments in the EMG values relative to knee movement ($F_{(2,54)} = 0.18$, $P = 0.837$). The ES explained by partial eta-squared is only 0.007 and the observed power is 0.076 (Table 2).

DISCUSSION

Herein, we investigated the acute effects of KT taping on knee extension performance and asked if motoneuron excitability is a contributing mechanism. We detected differences in the

concentric peak torque value between the 3 taping conditions, leading us to suggest that the KTM had effects on muscle performance in our study and that the direction of tape application influenced these effects. That is, when KTM was applied in opposite direction (from muscle origin to insertion vs insertion to origin), the effect on muscle performance was different. These results concur with studies that showed an increase in concentric^{18,21} and eccentric knee extensor peak torque²² following the application of the KT. However, the literature is not entirely in agreement with this conclusion. In several studies of isometric muscle contraction, no striking acute effects of KT were observed.^{23–28} Specifically, the KTM had no effect on isometric knee extensor strength, on maximal grip strength, or on isometric wrist flexor strength.^{21–23} Likewise, the taping technique, whether facilitative or inhibitory, also had no effect on isometric grip strength.²⁴ However, when the biceps brachii was taped and the isokinetic elbow peak torque was measured rather than isometric elbow flexor strength, the muscle taped with KT had greater concentric elbow peak torque than the placebo.²⁵ It may be, then, that the main effect of KT is to facilitate the muscle spindle reflex via the recoil effect, and the dynamic movement that activates the mechanoreceptors is necessary to facilitate the muscle contraction. This might not be achieved in isometric exercise. Nonetheless, we take note that there are studies that are inconsistent with the suggestion in which isokinetic knee extensor performance was unaffected by KT. For instance, Wong et al²⁹ showed no difference in concentric peak torque between KT-taped muscles and nontaped muscle groups. However, in this study, the tape was applied with strong tension of 75% of its original length. This tension used differs from the suggested guideline.³ With such tension the unique recoil properties of the tape is being lost and the application is likely to modify muscular activity similar to the intent with rigid sports tape application. Fu et al³⁰ also found that no changes in the isokinetic peak torque where the stretch tension applied was lower than the suggested tension. We note that there are 2 reports, those of Lins et al³¹ and Vercelli et al,³² in which the recommended amount of tension was applied with no effect on knee extensor peak torque.

In our study, the KT muscle facilitation treatment resulted in higher peak torque, on average 5.5 N m⁻¹ higher (ES = 0.26, power = 0.76) than the inhibition treatment, and on average 4 N m⁻¹ higher (ES = 0.18; power 0.54) than the Hypafix taping treatment. However, given the small ES, the increase in peak torque performance with KT treatment might not be clinically important in young healthy population. Indeed, a recent literature review on the effects of KT on muscle performance

TABLE 1. Isokinetic Peak Torque, Reflex Latency, and Electromyographic Signals of the Rectus Femoris Under 3 Different Taping Conditions

	KT: Facilitation	KT: Inhibition	Placebo	ANOVA
Peak torque at 60° s ⁻¹ , N m ⁻¹	92.50 ± 21.51	87.00 ± 21.67	88.50 ± 22.95	$F_{(2,54)} = 4.87$ $P = 0.011^*$
Reflex latency, ms	17.96 ± 0.72	19.36 ± 0.70	19.04 ± 0.84	$F_{(2,54)} = 2.84$ $P = 0.067$
EMG/knee angle, μV·deg ⁻¹	12.28 ± 9.30	11.93 ± 10.01	11.53 ± 8.77	$F_{(2,54)} = 0.18$

The electromyographic values are relative to the knee excursion. Data represent mean ± SD. ANOVA results are from a repeated-measures 1-way ANOVA.

ANOVA = analysis of variance, EMG = electromyography, KT = Kinesio Taping, SD = standard deviation.

*Significantly different $P < 0.05$.

TABLE 2. Mean Differences of Isokinetic Peak Torque, Reflex Latency, and Electromyographic Signals of the Rectus Femoris Muscle Under 3 Different Taping Conditions

	Mean Difference \pm SD	95% CI	P Value*	Effect Size	Power
Peak torque at 60° s ⁻¹ , Nm ⁻¹					
Facilitation vs inhibition	5.50 \pm 10.79	0.282, 10.72	0.036 [†]	0.26	0.74
Facilitation vs Hypafix	4.00 \pm 9.90	-0.78, 8.78	0.125	0.18	0.54
Inhibition vs Hypafix	-1.50 \pm 7.98	-5.35, 2.35	0.986	-0.07	0.16
Reflex latency, ms					
Facilitation vs inhibition	-1.41 \pm 2.93	-2.82, 0.01	0.052	-2.01	0.69
Facilitation vs Hypafix	-1.08 \pm 2.83	-2.45, 0.28	0.16	-1.41	0.50
Inhibition vs Hypafix	0.32 \pm 3.93	-1.57, 2.22	1.00	0.42	0.07
EMG/knee angle, μ V·deg ⁻¹					
Facilitation vs inhibition	0.34 \pm 7.04	-3.05, 3.74	1.00	0.27	0.06
Facilitation vs Hypafix	0.74 \pm 6.32	-2.30, 3.80	1.00	0.67	0.09
Inhibition vs Hypafix	0.40 \pm 6.34	-2.66, 3.46	1.00	0.30	0.09

CI = confidence interval, EMG = electromyography, SD = standard deviation.

