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Tactile stimulation with Kinesiology tape alleviates muscle weakness attributable to attenuation of Ia afferents

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ABSTRACT

Objective: Prolonged vibration stimulation to normal individuals could lead to muscle weakness attributable to attenuation of afferent feedback. This weakness is neurophysiologically similar to that seen in patients with knee injury. Theoretically, increasing input to gamma motor neurons could reverse this weakness. Sensory input to these neurons from skin could indirectly increase Ia afferent feedback. The present study examined the effect of this tactile stimulation in the form of Kinesiology tape on muscle weakness attributable to attenuation of afferent feedback.

Design: Randomized, crossover design.

Methods: All participants were measured their eccentric maximal voluntary contractions under the 2 conditions (taping and non-taping). First, maximal voluntary contraction during eccentric contraction was measured as baseline. For the taping condition, Kinesiology tape was applied around each subject's knee joint during maximal voluntary contraction measurement after vibration. For the non-taping condition, tape was not applied during maximal voluntary contraction measurement after vibration. Mean percentage changes between pre- and post-vibration stimulation were compared between two conditions.

Results: Maximal voluntary contraction and average electromyography of taping condition was significantly larger than that of non-taping condition.

Conclusions: Our results suggest that tactile stimulation in the form of Kinesiology tape inhibits the decline of both strength and electromyography. Alpha motor neuron activity attenuated by prolonged vibration would thus be partially rescued by tactile stimulation. These results indirectly suggest that stimulation of skin around the knee could counter quadriceps femoris weakness due to attenuated Ia afferent activity.

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1. Introduction

Substantial weakness of quadriceps resulting from neurophysiological abnormalities is typically observed following knee injury or associated pathology and remains long after other symptoms abate.^{1–3} Previous studies reported that quadriceps femoris (QF) weakness occurred in patients with knee ligament injury^{4–6} or osteoarthritis,⁷ elderly patients hospitalized due to falls, and even healthy elderly participants.^{1,8} The mechanism of QF weakness for these patients can be partially explained by a hypothesis set forth by Konishi et al.,^{9–11}. According to this hypothesis, normal afferent feedback travels from structures around the knee joint, such as ligaments, capsules, and skin, to gamma motor neurons. If these structures are damaged, their mechanoreceptors would also be histologically affected, and feedback would be hindered (Fig. 1). Normal afferent feedback from mechanoreceptors would not be sent to gamma motor neurons, which are important for Ia

afferent modulation. Previous studies reported that maximal voluntary activation of muscle could not be attained without normal Ia afferent feedback because adequate Ia afferent activity is necessary to recruit high-threshold motor units.^{12–14} Accordingly, hindered recruitment of these motor units is a possible mechanism for persistent QF weakness.

Prolonged vibration stimulation attenuates Ia afferents due to either neurotransmitter depletion, a heightened Ia fiber threshold, or presynaptic inhibition of the Ia terminal¹⁴ because selective Ia afferent activity evoked by the stimulation lasts for an extended period of time (20 min).^{14–16} High-threshold motor unit recruitment in the QF would thus be hindered since adequate Ia afferent activity is necessary.^{12,14} Thus, muscle weakness similar to that observed in patients with knee pathology could be induced through prolonged vibration stimulation of muscles in healthy individuals.

Therapeutic interventions that could counter QF weakness attributable to hindered high-threshold motor unit recruitment can be divided into two categories: those that modulate joint afferent discharge from structures around the knee to increase Ia afferent activity, and those that stimulate motor unit recruitment in the

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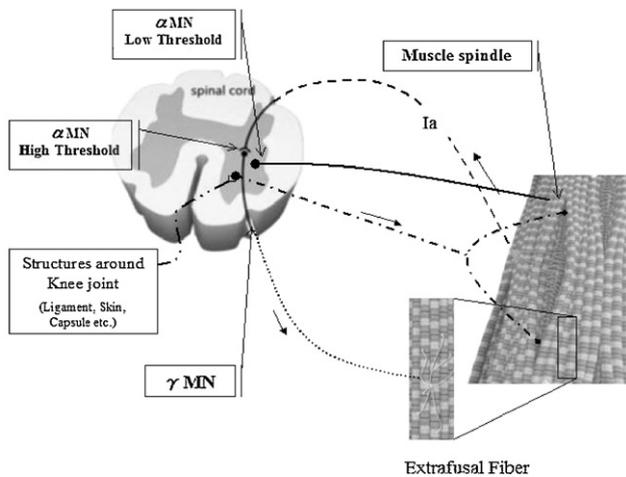