* Post hoc pair-wise comparison with Bonferroni adjustment.

[†] Significantly different $P < 0.05$.

indicated that the ES ranged from 0.25 to 0.49.² We also take note that benefits of the KT application may be best evaluated with the no taping condition.

The second goal of this investigation was to test whether movement of the KT on the skin during dynamic muscle contraction activates cutaneous mechanoreceptors. If the application of KT does affect afferent signals by stimulating the cutaneous receptors, motoneuron excitability should be monitored through an automatic response, such as a reflex, rather than voluntary contraction. We measured the myotatic patella tendon reflex, specifically reflex latency and its associated EMG signals, under the 3 taping treatments. The patellar tendon reflex is a monosynaptic reflex that includes Type 1a sensory fibers and an α -motor neuron. It is elicited as a result of the activation of the muscle spindle primary endings, the sensitivity of which is controlled by the γ -efferents. These latter entities should be sensitive to the KT applied to the skin.

In studies that utilized EMG as assessment of the effectiveness of KTM, responses were recorded during active muscle contraction. For instance, Lins et al³¹ applied KT over the RF, vastus lateralis, and vastus medialis muscles to the dominant leg of 20 asymptomatic subjects and compared them with an untaped control and a placebo group. No difference was observed between the 3 groups in the root-mean-square EMG values of the peak torque during concentric and eccentric knee extension. The authors concluded that applying KT to the femoral quadriceps did not alter the neuromuscular performance. In another study, Hsu et al³³ found greater EMG activity of the lower trapezius muscle in arm-lowering exercise from 60° to 30° in baseball players with shoulder impingement after applying KT as compared to placebo taping. Slupik et al³⁴ applied KT-facilitating treatment to the quadriceps muscle and measured EMG activity at isometric maximum knee extension at various time after taping. They suggested that KT increased the EMG activity of the quadriceps muscle 24 h after taping, but concluded that it had no immediate effect on it. Finally, the effect of KTM on the EMG activity of triceps surae muscle and vertical jump performance was investigated by Huang et al.³⁵ In this study, KT enhanced EMG activity of the medial gastrocnemius muscle but did not improve jumping height. Our approach differs from these other studies in that we

examine reflex contraction which might be enhanced through cutaneous stimulation via KT movement on the skin. The present study reveals trends of potentiation of neurological, reflexive responses. KT-facilitation treatment shortened the latency of the patellar reflex (17.96 \pm 0.72 ms) compared with the KT-inhibition treatment (19.36 \pm 0.70 ms) and the Hypafix taping group (19.04 \pm 0.84 ms). Our values for latencies are in agreement with those Frijns et al³⁶ in a group of healthy subjects.

We have proposed that the underlying physiological mechanism of the facilitating treatment on the enhancement of muscle performance is related the tape's stimulation of the skin mechanoreceptors, which promotes muscle spindle reflex contraction of the muscle³⁷ and excitability of the motor unit.¹⁴ These would shorten the latency period and, consequently, the time required to generate peak torque. We take note that the latency period between the facilitative and inhibitory KT treatment shows a trend toward significance ($P = 0.052$) with an ES of 2.01 and an observed power of 0.69 (Table 2). This might suggest the sample size that we adopted is too optimistic and further study with a larger sample size is warranted. Our earlier studies are consistent with this mechanism.²³ This scenario, if true, implies that the KTM would be of value in activities that require rapid generation of muscular force in response to sudden perturbation.

We take note that there was no significant difference in the stretch-induced EMG values between the 3 taping conditions when the data were normalized with the degree of knee movement. Thus, the present investigation does not provide clear evidence that the improvement in the isokinetic extensor peak torque performance is due to enhancement of the motor neuron excitability through increased input from cutaneous receptors associated with afferent neurons. Other mechanisms may contribute to the observed improvement of muscle performance.

There are several limitations that could have affected our study findings and interpretations. First, the small ES could be due to the fact that the sample size calculation was based on a population with knee osteoarthritis.¹⁸ Second, the intention of using Hypafix taping was to rule out any perceived beneficial effects of taping by the subjects. Nonetheless we take note that previous studies had indicated that rigid taping also alter muscle

activation.²⁹ Thus, an addition of no taping group is warranted to shed light on the true muscle effect from KTM. Whether the observed difference between the facilitative versus inhibition KTM is attributed to the activation of cutaneous receptors warrants further investigation with larger sample size. The present study was conducted with healthy adults. We cannot predict if there will be any tactile effects of KT in persons with musculoskeletal pain without impairment. For that group, the sensory inputs and force generation capacity should be altered by their pathological conditions and they might have different responses to the KT.

CONCLUSION

We conclude that the facilitating treatment with KT enhanced isokinetic knee extensor peak torque performance in healthy adults when compared with the inhibitory technique. However, the magnitude of effect is not large; the underlying mechanisms of the enhancement of muscle performance by KTM warrant further investigation. The addition of a no tape control group may provide insight to the benefits of KT. It would also be of interest to extend the study to subjects with musculoskeletal pain or impairment.

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