Fig. 1. Schematic diagram of the mechanism underlying QF weakness. Broken line 1 (---) represents attenuation of afferent feedback from structures around the knee joint to the spinal cord. This feedback results in a decline in gamma motor neuron activation (broken line 2; - - -). The decline in activation, in turn, results in attenuation of Ia afferents at the injured and uninjured sides (broken line 3;) due to the reduced sensitivity of muscle spindles. Recruitment of high-threshold motor units (HTMUs) in the injured and uninjured sides requires Ia feedback and is therefore hindered.

quadriceps muscle directly. Therefore, increasing input to gamma motor neurons could reverse QF weakness because Ia afferent activity is modulated by efferent input from these neurons. A previous study demonstrated that sensory input from skin around the joint could activate gamma motor neurons¹⁷; therefore, a possible method to compensate for decreased input to gamma motor neurons would be to give sensory stimulation to skin around the knee. Indeed, medical practitioners have often asserted that tactile stimulation affects muscle activation levels; proprioceptive neuromuscular facilitation (PNF) and Kinesio Taping are examples of this, although there is little demonstrated evidence to support their efficacy. Since the sensitivity of muscle spindles is modulated by efferent input from gamma motor neurons, sensory input to these neurons from skin could indirectly increase Ia afferent feedback. The present study examined the effect of this tactile stimulation on muscle weakness attributable to attenuation of afferent feedback.

2. Methods

Ten male participants (age: 22.2 ± 6.9 years, height: 168.1 ± 4.8 cm, weight: 61.6 ± 5.4 kg, mean \pm SD), were enrolled in the present study. Patients with any knee joint injury were excluded from this study. All participants in the present study engaged in daily sports activity such as long jump, triple jump, short sprint and long sprint. All participants gave their informed consent to participate in the study. Approval was given by the National Defense Academy Research Ethics Committee, conforming to the Helsinki Declaration.

Two sessions of maximal voluntary contraction (MVC) were conducted and the second session was carried out more than a week after the first session. All participants had maximal eccentric contraction measured following taping and non-taping conditions. First, MVC during eccentric contraction was measured as baseline. For the taping condition, Kinesiology tape (Nitto Denko Corp., Tokyo, Japan), which is commonly used for clinical purposes, was applied around each subject's knee joint (Fig. 2). The tape was applied just after completing the vibration stimulation, and left on during MVC measurements. For the non-taping condition, the tape was not applied to participants during MVC post-vibration measurements. To reduce the placebo effect, participants were not notified about the commercialized effects of the tape.

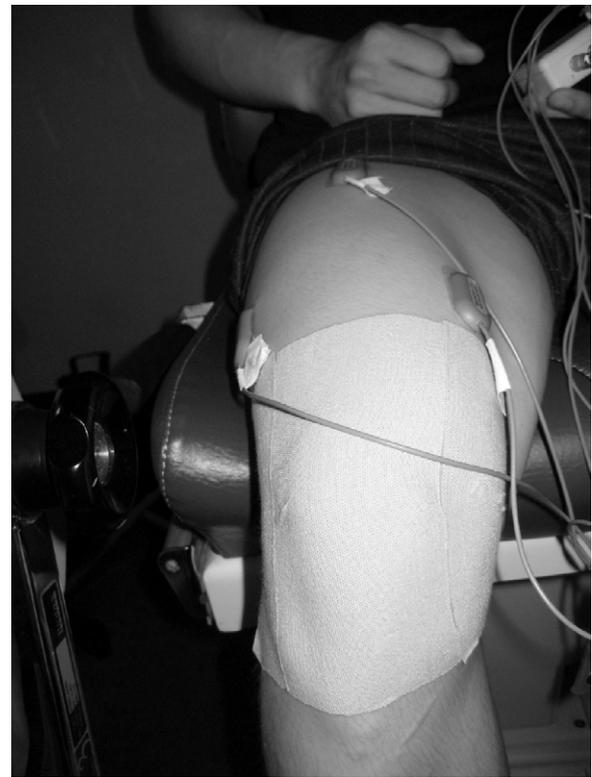


Fig. 2. Experimental setup used during tactile stimulation.

Eccentric MVCs were measured in all participants. The order of sessions (taping and non-taping) was randomly assigned to each subject. During measurements, participants were in a sitting position with the upper body and thigh kept tightly secured to the seat of the Biodex System III (Biodex Medical Systems Inc., Shirley, NY) by belts. EMG signals from muscles were simultaneously measured during MVC measurements. The passive mode was used for eccentric contraction measurements. Angle velocity and range of motion were set to $60^\circ/\text{s}$ and $0\text{--}90^\circ$, respectively. To establish a baseline of strength, all participants were asked to perform MVC of knee extension three times each session. The highest peak torque was used as the baseline, and the average EMG (AEMG) was calculated. Electromyography (EMG) measurement was performed on the vastus medialis (VM), vastus lateralis (VL), and the rectus femoris (RF) during MVC measurement at a sampling rate of 1 kHz. EMG was recorded using bipolar surface electrodes placed on the belly of the vastus medialis, vastus lateralis, and rectus femoris. The inter-electrode distance was 20 mm. The electrodes were connected to an EMG measurement unit (SX230-1000, Biometrics Ltd., Gwent, UK). EMG data were transferred into PowerLab (ADInstruments) via an A/D conversion unit. Then, the sampled signals were full-wave-rectified. To calculate the average EMG (AEMG), rectified EMG signals were integrated and divided by time throughout lever arm movement.

After completing torque and AEMG measurements, vibration stimulation was applied for 20 min. MVC of knee extension and AEMG were measured again immediately after stimulation using the same methods as those used pre-vibration. Since the effect of prolonged vibration on muscle contraction was important for purposes of the study, participants were asked to perform one maximal contraction immediately after stimulation. All tasks were completed within 30 s after vibration stimulation. The method of vibration administration described in previous study¹⁸ was used in the present study. Briefly, participants sat on the seat of the Biodex system III (Biodex Medical System Inc., Shirley, NY) with their legs

hanging down from edge of the seat. They were asked to relax their thighs as much as possible during the application of vibration. Vibration stimulation was applied manually to the mid-portion of the infrapatellar tendon using the Hit Masser (Sun.R Co., Tokyo) while the participants seated in the Biodex III to induce attenuation of Ia through the tonic vibration reflex of the quadriceps muscle. The frequency, amplitude, force of application, and duration of vibration stimulation were modified in this study. Theoretically, the induction of Ia discharge is necessary to induce effective attenuation of the Ia afferents. However, the vibrating protocol of the previous study¹⁸ is less effective in inducing Ia discharge than that used in previous studies, since 30 Hz of vibration stimulation would not be enough to induce maximal Ia discharge.^{15,16} The selected vibration frequency was 50 Hz, which resulted in 1.5 mm displacement. The force and duration of application were approximately 30 N and 20 min, respectively.¹⁹

Continuous tactile stimulation during voluntary muscle contraction was necessary for the present study; therefore, Kinesiology Tape that designed to give cutaneous stimulation was used given that its elasticity results in less mechanical constraint compared to conventional tape.²⁰ In addition, its adhesive properties allow for direct application on skin without irritation. Since Johansson and Sojka demonstrated that sensory input from skin around the joint could indirectly activate alpha motor neurons via activation of gamma motor neurons,¹⁷ the anterior side of each subject's knee joint was covered from the tibial tuberosity to 5 cm above the superior edge of the patella (Fig. 2). No tension was used during tape application. In present study, we had not used tape configuration for quadriceps muscle which recommend by Kinesio Taping Association.²⁰ This is because it is not scientifically clear whether a specific muscle can be activated by taping skin over the targeted muscle as asserted.²⁰ While, a previous study found afferent input from around the joint could activate motor neurons.¹⁷ In present study, therefore, we cover up skin around anterior knee.

All data were expressed as mean \pm SD. A *P* value less than 0.05 denoted the presence of a statistically significant difference. 2 (condition; tape vs. no-tape) \times 2 (vibration; pre vs. post) repeated measures analysis of variance (ANOVA) was used to determine differences between the mean percentage change of MVC and AEMG between groups.

3. Results

3.1. MVC and AEMG

Mean values and SDs of MVC and AEMG (VL, VM, RF) before and after 20 min of vibration stimulation are listed in Table 1. The MVC and AEMG of VL, VM, and RF were analyzed using 2 \times 2 repeated

measures ANOVA with vibration (pre-vibration vs. post-vibration) and condition (tape vs. no-tape) as within-subject factors. There was a significant interaction effect (vibration \times condition) with MVC, VL, VM, and RF. This effect was further analyzed using a simple main effects analysis of action for each condition. In the pre-vibration, no significant difference was detected between conditions for all parameters. In the post-vibration, MVC of the tape condition was significantly higher than that of the no-tape condition. In the no-tape condition, post-vibration values were significantly lower than pre-vibration values for all parameters. The results of present study demonstrated clinically significant effect sizes in all parameters.

4. Discussion

All participants in the present study received 50 Hz of vibration stimulation to the infrapatellar tendon for 20 min. This stimulation temporally diminished the activity of alpha motor neurons while exerting maximal voluntary contraction. Previous studies demonstrated that prolonged vibration stimulation to healthy participants' muscles hindered recruitment of high-threshold motor units due to attenuation of Ia afferent feedback.¹⁴ Indeed, several studies have reported a decline in the activity of alpha motor neurons of healthy individuals upon prolonged vibration stimulation.^{3,7,11,18} This hindrance of recruitment of motor units also occurred in patients bothered by persistent QF weakness^{1,3,7}; muscle weakness found after prolonged vibration would have a neurophysiological mechanism similar to that observed in these patients. Our results suggest that tactile stimulation with Kinesiology tape inhibits the decline of both strength and EMG activity. Alpha motor neuron activity attenuated by prolonged vibration would thus be partially rescued by stimulation. These results indirectly suggest that stimulation of skin with Kinesiology tape around the knee could counter QF weakness by attenuating Ia afferent activity.

As for the relationship between sensory input and motor neuron activity, Johansson and Sojka demonstrated that sensory input from skin around the joint could activate gamma motor neurons to modulate Ia afferent activity and suggested that the same sensory input could also indirectly activate alpha motor neurons.¹⁷ The results of the present study, however, indicate that tactile stimulation cannot increase strength over pre-vibration levels. Even though Dr. Kenzo Kase, inventor of the Kinesio Taping Method, insisted that his method is useful for increasing muscle strength, it remains inconclusive whether tactile stimulation by taping enhances strength in healthy participants. Indeed, previous studies demonstrated that Kinesio Taping did not significantly enhance muscle strength in athletes.^{21–23} In present study, moreover, we had not used taping

Table 1

Mean MVC of knee extension and AEMG values in each quadriceps femoris muscle (VL, vastus lateralis; VM, vastus medialis; RF, rectus femoris) measured before and after 20 min of vibration stimulation.

Conditions		Pre-vibration (Nm)	Post-vibration (Nm)	Vibration \times tape	Effect size	Multiple comparison
MVC						
No tape		284.0 \pm 55.9	244.9 \pm 71.2	<i>p</i> = 0.002	η^2 = 1.95	No tape; pre > post Post vib.; tape > no tape
Tape		282.7 \pm 71.2	270.2 \pm 75.6			
Muscles	Condition	Pre-vibration (mV)	Post-vibration (mV)	Vibration \times tape	Effect size	Multiple comparison
AEMG						
VL	No tape	0.29 \pm 0.09	0.25 \pm 0.05	<i>p</i> = 0.006	η^2 = 1.35	No tape; pre > post
	Tape	0.27 \pm 0.08	0.28 \pm 0.08			
VM	No tape	0.31 \pm 0.07	0.27 \pm 0.05	<i>p</i> = 0.024	η^2 = 0.08	No tape; pre > post
	Tape	0.35 \pm 0.17	0.36 \pm 0.15			
RF	No tape	0.29 \pm 0.14	0.24 \pm 0.11	<i>p</i> = 0.004	η^2 = 1.61	No tape; pre > post
	Tape	0.27 \pm 0.13	0.26 \pm 0.11			

Values are expressed as mean \pm SD. η^2 indicates the effect size of ANOVA.

method which recommend by Kase.²⁰ We covered up skin around knee because a previous study found afferent input from around the joint could activate motor neurons.¹⁷ It would be clinically useful to know if application of tape over the joint is more effective than that proposed applications by Kase²⁰ in further study.

5. Conclusions

In conclusion, our findings suggest that tactile stimulation could alleviate muscle weakness attributable to attenuation of Ia afferents. Thus, these results might support the use of tactile stimulation via Kinesiology tape to enhance muscle activity in injured populations. However, we note that only healthy males were examined in present study. Moreover, although prolonged vibration stimulation can induce muscle weakness similar to neurophysiological changes that result from knee pathology, the corresponding mechanism does not completely coincide with QF weakness. This is because gamma motor neuron activity would not be attenuated by the vibration stimulation because the stimulation does not affect gamma motor neuron activity (Fig. 1). Although this study used muscle weakness induced by prolonged vibration stimulation as a model of QF weakness induced by knee pathology, further research should be performed to examine the relationship between gamma motor neuron activity and QF weakness.

Practical implication

- Tactile stimulation could alleviate muscle weakness attributable to attenuation of Ia afferents.
- The results of present study did not indicate that tactile stimulation could increase strength of normal healthy people.

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